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Deep Trek: Technologies and approaches for finding water, habitats, and potential life on Mars

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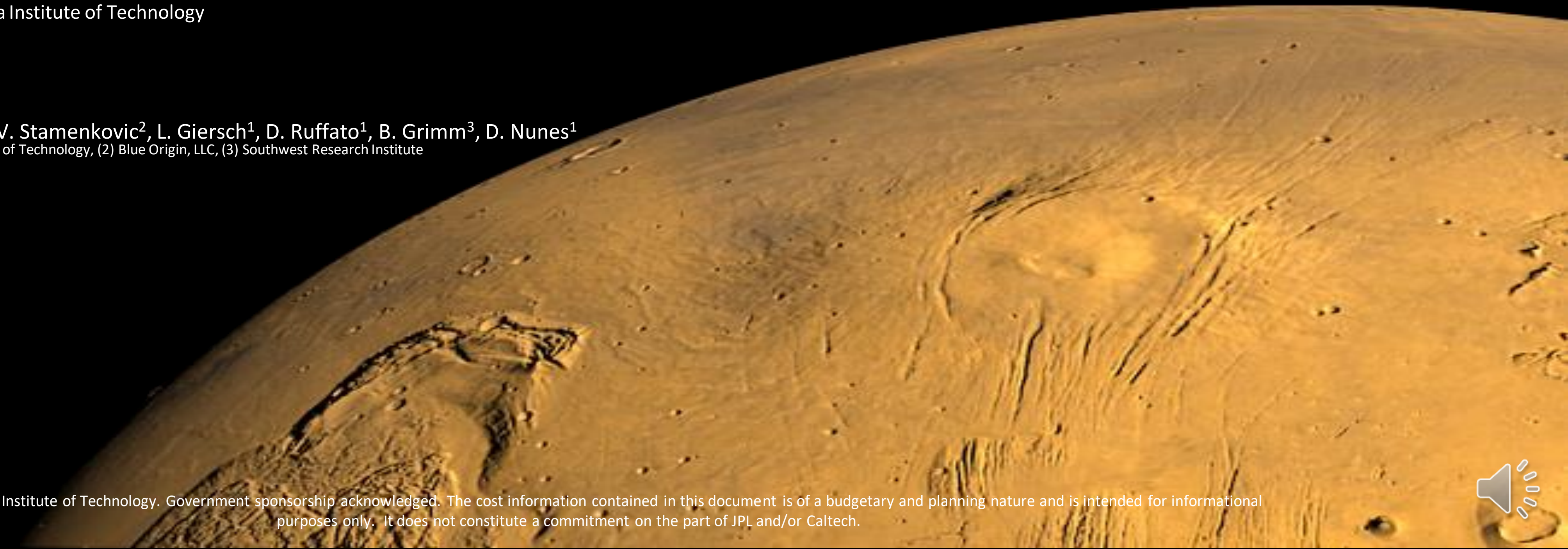

