LSSW-V: #6010

LWIR: 3D SURVEY FOR LUNAR VOLATILES

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Science and Exploration Goals

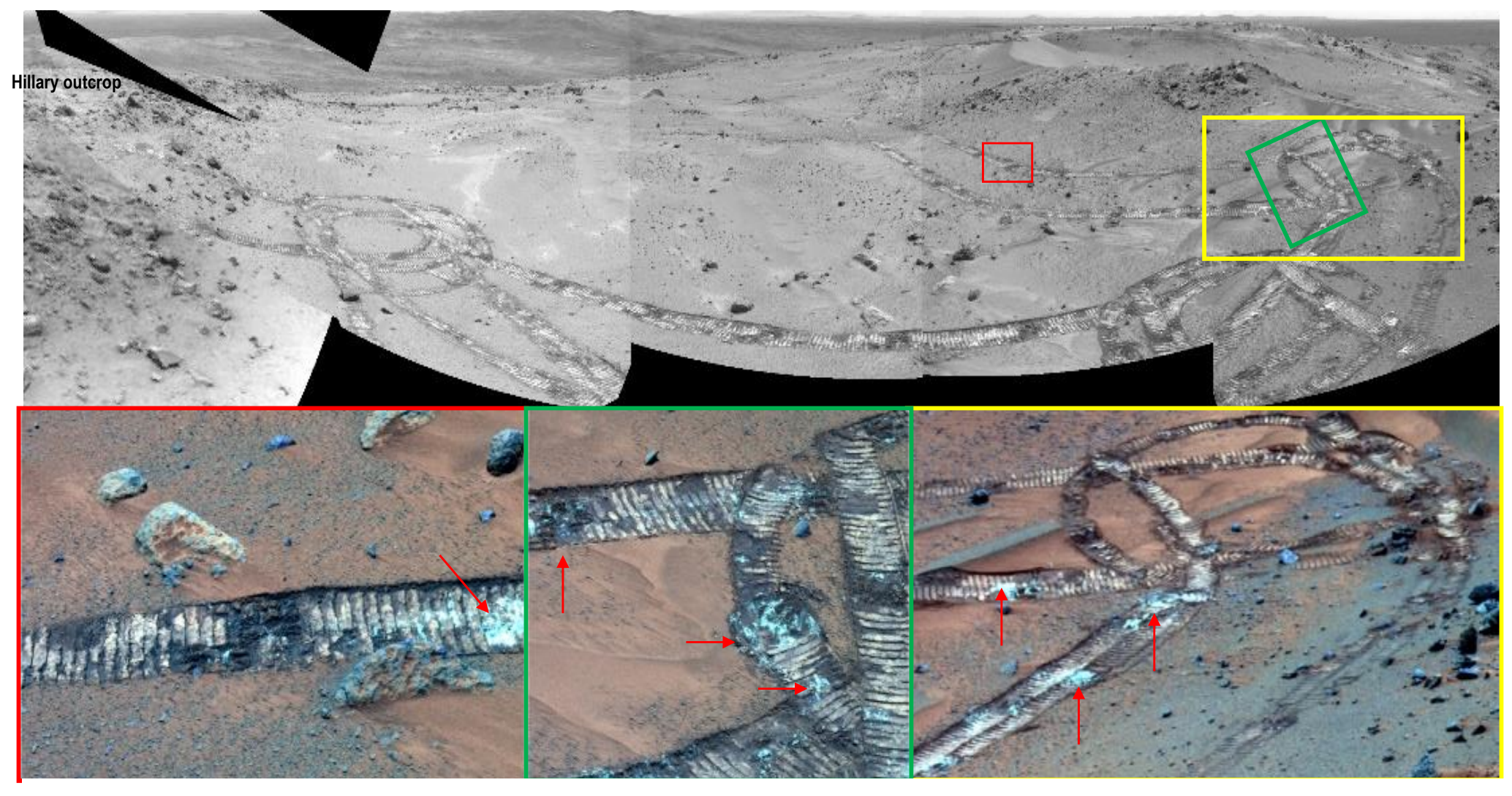
- Determining the lateral and vertical distribution, and state of lunar volatiles are top science objectives in NASA's new phase of lunar exploration.
- The primary goal of science is to characterize the molecular/structural forms of volatiles and to assess their occurrence in various lunar minerals and regolith.
- The critical goal of exploration is to quantify the concentration and spatial distribution of volatiles in the Moon's polar and non-polar regions for their potential use as raw material for In Situ Resource Utilization (ISRU).
- These goals in the next phase of lunar exploration have great significance for the strategies of ***sustainable human exploration***, ***ISRU***, and ***relevant technology development***.

