The MERLIN Phobos Ionizing Radiation Experiment (MPIRE)

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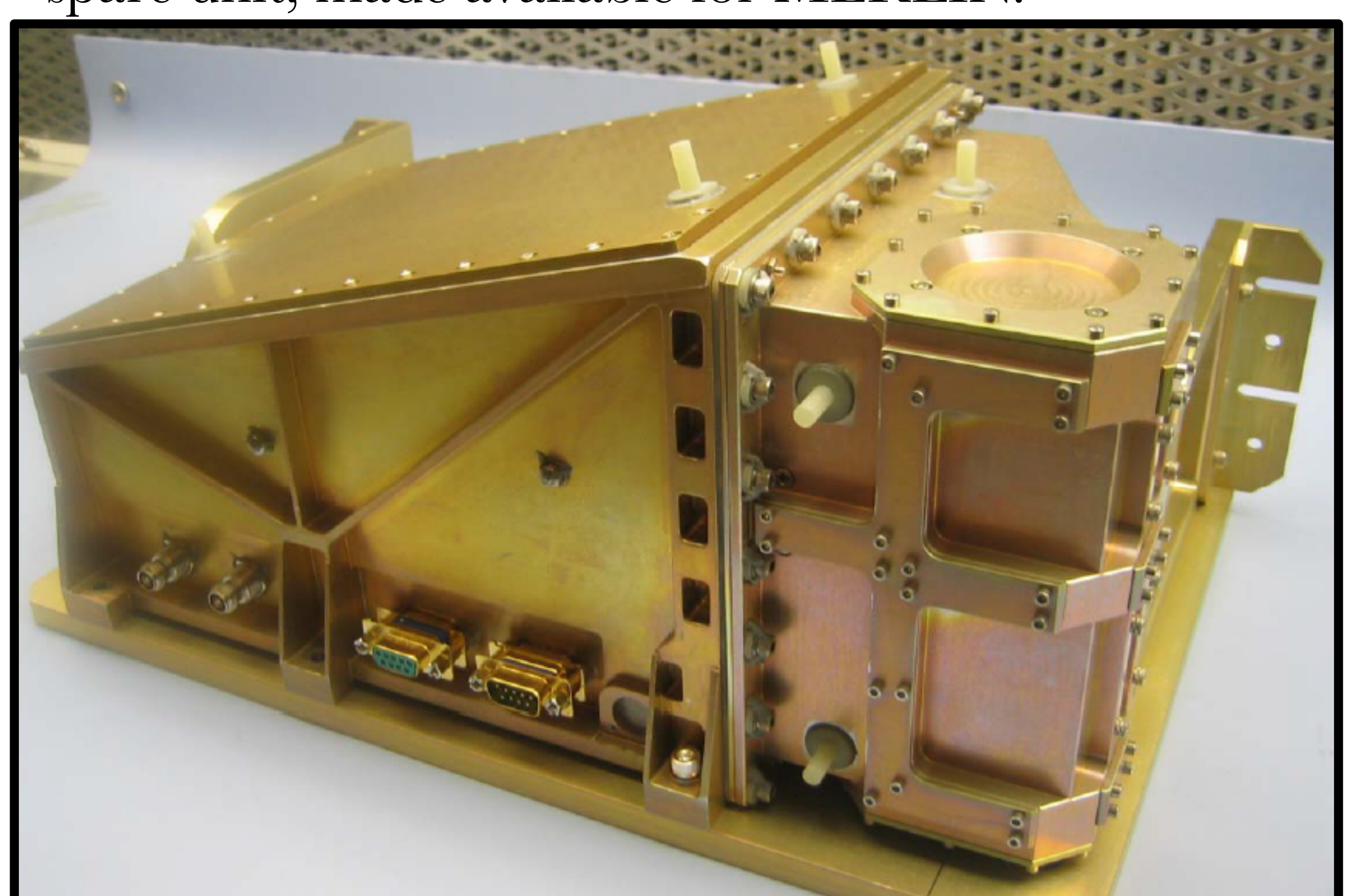
Summary

