TH2OR ELECTROMAGNETIC SOUNDING FOR SUBSURFACE BRINES ON MARS. D. C. Nunes[1], R. E. Grimm[2], N. Barba[1], M. Burgin[1], K. Carpenter[1], R. Manthena[1], [1]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Dr., Pasadena CA 91109, Daniel.Nunes@jpl.nasa.gov) for first author, [2]Southwest Research Institute (Boulder, CO).

Introduction:
A variety of recent MEPAG documents and Origins, Worlds, and Life (OWL), the new Decadal Survey mapping the science priorities for the next 10 years continues to highlight the importance of following the water at Mars **[1, 2]**. Determining the presence, distribution, inventory and chemistry of water and brines is key to high-priority science questions pertaining to accretion of terrestrial planets, atmospheric and climatic evolution, habitability, and astrobiology. Although the Mars Exploration Program has dramatically increased our understanding of water at Mars with the characterization of the polar layered deposits, detection of ground ice, and determination of atmospheric escape, our knowledge of water in the Martian subsurface is scant. There are indications that it existed and might still exist, but unambiguous detection of groundwater has not been made either in the shallow or deep subsurface.

Transient electromagnetic (TEM) sounding is a common geophysical method used to map groundwater on Earth, as it is sensitive to electric resistivity of the medium through which the sounding currents travel, and water saturation and salinity are key controlling factors for electric resistivity **[3]**. Thermal modeling of Mars suggests that liquid water could exist at depths of a few kilometers if fresh, or much closer to the surface depending on salinity and freezing point **[4, 5]**.

Yet, TEM has never been utilized in planetary missions. Here we make the case for further development of a planetary TEM instrument, TH2OR (TEM H2O Reconnaissance) and its inclusion in future missions.

TEM and TH2OR:
TEM operates through the induction and downward propagation of eddy currents in the subsurface (Fig. 1). To generate these currents, the TEM instrument imparts and interrupts and electric current in a transmitting (TX) loop antenna sitting at or above the surface. The flowing current creates a vertically oriented primary magnetic field within the loop and that extends downwards into the subsurface. When the current within the loop is interrupted, the decay of the primary magnetic field creates eddy currents in the subsurface and an associated secondary magnetic field.

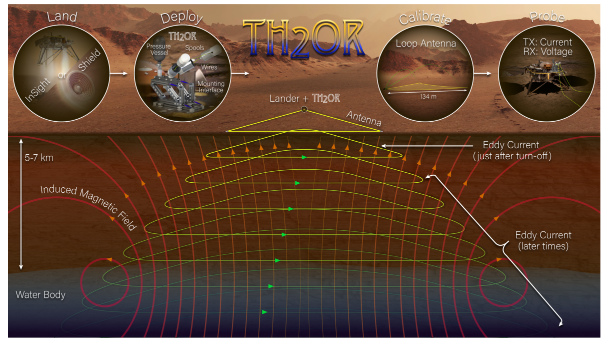

Figure 1 – Diagram showing the TH2OR concept and the general sounding principle behind TEM.

Unlike radar waves, eddy currents diffuse downward and decay with time, their intensity being dependent on the electric resistivity of the material, thus modulating the secondary magnetic field **[5]**. A receiving (RX) loop antenna or coils detect the evolution of the secondary magnetic field.

TH2OR (Fig.1) is a TRL-4 prototype (7 kg, 30 W) for planetary TEM intended for the detection of subsurface water on Mars funded internally by JPL and in collaboration with the Southwest Research Institute. Its current implementation consists of two loop antennas (TX and RX), an antenna deployment system, and the electronics box. The size of the loops, which controls gain, depends on the desired depth of sounding and conductivity of the subsurface water, but for soundings of several km, a single winding loop needs to be ~100 m wide. Smaller loops can be employed if the depth of sounding is reduced. We have tested the prototype electronics and loop deployment system at the Arroyo Seco sedimentary basin near JPL, which overlies a ~50-m unconfined aquifer.

The ballistic deployment system employs cold compressed gas to launch two projectiles that carry two spools of wire each. The spools are interconnected to the launcher and between the two projectiles (Fig. 2). The Arroyo area is a very useful analog for the deployment system because its surface varies from a smooth sandy surface to a cobble-and-boulder dominated surface, and allows us to understand the laying of the triangular wire loop ballistically on the surface. The maximum loop size achieved by our deployment subsystem was 47 m, which scales up to 123 m under Martian gravity.

Figure 2 – Deployment of TH2OR antenna loop via projectiles launched by a compressed cold-gas launcher at the Arroyo Seco in Pasadena, CA.