A new concept -- Ground Truth Survey

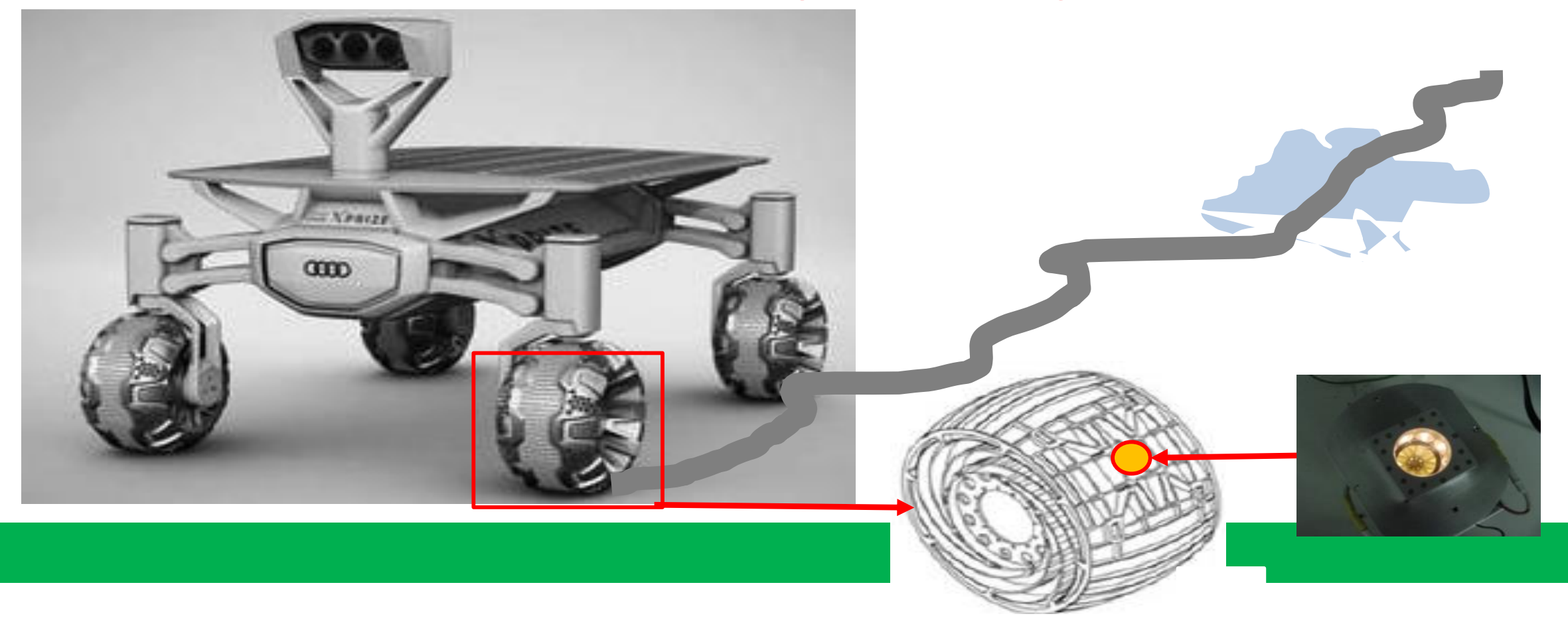
- Most of the evidence for lunar volatiles, up to now, has been revealed by remote sensing observations [1-10].
- A natural next step is to send landers, rovers, or hoppers to the surface, to establish ***ground truth*** for these observations.
- We are developing a concept of ***Ground Truth Survey*** using a tiny and efficient NIR sensor, LWIR (Lunar Water-IR) sensor, with its highly versatile deployments.
- In this concept, ***ground truth*** for remote sensing NIR observations of lunar volatiles will be verified by LWIR that works in the same NIR wavelength range. The ***Survey*** for ground truth will be realized by making a large number of measurements over a large area in a short time, with a simple sampling scheme and autonomous on-board data analytical algorithm (Fig. 1).