Mars Subsurface and an Unprecedented Opportunity to Explore Life

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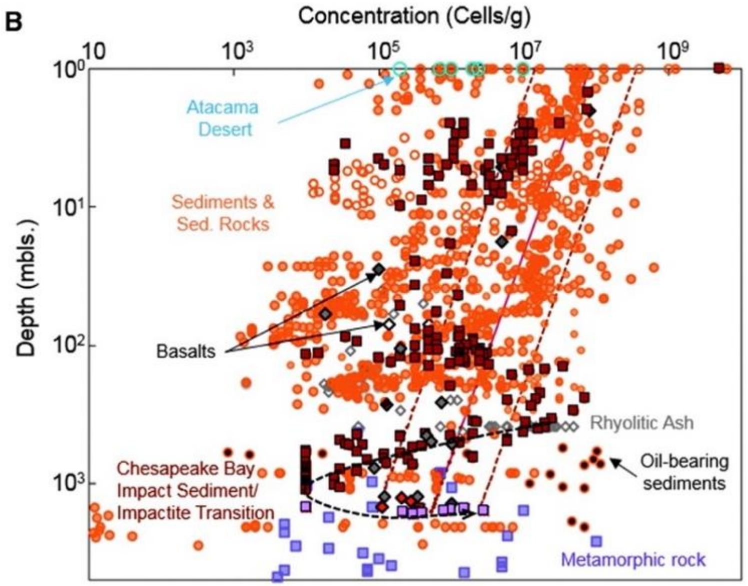
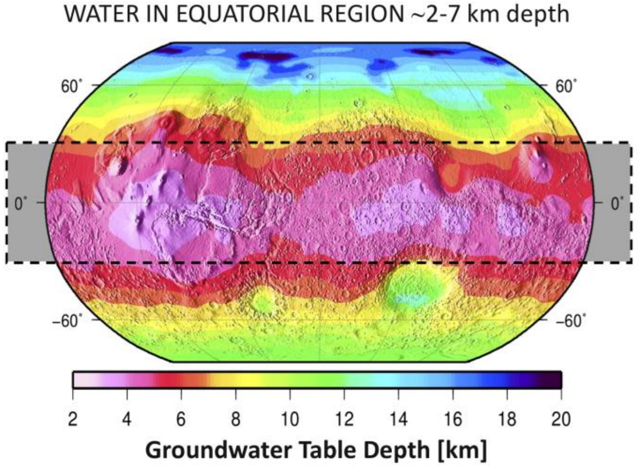
- Today's Martian surface is currently inhospitable to life as we know it.
- *"If Mars ever supported life, an earlier martian biosphere might have found refuge in the subsurface, where liquid water and rock-water reactions could provide all the needed bioessential resources, similar to the deep subsurface biosphere on Earth."* (Banfield et. al, MEPAG Science Goals, Goal 1, 2020)
- "*The Martian subsurface today is generally thought to meet the environmental requirements necessary to support life. Liquid water is the limiting factor and can occur at depths of hundreds of meters to kilometers, where temperatures are warmer than the surface*" (Jakosky, et. al, 2003)
- "*Our understanding of subsurface thermal gradients suggests that liquid water is stable for long timescales at depths of kilometers*." (Stamenkovic, et al., 2020)
- The Martian subsurface is one of the most promising places on Mars to search for life, but we have yet to send a dedicated mission to investigate the modern-day subsurface habitability of Mars or to search for signs of extant subsurface life.

