ORBITING OBSERVATORY FOR STUDYING HYDROLOGICALLY ACTIVE REGIONS ON MARS

D. A. Paige[1], C. J. Hansen[2], A. S. McEwen[3], T. A. Komarek[4], J. O. Elliott[4], A. E. Nash[4] ,T. P. McElrath[4], R. O. Green[4] and M. C. Foote[4] [1]Dept. of Earth and Space Sciences, UCLA, Los Angeles, CA, [2]Planetary Science Institute, [3]University of Arizona, [4]JPL/Caltech, Pasadena, CA.

Introduction: We propose that the next mission in NASA's Mars Exploration Program be an orbiting observatory capable of studying special regions with recent and current hydrologic activity. Rather than mapping the entire planet, the observatory would focus on obtaining high spatial and temporal resolution observations of Recurring Slope Lineae (RSL) and other predominantly mid-latitude features to determine more precisely what they are, how they form, and the implications for current Martian habitability. We argue that the discovery of the RSL, along with our new appreciation of hygroscopic salts on Mars, marks an important turning point in our exploration of the planet, and that a dedicated orbiting observatory mission to understand these features is the next essential step.

The New Hydrologically Active Mars: The history of Mars spacecraft exploration can be characterized by a series of exciting discoveries that have dramatically overturned previously held beliefs about the planet. Until very recently, the dominantly held position within the scientific community was that while geologic and climatic conditions during Mars' distant past may have been conducive to the potential origin and evolution of life, conditions on Mars today offer slim hope for life as we know it due to the unlikely existence of near-surface liquid water environments. However, in August 2011, new results from HiRISE investigations were published in *Science* which showed dramatic evidence for seasonally recurring down-slope flows emanating from equator-facing mid-latitude bedrock outcrops [1]. The original paper made a strong case based on the morphology and timing of the flows, and the thermal conditions that existed when they were active, that Recurring Slope Lineae (RSL) features were due to surface or near-surface liquid water. The water in RSL may be quite salty, because we know from landers, meteorites, and remote spectroscopy that the surface of Mars is rich in salts that can dramatically lower the freezing point and evaporation rate of water on Mars. Furthermore, lab experiments have even shown that perchlorates discovered by *Phoenix* [2] must form liquid drops on Mars at certain times of day and season, even near the equator [3].

The existence of liquid water on Mars today is a real game-changer from many perspectives. If the conclusion that RSL's are formed by liquid water is correct, then the possibility that that these are indeed habitable environments cannot be ignored. Furthermore, because of the widespread distribution of these features, the properties and processes that are responsible for their formation must be fairly common on Mars today. Although the initial set of confirmed RSL were confined to the southern mid-latitudes, an equatorial site (Coprates Chasma) was recently confirmed [4]. Furthermore, the fact that RSL's are forming regularly on Mars today means that they have also likely been forming regularly on Mars in the past, which improves the odds that Martian organisms have persisted near the surface.

The Case for an Orbiting Observatory: HiRISE has provided an excellent first-order reconnaissance of the RSL, but today we can only speculate regarding the source(s) of the water, how it is replenished, or whether it contains significant quantities of dissolved components that may improve its stability and affect its potential for habitability. Eventually, these and many other questions about the RSL will be addressed *in situ* with mobile robotic platforms, and by samples brought back to Earth for detailed analysis. Unfortunately, due to the relative inaccessibility of the rugged RSL source and run-out regions, as well as planetary protection considerations, the RSL will not likely be prime targets for the next wave of landed missions.

We propose that the next step for NASA's Mars Exploration Program should be a new orbiting observatory that is optimized for detailed characterization of hydrologically active regions. The key goals for the observatory would be to provide:

1. Definitive yes/no answers regarding the presence of surface or near-surface liquid water and associated minerals
2. Detailed information regarding environmental conditions in the RSL source and runout regions and other locations of water activity
3. High-spatial resolution topographic mapping of key sites and nearby candidate landing sites

With this information in hand, it will be possible to confidently plan future water-focused landed missions *and* understand enough about the present environment and habitability of Mars to optimize planning for the next wave of robotic and human missions.

Programmatic Considerations: The overarching scientific thrust of current Mars exploration is well captured in the current Decadal Survey: *"The committee, building on numerous community assessment groups, open discussions, and white papers, places as* *the highest priority Mars science goal to address in detail the questions of habitability and the potential origin and evolution of life on Mars....".* The current Decadal Survey recommends a three-element sample return mission campaign as the next step towards advancing this overarching scientific goal. The proposed orbiting observatory mission would serve as a precursor to such a campaign, providing critical new science information as well as an orbital communications relay for subsequent landed activity.