3D survey of lunar volatiles

Science enabled by mobility on Mars

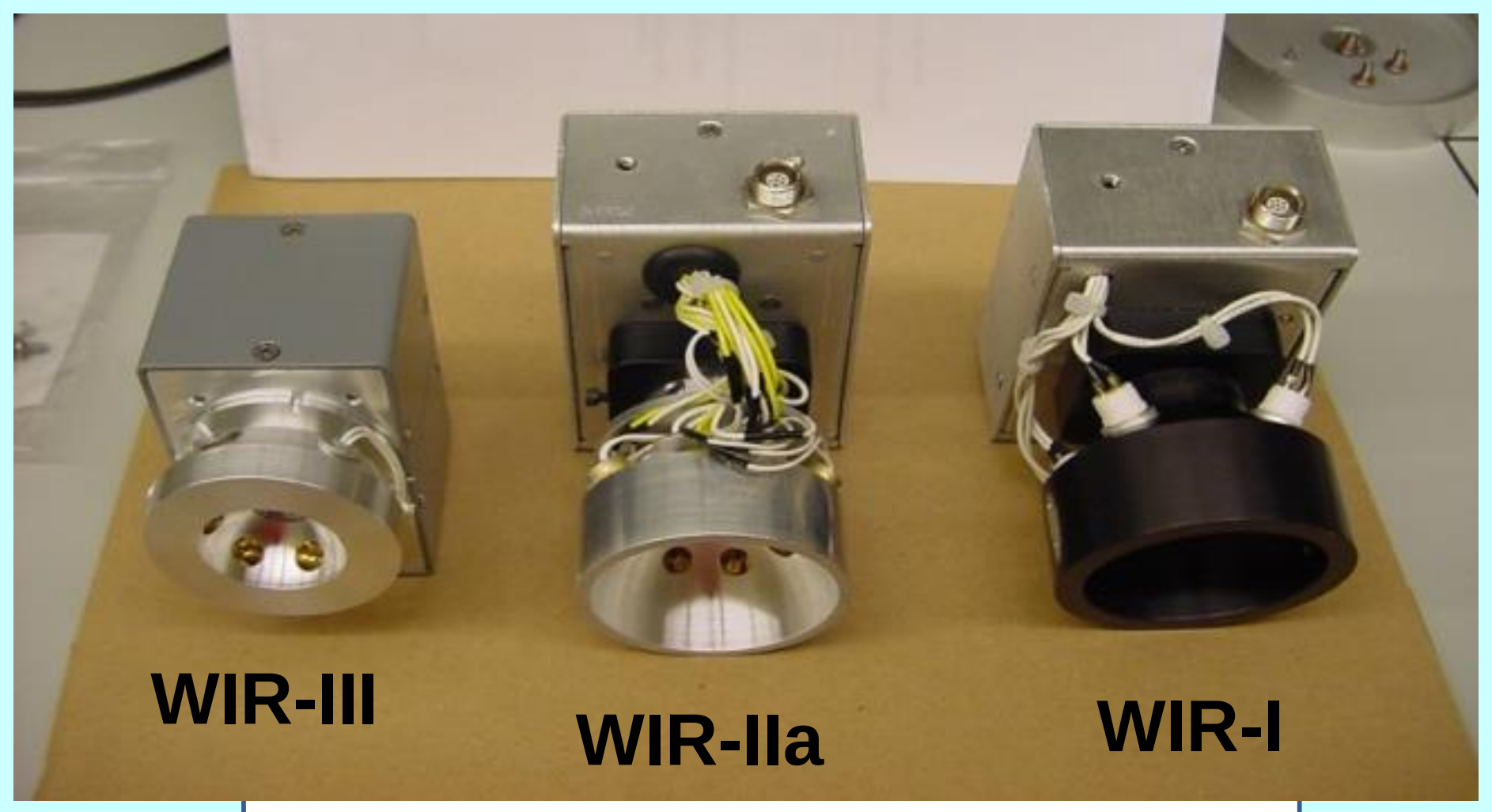


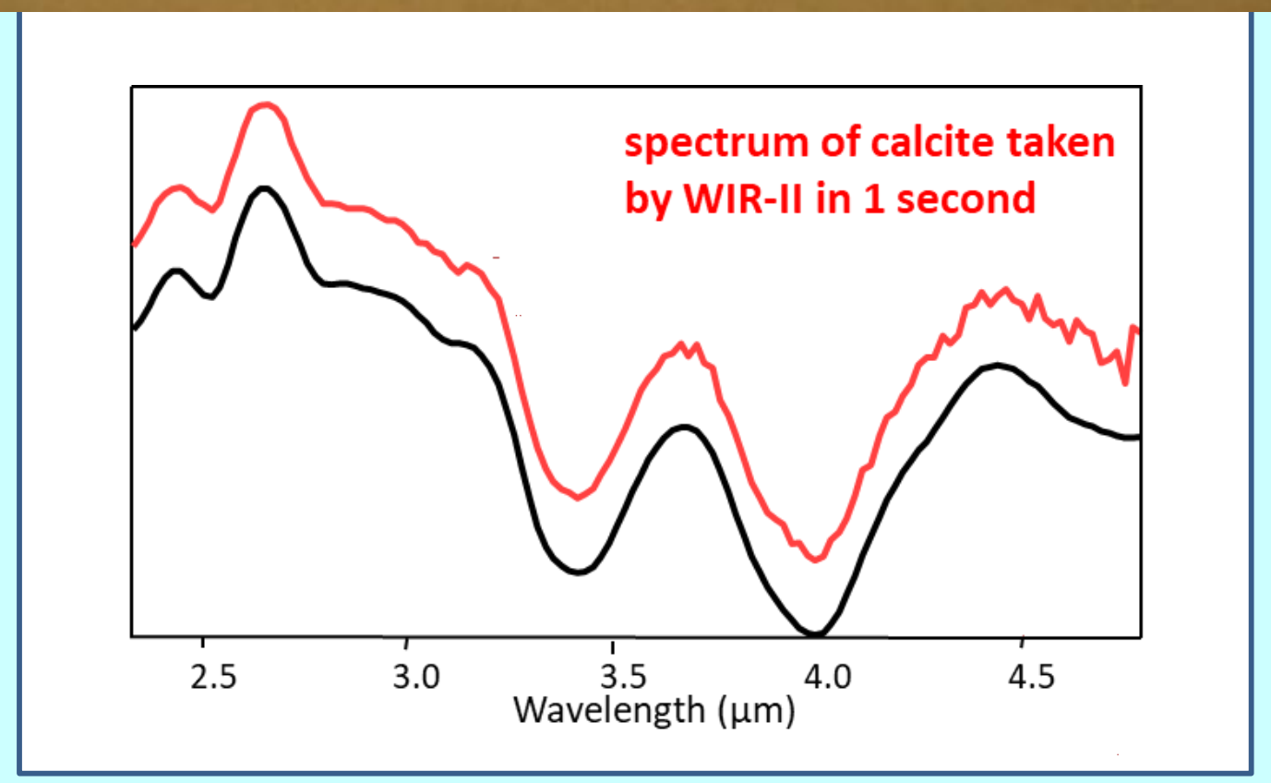
Science will be enabled by mobility on the Moon



A tiny, highly efficient NIR sensor adapt to lunar missions

The initial development of WIR (Water-IR) was supported by two NASA- ASTID projects (NSAG5-12114, and NNG05GM95G) [11, 12, 16]