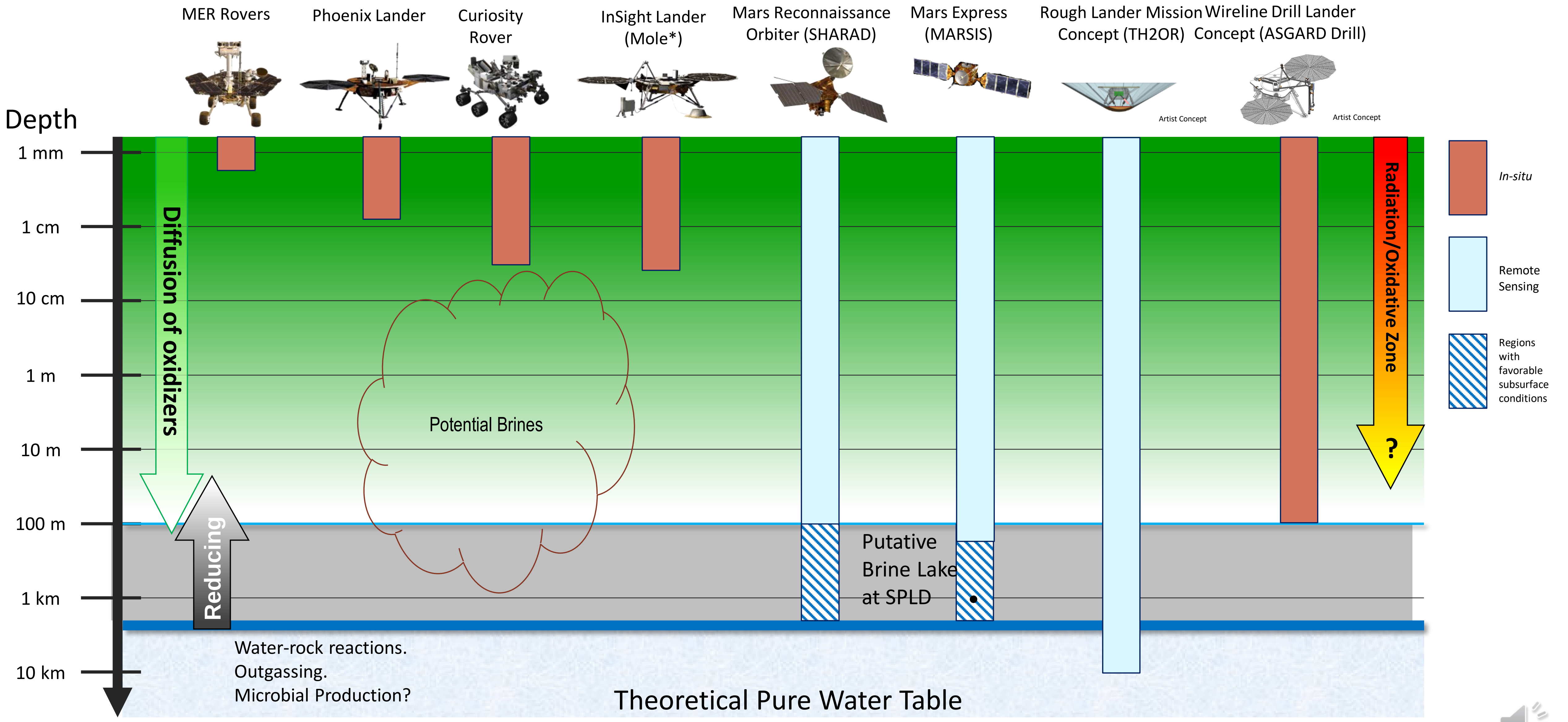


Biomass in Earth's subsurface. Plot of cell concentration vs depth for rock & soil cores from nonpolar regions. See Onstott et al. (2019)

mbls = meters below land surface.



Go Deep….


MER Rovers
Phoenix Lander
Curiosity Rover
InSight Lander (Mole*)
Mars Reconnaissance Orbiter (SHARAD)
Mars Express (MARSIS)
Rough Lander Mission Concept (TH2OR)
Wireline Drill Lander Concept (ASGARD Drill)
Artist Concept
Artist Concept
Depth
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
10 km
Diffusion of oxidizers
Reducing
Potential Brines
Putative Brine Lake at SPLD
Radiation/Oxidative Zone
?
Water-rock reactions.
Outgassing.
Microbial Production?
Theoretical Pure Water Table
In-situ
Remote Sensing
Regions with favorable subsurface conditions

VALKYRIE: Volatiles And Life: KeY Reconnaissance & *In-situ* Exploration

Phase 1: Is there ground water today?

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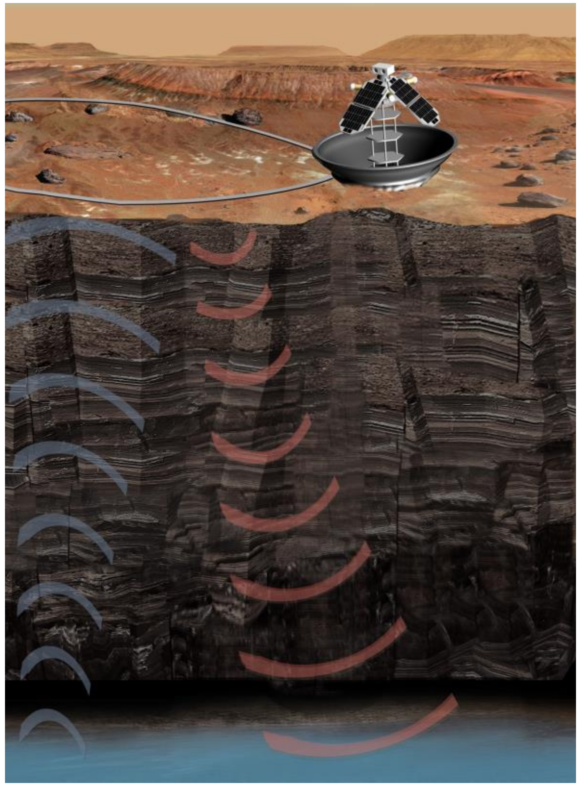
Phase 1 Mission Concept Description:

The goal of VALKYRIE Phase 1 is to determine the amount of adsorbed subsurface water as a function of depth, as well as the depth, thickness, and chemistry of the putative ground water table hypothesized to exist many kilometers beneath the surface.



Science Goals:

- G1: Quantify modern Martian subsurface habitability
  - locate & characterize liquid water

Science Instruments:

- Transient Electromagnetic Sounder (TH2OR)
  - 3.5 - 7 km depth detection capability
- Surface Context Imager

Mission Architecture:

- Ballistic Trajectory as Rideshare or Primary on Mars Bound LV
- Single Rough Lander (SHIELD) with single cruise stage
- Three Rough Landers with three individual cruise stages

Estimated Mission Cost	Single Rough Lander	Three Landers
Mission Cost Ph A – D FY20	$150 M	$301 M