The MERLIN Phobos Ionizing Radiation Experiment (**MPIRE**) closes Strategic Knowledge Gaps (SKGs) for Mars' moons and the circum-Mars environment not addressed by other instruments on the proposed MERLIN Discovery mission. **MPIRE** measurement requirements and flight spare hardware both derive from the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) [1] instrument onboard the Lunar Reconnaisance Orbiter (LRO). CRaTER is *characterizing the global lunar radiation environment and its biological impacts;* **MPIRE** accomplishes the same objectives but in the Mars environment with the CRaTER flight spare unit, made available for MERLIN.



(from Spence et al. [1])

Goals: **MPIRE** investigates galactic cosmic rays (GCR), solar energetic protons (SEP), and secondary radiation produced at Phobos' surface using tissue equivalent plastic (TEP) to simulate astronaut self-shielding or shielding of a moderately thick spacecraft. **MPIRE** measures linear energy transfer (LET) spectra over a wide dynamic range behind different volumes of TEP and under different levels of solar activity and GCR flux.

References:

[1] Spence et al. (2010), *Space Science Rev.*, 10.1007/s11214-009-9584-8.

[2] Zeitlin et al. (2013), *Space Weather Journal*, 10.1002/swe.20043.

[3] Case et al. (2013), *Space Weather Journal*, 10.1002/swe.20051.

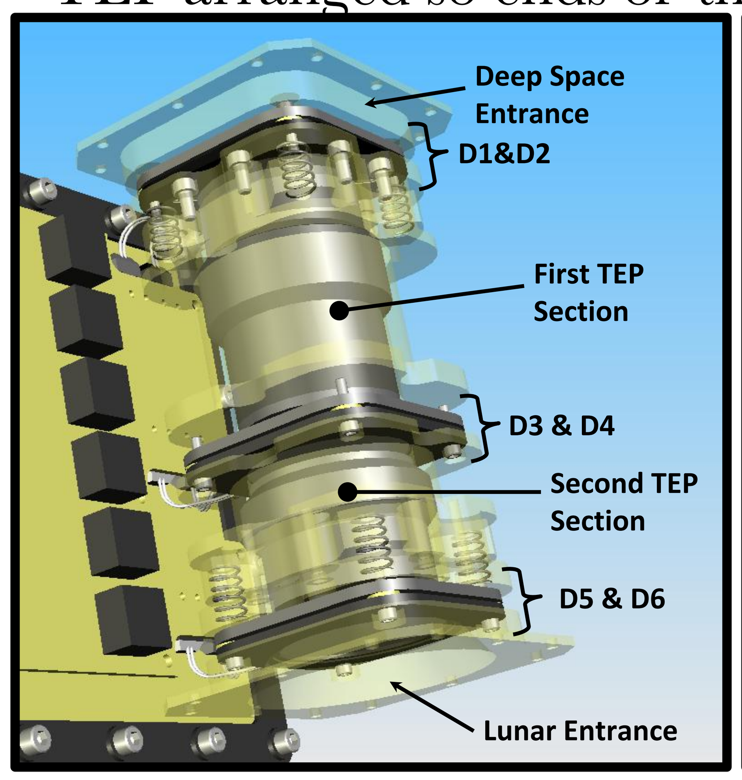
[4] Joyce et al. (2013), *Space Weather Journal*, 10.1002/swe.20059.

[5] Wilson et al. (2012), *J. Geophys. Res. – Planets*, 10.1029/2011JE003921.

[6] Schwadron et al. (2012), *J. Geophys. Res. – Planets*, 10.1029/2011JE003978.

[7] Jordan et al. (2014), *J. Geophys. Res. – Planets*, 10.1002/2014JE004648.