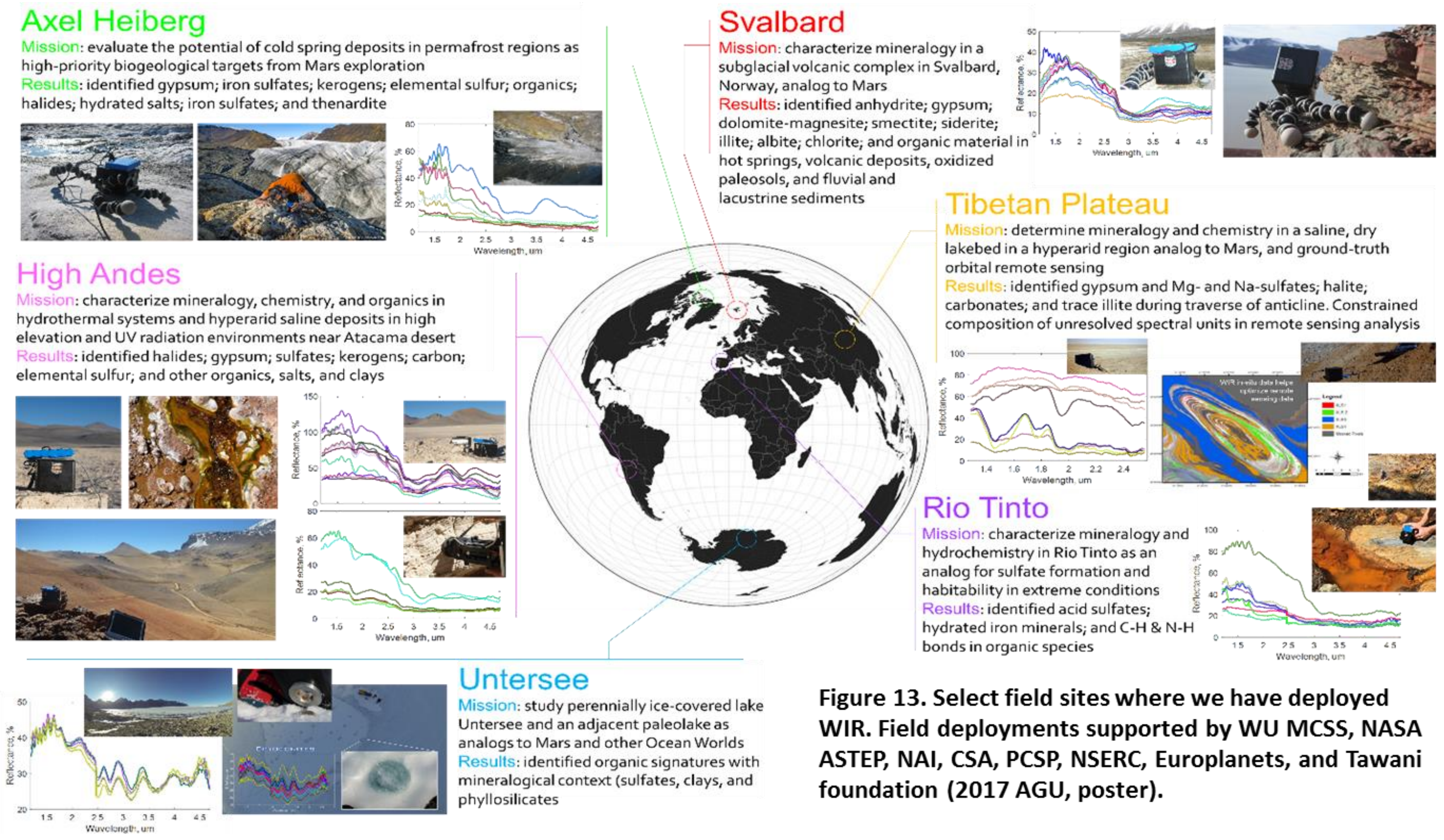


WIR-III specifications

- Active source: **Vis-NIR**
- Reflective spectra: **1.14 - 4.76 µm**
- Resolution: **0.14 µm/pixel**
- Volume: **7.5 x 7.5 x 5 cm**
- Mass: **294 grams**
- Power consumption: **3.3 W**
- Min meas. time: **1 sec**

Current LWIR under SSERVI: vacuum & low T operation of critical components

Eight field tests of WIR-II & WIR-III were supported by NASA-ASTEP, NAI, CSA, PCSP, NSERC, Europlanets, Tawani fundation & WUSTL-MCSS [14, 15]



Axel Heiberg

Mission: evaluate the potential of cold spring deposits in permafrost regions as high-priority biogeological targets from Mars exploration

Results: identified gypsum; iron sulfates; kerogens; elemental sulfur; organics; halides; hydrated salts; iron sulfates; and thenardite

Svalbard

Mission: characterize mineralogy in a subglacial volcanic complex in Svalbard, Norway, analog to Mars

Results: identified anhydrite; gypsum; dolomite-magnesite; smectite; siderite; illite; albite; chlorite; and organic material in hot springs, volcanic deposits, oxidized paleosols, and fluvial and lacustrine sediments

High Andes

Mission: characterize mineralogy, chemistry, and organics in hydrothermal systems and hyperarid saline deposits in high elevation and UV radiation environments near Atacama desert

Results: identified halides; gypsum; sulfates; kerogens; carbon; elemental sulfur; and other organics, salts, and clays

Tibetan Plateau

Mission: determine mineralogy and chemistry in a saline, dry lakebed in a hyperarid region analog to Mars, and ground-truth orbital remote sensing

Results: identified gypsum and Mg- and Na-sulfates; halite; carbonates; and trace illite during traverse of anticline. Constrained composition of unresolved spectral units in remote sensing analysis

Rio Tinto

Mission: characterize mineralogy and hydrochemistry in Rio Tinto as an analog for sulfate formation and habitability in extreme conditions

Results: identified acid sulfates; hydrated iron minerals; and C-H & N-H bonds in organic species