TH_2OR: Transient Electromagnetic Sounder

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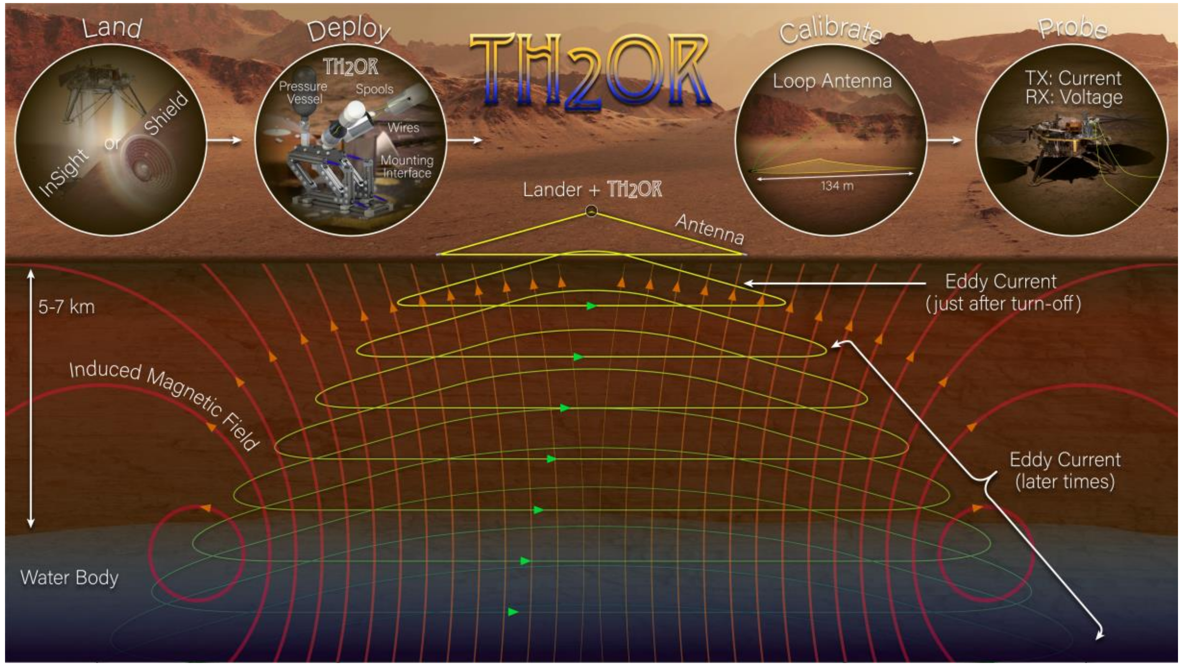
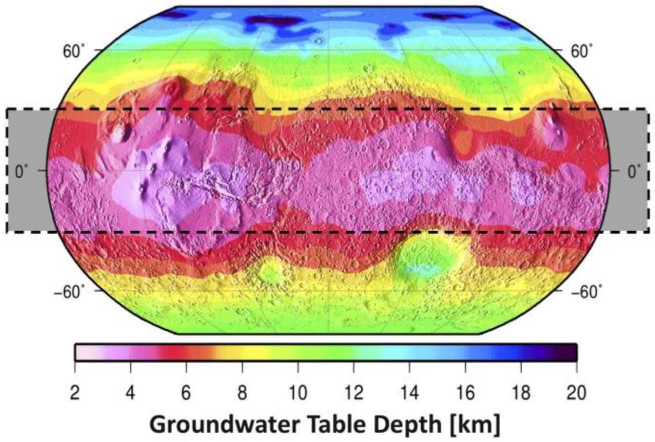
Transient Electromagnetic (TEM) Sounder

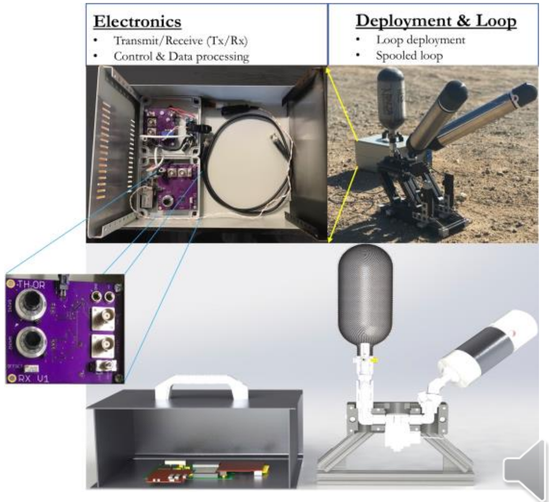
- Deployed Co-Incident Antenna
- 7 km depth capability
- 6 kg
- 30 cm x 10 cm x 10 cm
- 500 Wh/sol
- Target TRL5 by end of FY21.
- Ruggedized to survive impact up to 1000 Earth g.
- Decades-old technology on Earth



How TH_2OR works:

- *Bipolar periodic switching on and off of a 1-5 Amp DC current generates EM fields that propagate into the subsurface and induce eddy currents in liquid water aquifers.*
- *Those subsurface eddy currents then generate a variable magnetic field,*
- *which induces a current in the same loop on the surface and is measured during the loop's current time-off*.