Design: Functionally, **MPIRE** consists of a stack of circular silicon semiconductor detectors and cylindrical sections of TEP arranged so ends of the stack have unobscured views



Parameter	Value
Low LET range (D2, D4, D6)	0.09 keV/µm to 85 keV/µm
High LET range (D1, D3, D5)	2.2 keV/µm to 2.2 MeV/µm
LET resolution	<0.3% of maximum in each range
Temperature Range	-25C to +50C operational -35C to +60C survival
Telemetry rate	High rate: 89.1 kbps Normal for Mars orbit: 200 bps Low for cruise: 20 bps
Max. event detection rate	1200/sec
Zenith full angle FOV	31.4°
Nadir full angle FOV	65.9°
Mass	5.53 km
Power	6.66 W
Volume	24.1 X 23.0 X 15.9 cm
Alignment	On side deck, canted to align "nadir" with Phobos at 45° phase angle

Radiation passing through the stack, including ions and electrons, and to a lesser extent neutrons and gamma-rays, loses energy while passing through the silicon detectors. When ionizing radiation passes through a detector a signal is produced proportional to the total energy DE lost in the detector. Combined with the thickness Dx of the detector, an approximate LET is determined for the single particle where *LET* = DE/Dx. Together, the detector pairs and associated amplifiers provide sensitivity to a broad range of LET from approximately 0.1 keV/µm to 2.2 MeV/µm (see table).

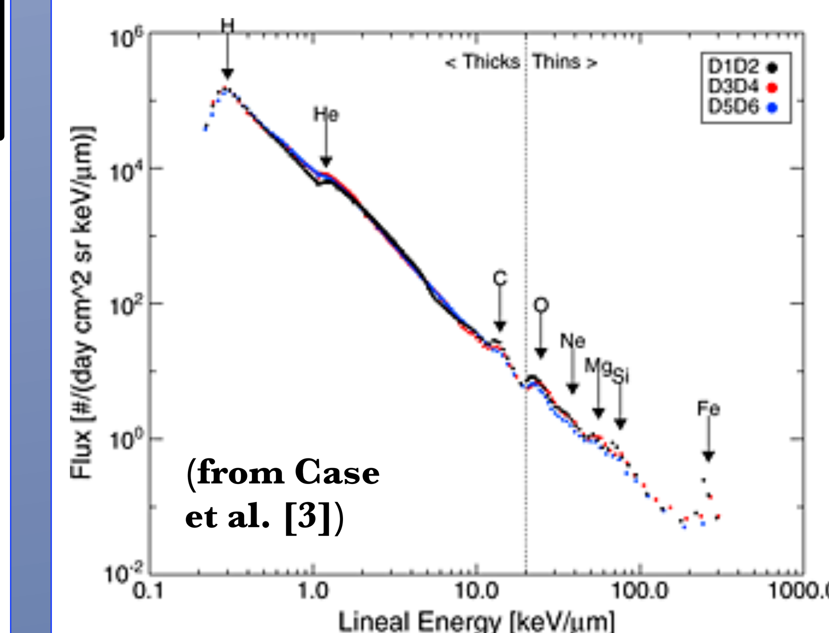
Closing Human Exploration SKGs: By combining signals to identify the path of individual particles, **MPIRE** will be used to understand how radiation loss evolves in human tissue and how dose rates change during periods of heightened solar activity and ultimately over the course of the solar cycle in Mars' environment, not only filling two SKGs but also complementing identical measurements at Earth's Moon.