Sounding with the prototype electronics detected the water table of the unconfined aquifer beneath, and the overall resistivity structure of the Arroyo is a scaled-down version of the Mars subsurface (Fig. 3) during the testing season, as it consisted of a 40-to-50-meter resistive dry layer over a conductive saturated aquifer. The depth to water table was verified via other geophysical methods and well data.

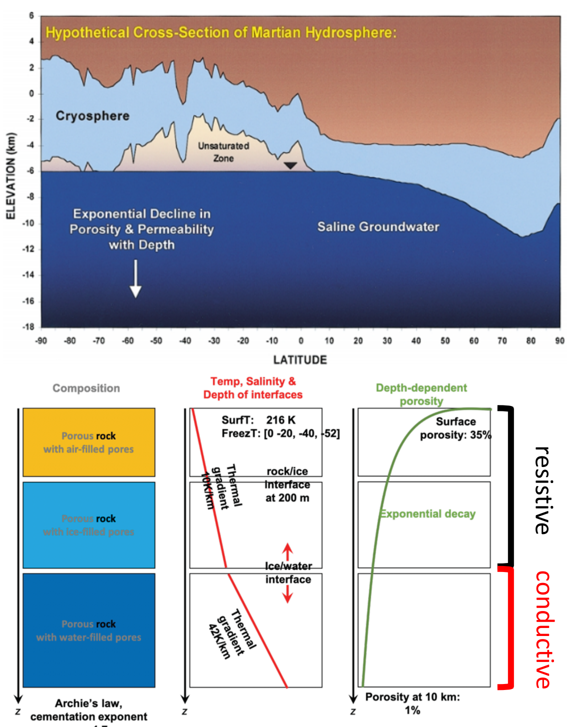

*Figure 3 – (Top) Diagram from **[6]** denoting the hypothesized planet-wide hydrogeologic structure. (Bottom) From left to right, panels show the 1-D hydrogeologic stratigraphy, thermal model, and porosity/resistivity structure deriving from the model on the top.*

High-Level Con-Ops:

Upon delivery to the surface TH2OR electronics will be powered on and trigger the deployment system to fire and laid down the antenna loop ballistically onto the surface. For the first few days of operation the instrument will execute several test soundings for commissioning and testing the integrity of the antenna loop. Engineering cameras may assist in the verification of the antenna configuration. Afterwards, the science-phase will take place, and the instrument will repeat soundings many times a day for a period of up 90 sols. Sounding over a long timeline allows for improvement of signal-to-noise-ratio and increased depth of sounding. The exact duration of the science-phase and total number of soundings will depend in part on the exact area of the deployed loop. Data for a recurring number of soundings may be stacked onboard to reduce downlink volume requirements.

Path to Flight:

TH2OR is a stand-alone instrument that can be paired to different types of landers in order to perform a geophysical mission seeking to determine the presence of subsurface water or brines. Its relatively low mass and power allow TH2OR to be a viable instrument in future low-cost missions, such as enticing mission Phoenix/InSight derivative soft lander, or with the JPL SHIELD rough lander **[7]**. While TH2OR could be deployed to a single location where subsurface water is deemed to be most likely present and detectable, multiple deployments (via multiple SHIELD landers, for instance) would be ideal as they would permit the validation of the thermal models and ground water distribution for Mars.

References:

[1] Jakosky, B., et al., *Mars, the Nearest Habitable World—A Comprehensive Program for Future Mars Exploration*, in *Mars Architecture Strategy Working Group (MASWG)*. 2020. **[2]** National Academies of Sciences, E. and Medicine, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*. 2022, Washington, DC: The National Academies Press. 800. **[3]** Fitterman, D.V. and M.T. Stewart, *Transient electromagnetic sounding for groundwater.* Geophysics, 1986. 51(4): p. 995-1005. **[4]** Stamenković, V., et al., *The next frontier for planetary and human exploration.* Nature Astronomy, 2019. **3**(2): p. 116-120. **[5]** Grimm, R.E., *Low-frequency electromagnetic exploration for groundwater on Mars.* Journal of Geophysical Research: Planets, 2002. 107(E2): p. 1-1-1-29. **[6]** Clifford, S.M. and T.J. Parker, *The evolution of the Martian hydrosphere: Implications for the fate of a primordial ocean and the current state of the northern plains.* Icarus, 2001. 154(1): p. 40-79. **[7]** Barba, N., et al. *Access to Mars Surface Using a Low-Cost Rough Lander*. in *2021 IEEE Aerospace Conference (50100)*. 2021.