Untersee

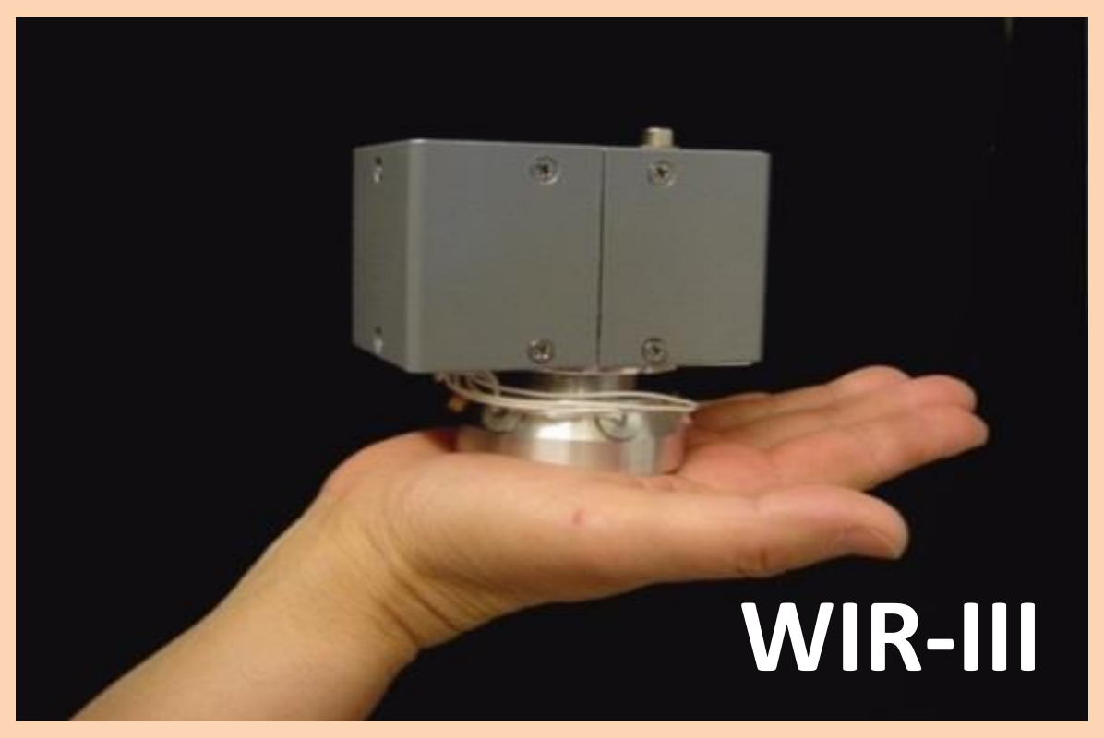
Mission: study perennially ice-covered lake Untersee and an adjacent paleolake as analogs to Mars and other Ocean Worlds

Results: identified organic signatures with mineralogical context (sulfates, clays, and phyllosilicates

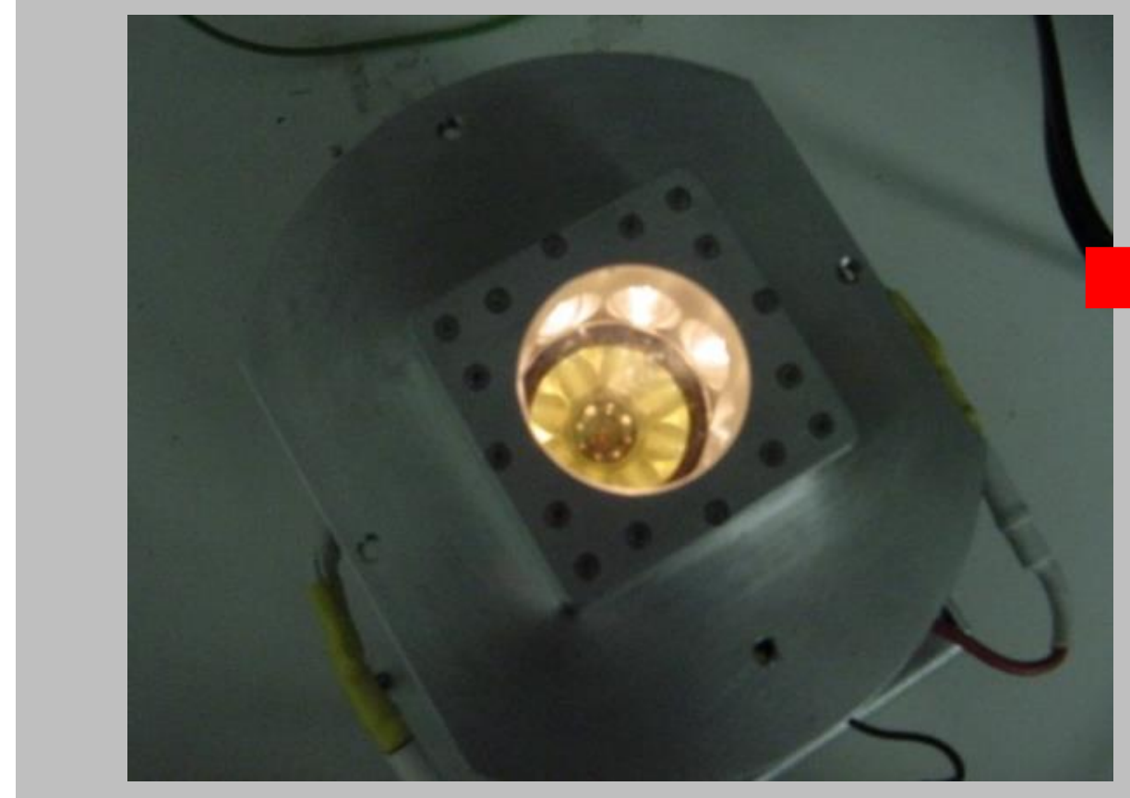
Figure 13. Select field sites where we have deployed WIR. Field deployments supported by WU MCSS, NASA ASTEP, NAI, CSA, PCSP, NSERC, Europlanets, and Tawani foundation (2017 AGU, poster).