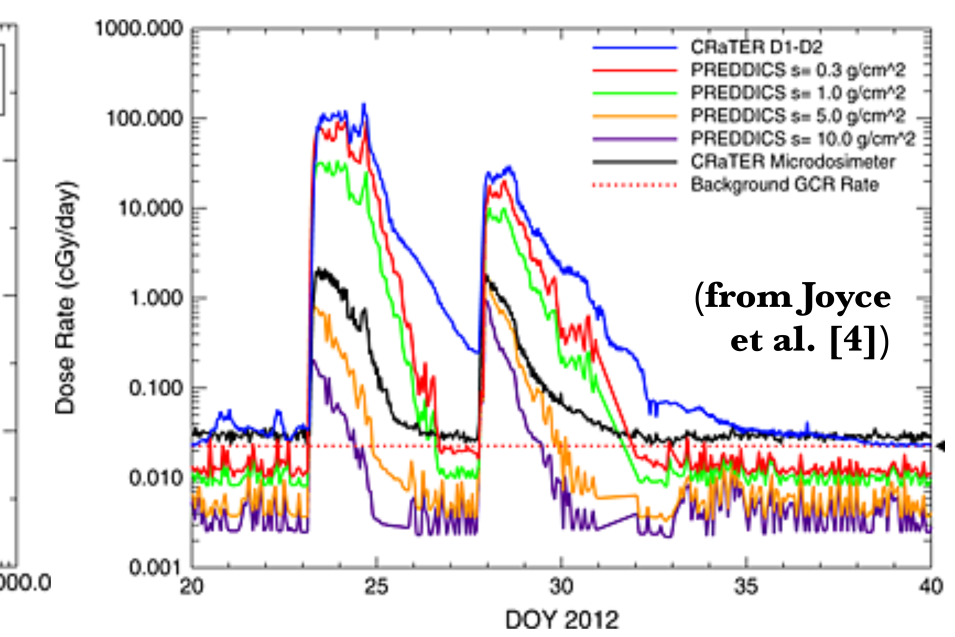
Figure D-17. MERLIN's science payload contributes crucial information to the retirement of Strategic Knowledge Gaps for future human exploration missions.

Strategic Knowledge Gap (P-SAG 2012)	Risk Reduction or Benefit	Human Mission Risk	Relevant MERLIN Measurements or Activities
A3-1. Orbital particulate environment	Crew/Mission, Operations, Cost	Medium	• Particle density of dust belts from **MDEX**
A4-2. Demonstration of optical communication	Crew/Mission, Operations, Cost, Performance, Science/Engineering	High	• **DSOC** data transmission during cruise, Mars orbit
B3-3. Cosmic rays in Mars system	Crew/Mission, Operations, Cost	High	• **MPIRE** orbital measurements
C1-1. Surface composition/potential for ISRU	Crew/Mission, Operations, Cost, Performance, Science/Engineering	High	• Elemental comp., including C, from **APXS and S-GRS** • Mineral composition, including hydrous phases, from **M6** microscopic imaging spectrometer • Global spectral context, from **orbital imaging** • H to 200 ppm from **S-GRS**
C2-1. Charged particle environment	Crew/Mission, Operations, Cost, Science/Engineering	Low	• Near-moon total dose and energy measurements by **MPIRE**
C2-2. Gravitational fields	Operations, Cost, Performance, Science/Engineering	Medium	• Mass, mass distribution from **radio science** • Global shape through **DAPHNI orbital stereo imaging**
C2-3. Regolith geotechnical properties	Crew/Mission, Operations, Cost, Performance, Science/Engineering	High	• Thickness, rock abundance from **orbital imaging** • Particle size determination with 5-mm to 75-µm pixel scale from **OpsCam and M6 landed imaging** • Surface dust environment characterization from **Student Collaboration dust imaging** • Regolith mechanical properties from **excavation**
C2-4.Phobos thermal environment	Operations, Cost, Performance, Science/Engineering	Low	• Temperature sensors on lander feet, from **Student Collaboration**
C3-1.Surface mobility demonstration	Crew/Mission, Operations, Cost, Performance, Science/Engineering	High	• **Ascent & relanding during Science Enhancement Option (SEO)**