PI: Daniel Nunes/JPL, Vlada Stamenkovic/Blue Origin
Bob Grimm/SwRI

SHIELD Rough Lander

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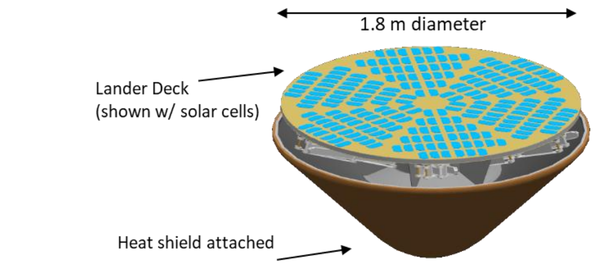
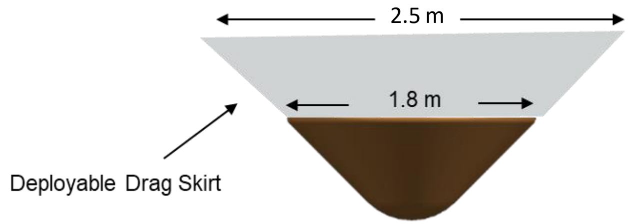
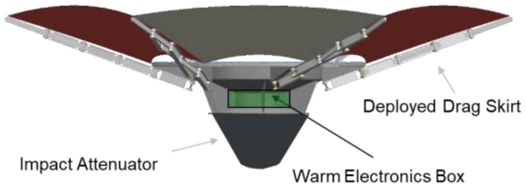
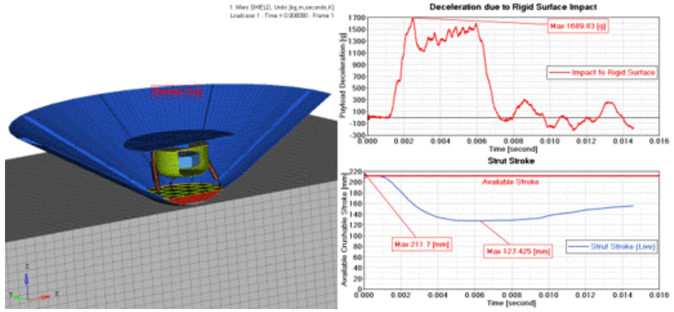
SHIELD Rough Lander:





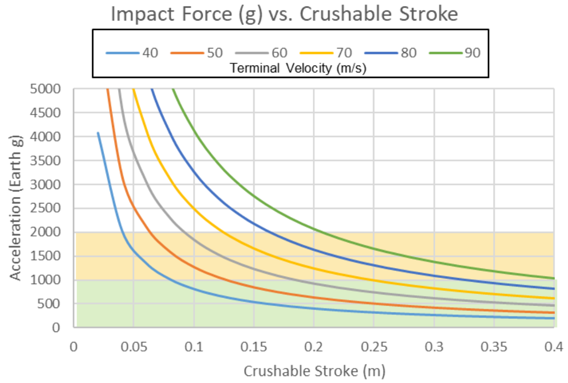


Entry Mass (kg)	100	kg
Aeroshell Diameter (m)	1.8	m
Drag skirt Diameter	2.5	m
Touchdown Mass (kg)	50	kg
Nosecone Angle	45	deg
Payload Mass (kg)	6	kg
Peak Acceleration	<2000	g
Impact Pulse Duration	8	ms
Landing Site Elevation (km)	-3.0	km
Landing Ellipse, Major Axis (km)	40	km
Landing Ellipse, Minor Axis (km)	4	km



SHIELD uses a low ballistic coefficient (BC) to slow down using Mars atmosphere.

SHIELD has a low mass, and uses a deployed drag skirt to increase the projected area during entry to reduce ballistic coefficient further.



Low-cost architectural approach

Launch → Cruise → Entry and Descent → Landing

Launch: To reduce cost SHIELD could be flown as a rideshare or piggyback.