Highly versatile ways of deployment

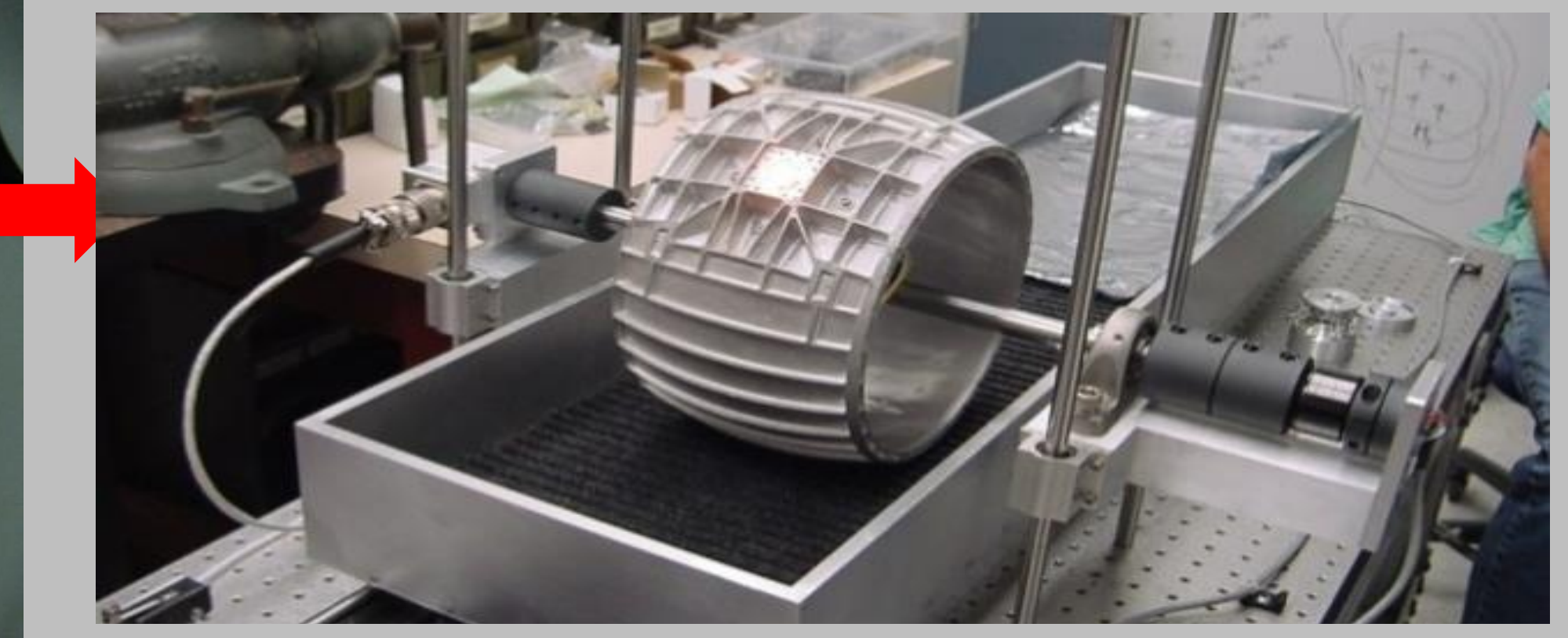
A. Hand deploy on Earth and on the Moon



B. Robotically deployment by a rover wheel

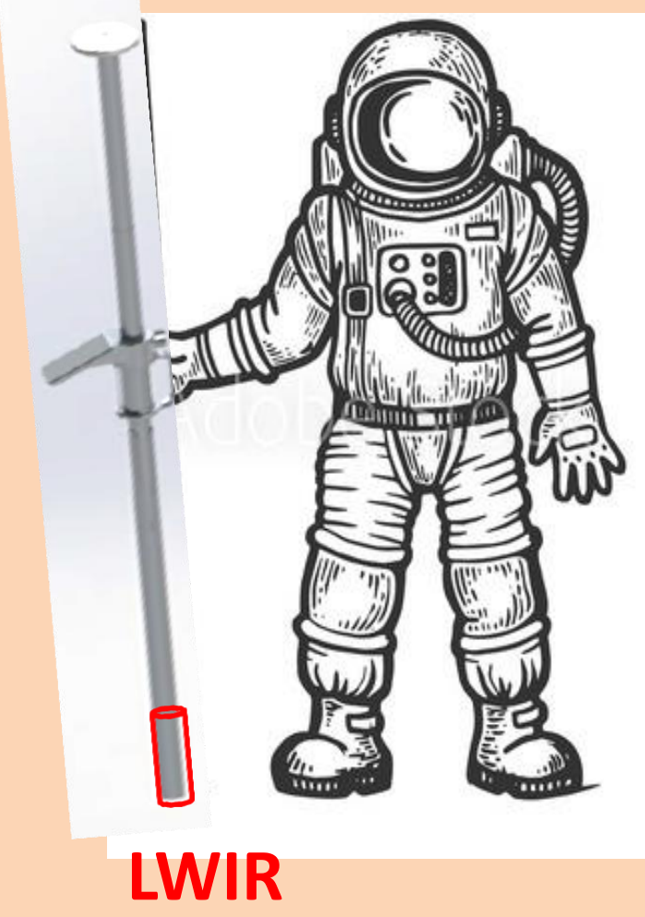


Modified WIR-IIb



WIR-IIb installed on a MER wheel at JPL

C. Deployed by astronaut using a "Walking Stick"[18] within PSR in Artemis missions



LWIR is included in a selected conceptual design study "Gandalf Staff" scientific EVA Walking Stick project at NASA-JSC relevant to Artemis program

Conclusion

- ➢ LWIR is a ultra-compact NIR sensor, with field-demonstrated science performance, and Technical Readiness Level of 4-5. The current development under SSERVI: ICE Five-O will further achieve lunar environmental adaptation of its critical parts.
- ➢ LWIR has highly versatile ways of deployment, such as on-wheel of a lunar rover, in a walking stick of astronaut, or simple as a hand-held tool of astronaut.
- ➢ LWIR will provide fast ID and quantification of lunar volatiles , including H_2O, CO_2 ice and organic ices (such as NH_2, CH_3OH, CH_4, C_2H_4, detected by LCROSS).