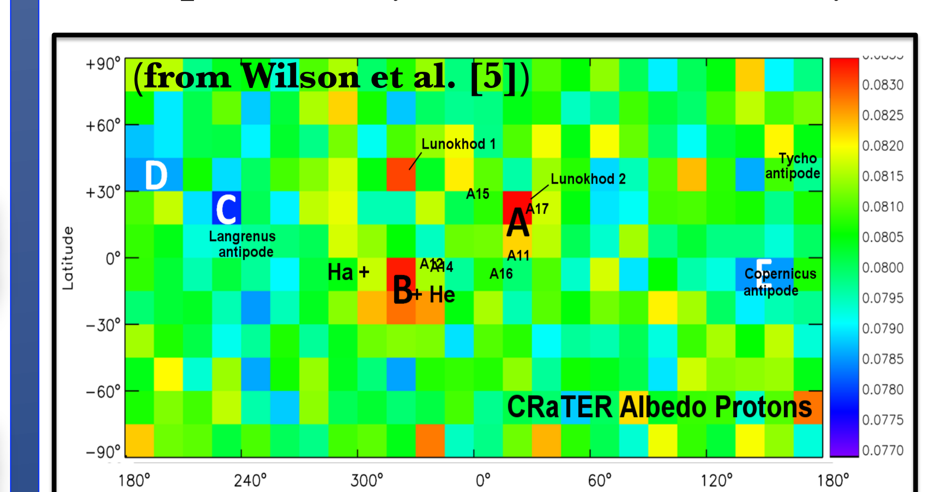
Crew/Mission · Operations · Cost · Performance · Science/Engineering

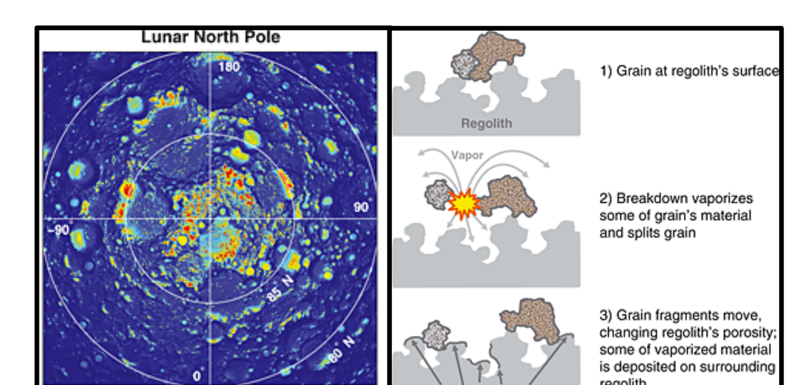
Science Products and Deliverables: Unique **MPIRE** capabilities are: (1) inclusion of TEP to make biologically relevant radiation measurements; and, (2) telemetry rate sufficient to capture high resolution LET values for up to 1,200 events/sec. Whereas previous instruments were hampered by reduced LET resolution or number of events recorded owing to limited telemetry, **MPIRE** produces spectra with high resolution in both LET and time en route to and while in Mars' planetary system. As with CRaTER this allows **MPIRE** to estimate GCR (below left) and SEP fluxes, dose rates (below right), and shielding [2] needed to enable human exploration.





Spence et al. [1] derived level 2 and 3 instrument requirements on the LRO CRaTER (and by extension **MPIRE**) instrument to meet level 1 mission goals needed to characterize the deep space and Mars moon radiation environments, and to establish radiation effects on human tissue equivalent for exploration. All derived requirements are met by both the LRO flight model as well as more critically the spare for MERLIN. We note that these requirements let CRaTER accomplish novel secondary lunar science (e.g., maps of lunar particle albedo [5], regolith modification through electrical discharges [6], and chemical weathering [7]); we anticipate similar opportunities for planetary science discovery at Mars/Phobos with **MPIRE**.





Dielectric breakdown weathering of polar regolith **(from Jordan et al. [6])**

To acquire its measurements, **MPIRE** operates continuously during cruise and Mars orbit phases. After landing on Phobos it will operate at times during daylight when power is not being drawn by arm motions for at least 3 hrs. We expect ~150 ≥3-hr radiation measurements over 214 sols of landed operations.