Cruise: Reduction in cost by using a commercial cruise stage.

Entry and Descent: SHIELD does not a parachute or propulsive deceleration; instead we use a deployed drag skirt to increase the projected area.

Landing: SHIELD has a impact attenuator that utilizes stroke to absorb the impact acceleration.

PI: Lou Giersch/JPL

VALKYRIE: Volatiles And Life: KeY Reconnaissance & *In-situ* Exploration

Phase 2: Search for extant life

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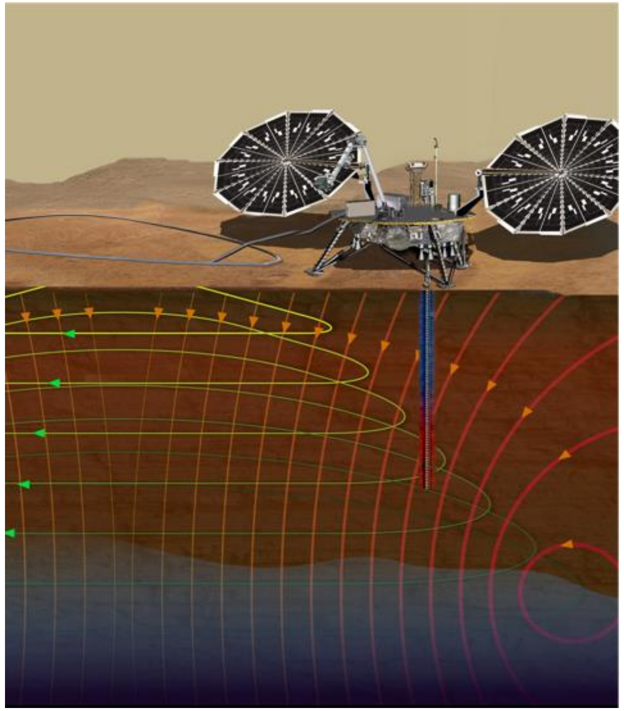
Phase 2 Mission Concept Description:

Augment Phase 1 subsurface sounding with deep drilling capability to provide direct access to characterize subsurface (bio)geochemistry to depths of ~100 m



Science Goals:

- G1: Quantify modern Martian subsurface habitability
  - locate & characterize liquid water
  - identify energy & nutrient sources
  - assess molecular and cellular stability potential with depth
- G2: Search for evidence of extant subsurface life
  - Seek biomarkers & signs of metabolic activity

Science Instruments:

- Transient Electromagnetic Sounder (TH2OR), Surface Context Imagers
- 100-m wireline drill w/ suite of topside and/or downhole instruments (e.g., *Mini-TLS, SHERLOC, MOMA)*

Mission Architecture:

- "PHX+" propulsive lander

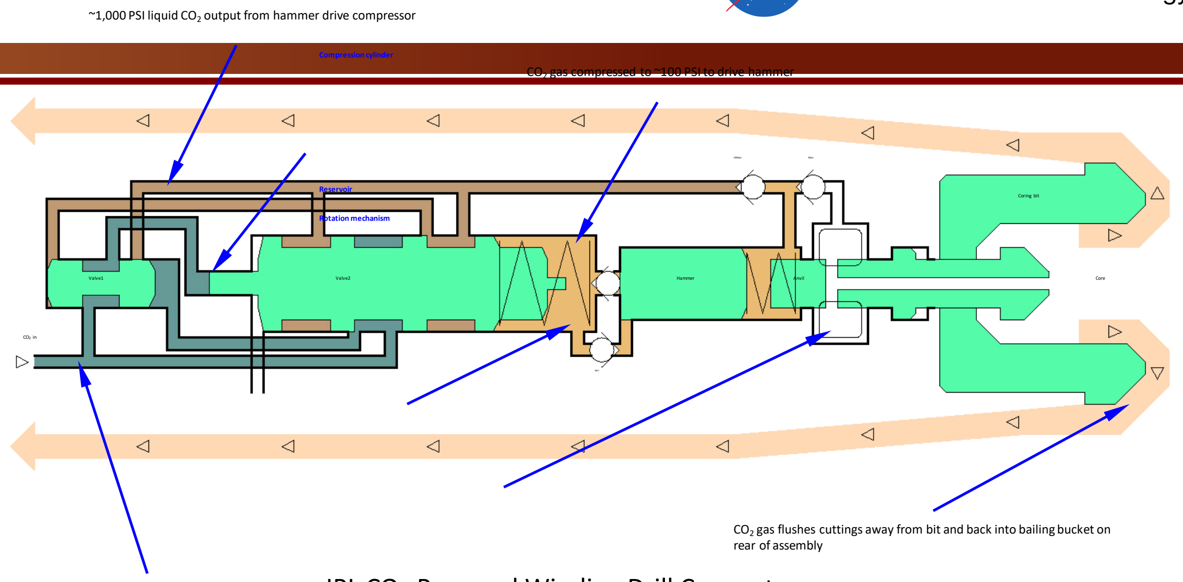
Estimated Mission Cost	Single Rough Lander
Mission Cost Ph A – D FY20	$~1,000 M