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References: [1] Pieters et al. (2009) *Science*, DOI: 10.1126/science.1178658; [2] Clark et al. (2009) *Science*, Vol. 326, DOI: 10.1126/ science.1178105; [3] Sunshine et al. (2009) *Science*, 326, DOI:10.1126/ science1179788; [4] Colaprete et al. (2010) *Science,* V330, 463-468; [5] Colaprete et al. (2012) *Space Science Reviews,* V167, 3-2; [6] Gladstone et al. (2010) *Science*, v330, 472-476; [7] Schultz et al. (2010) *Science*, V330, 468-472;[8] Spudis et al. (2013) *JGR-Planet,* V118, 2016-2029; [9] Patterson et al. (2016) *Icarus,* V283, p2-19; [10] Honniball et al., (2020), Nature Astronomy, https://doi.org/10.1038/s41550-020-01222-x [11] Freeman et al. (2008) *Lunar Planet Sci.* 39, #2190; [12] Wang et al. (2004) *Lunar Planet Sci.* 35, #1510; [13] Lindemann et al. (2006) IEEE, 1070-9932; [14] Sobron et al. (2009) *Lunar Planet Sci.* 40, #2372; [15] Sobron et al. (2018*) Astrobiology* 18, 1277-1304. [16] Wang et al. (2010) *Lunar Planet Sci.* 41*,* #2018; [17] Vaniman et al. (1991) The Lunar Environment, Chapter 3 in *The Lunar Source Book*; [18] Evans et al. (2020) *LSS workshop*, #5031.