VALKYRIE: Volatiles And Life: KeY Reconnaissance & *In-situ* Exploration

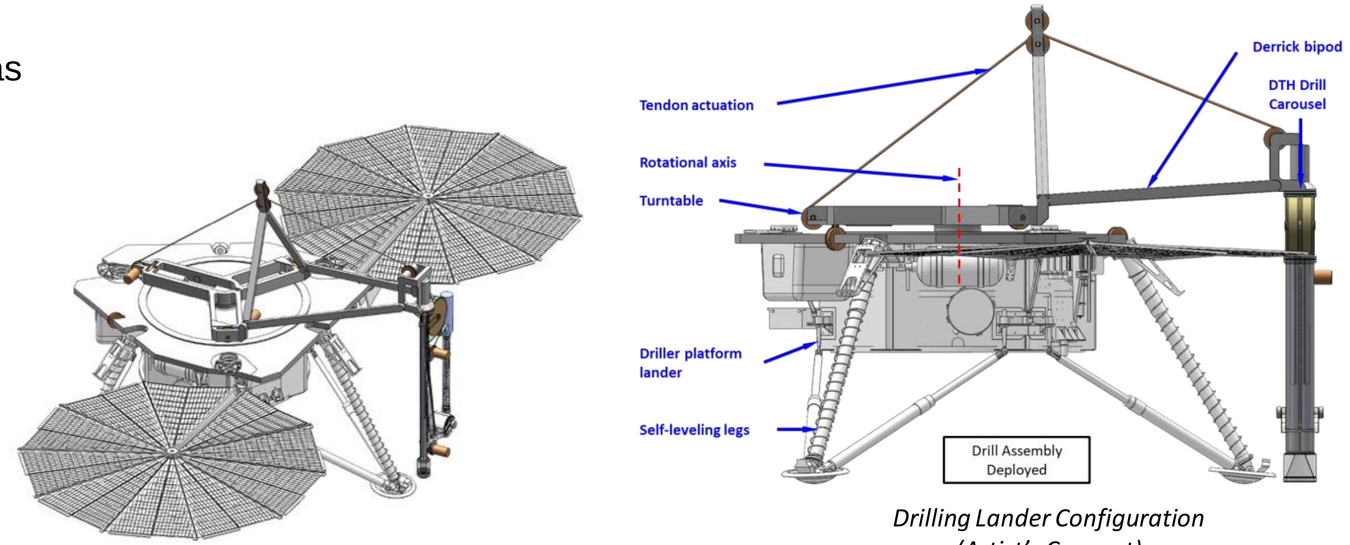
Phase 2: Geochemical Gradients with Depth

Deep Drilling

- Wireline drill concept for accessing depths of ~100 m with low mass and power
  - Reduced drill bit diameter (3 cm)
  - Reduced mass and power (<100 kg, <100 W)
  - Autonomous operations
  - Use of compressed liquid CO_2 (extracted from Mars atmosphere) to power drill
  - Same CO_2 – upon vaporizing – serves to flush cuttings from borehole into bailing bucket
  - Sub-mm fused silica capillary serves as wireline and also as conduit for pressurized CO_2
  - All downhole parts rated for > 350°C, enabling straightforward sterilization
- Instrument options
  - Borehole in-situ instrumentation
  - Sample delivery to lander deck for analysis, or more sophisticated organics analyzers (e.g., MOMA, SAM)



JPL CO_2-Powered Wireline Drill Concept



Drilling Lander Configuration (Artist's Concept)

PI: D. Ruffatto/JPL

Conclusions

- Decades of exploration on Mars using orbital and landed spacecraft, coupled with knowledge of Deep life on earth, suggest that the subsurface on Mars may still host a long-lived habitable environment that could host extant life.

- Small low-cost landers could enable options for characterizing groundwater using TEM and single or multiple rough landers.

- Wire-line drills used to determine subsurface (bio)geochemistry at depths of 100 m or more fit within a NF and Flagship mission class .

- These mission concepts are not only relevant to NASA’s and MEPAG’s overarching science goals but also spark the interest of the public at the possibility of extant life on other worlds.

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Backup

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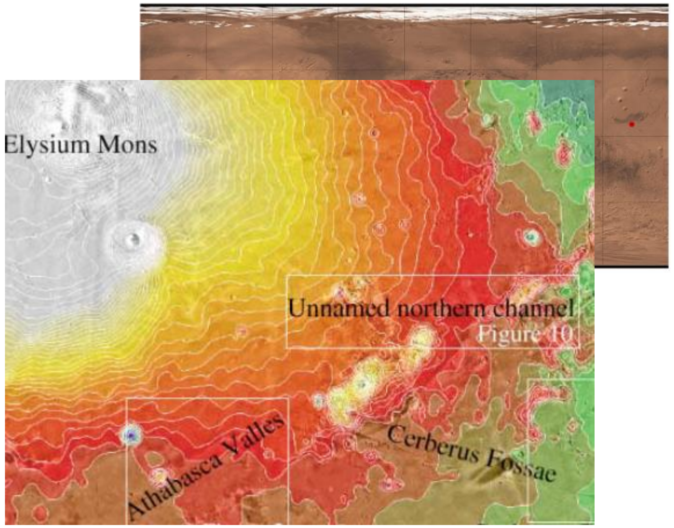
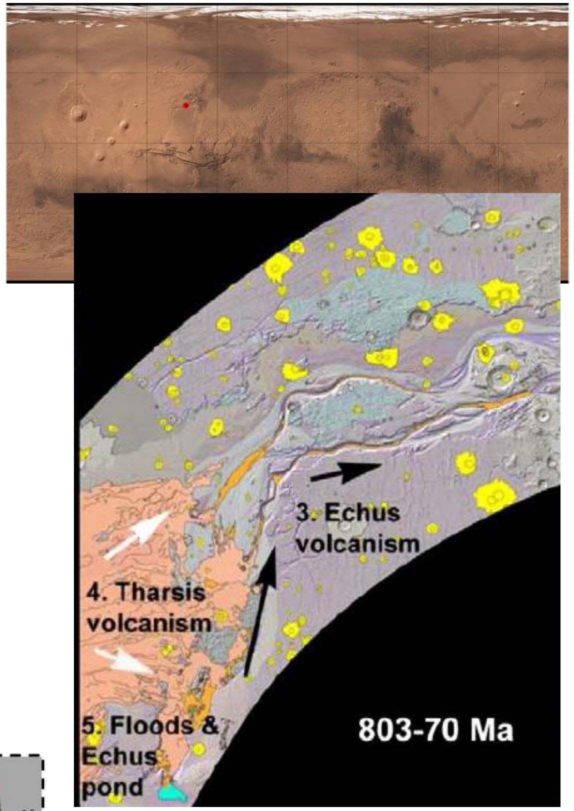
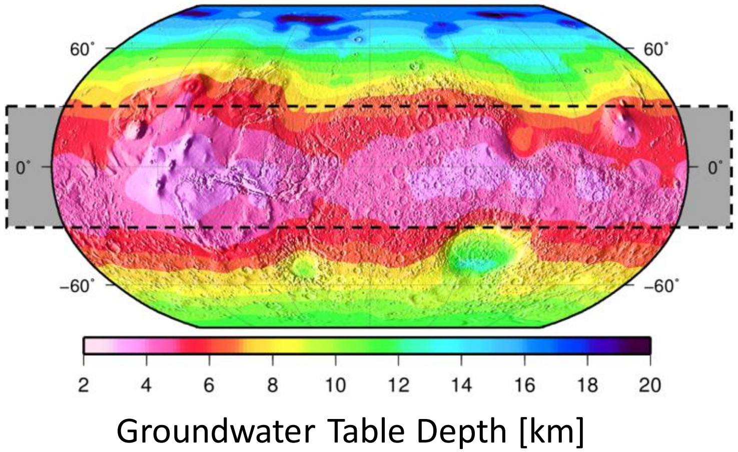
TH_2OR concept: Where to land?

We can land where:

- Available data suggest:
  - Recent water outflows (e.g., Kasei, Athabasca)
  - Trace gas outgassing (East of Gale crater?)
- Where models predict:
  - Shallow liquid water accumulation.
- *Any place* will help us understand global water inventories (especially if we land at low elevation or with more than one asset)
  - Probing hydration/salinity with depth will reveal modern groundwater inventory and groundwater history







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