The current Decadal survey was developed largely during 2008-2010, and since that time, two important considerations have changed. The first is that we have now identified several locations in the Martian mid-latitudes that may be habitable today, and thus, consistent with the overarching scientific goals of the Mars program, warrant immediate and intensive scientific study. The second consideration that has changed is NASA's desire for a closer coupling between NASA's robotic exploration and human exploration programs. In a future where humans may ultimately visit and live for extended periods on Mars, the availability of resources such as water will be important, but the environmental impacts of human activities will also be a fundamental concern. Even in today's era of robotic exploration, considerations of planetary protection are primary scientific and technical drivers. If we are going to explore Mars in a knowledgeable and responsible manner, it is vital that we do our best to better understand those aspects of the Martian environments for which our exploration activities may have the greatest impacts.

Hydrology Orbiting Observatory (H2O) Mission Concept: We have developed an Orbiting Observatory mission concept for the 2018 opportunity that employs a MAVEN to MRO-class orbiter with an orbit that is optimized for high spatial resolution, high recurrence and wide local time coverage in the mid-latitude regions of Mars. During a 1.75 Mars year primary mission (including two southern summers when RSL are most active), the orbiter would monitor regions of current hydrologic activity by providing simultaneous measurements of high-resolution multi-color imagery, near-infrared imaging spectroscopy and thermal imaging, and profiles of atmospheric temperature and water vapor. Measurements would be acquired at multiple times of day within a period of weeks to enable a detailed local characterization time variable thermodynamic parameters relevant to the distribution and behavior of water on Mars, as well as the ability to detect changes in the distribution of solid, liquid and gaseous water and aqueous minerals at the necessary spatial scales. These measurements would be accomplished with a threshold payload consisting of three instruments and a total mission development cost of less than $750M, including ample reserves. While the main scientific focus of the orbiting observatory would be to monitor current hydrological activity on Mars, the orbiter would also serve as a communications relay for future surface assets, EDL, and a high-resolution mapper for detailed characterization of future landing sites. With the availability of additional funding, the orbiter could also serve as a carrier for technology demonstration experiments such as optical communications, or carry additional science instruments such as a synthetic aperture radar system or an atmospheric monitoring package.

Table 1. H2O Mission Technical Baseline

Mission Class	Between MAVEN and MRO
Mission Design	
Launch Date and C3	May 2018, C3=8.8 (Type I traj.)
Mars Arrival Date	January 14, 2019
Aerobraking	4 to 6 months
Orbit Altitude	150 x 530 km
Orbit Inclination	45 degrees (~sun-synch periapsis)
Orbit Local Time Coverage	7am to 3pm (under 200 km)
Repeat coverage at <200 km range	13 times in 10 days at 45N or 45S (~20x better than MRO)
Primary Mission Duration	1.75 Mars Years
Flight System	
Launch Vehicle	Falcon 9
Launch mass / Dry mass	1590 kg / 840 kg (incl. margin)
Communications	X-Band (3 meter fixed antenna)
UHF Relay	Electra
Optional Communications	*Ka Band and Optical*
Data Volume	14 to 115 Gb/Day (2.5-0.5 AU)
Season of peak data rate	Late S spring through S summer in 2019-21 (this is ideal)
Pointing Control	3 mrad (3σ)
Power	1500 W at Mars
Stereo Color Imager	HiSCI Design Heritage
Aperture	14 cm
Spectral Range	0.4 to 1 μm (4 colors)
Spatial Resolution at 150 km range	1.5 m optical (0.75 m/pixel)
Minimum Swath Width	3.2 km
CBE Mass	20 Kg
Near-IR Spectrometer and Thermal Imager	M3 / ARTEMIS Heritage
Aperture	50 cm
Spectral Range	1 - 5.1 μm
Spatial Resolution at 150 km range	1 m optical at 1 μm to 4.6 m optical at 5 μm (2 m/pixel)
Minimum Swath Width	1.7 km
Cooler	95K Passive
CBE Mass	60 kg (CBE)
Submillimeter Spectrometer	Rosetta/MIRO Heritage
Aperture	30 cm
Operation Mode	Nadir
Spectral Range	320-350 GHz
Maximum Optical Resolution	0.5 km at 150 km range
Primary Species	CO, H2O plus surface temp.
CBE Mass	20 kg
Optional Payload Elements	*High-resolution SAR (near surface solid and liquid water), Atmospheric Monitoring, and Radiation Monitoring*
Mission Operations System	High heritage from MRO
Development Cost	<$750M (RY$ including reserves)

References: [1] McEwen, A. et al. (2011) Science 333, 740. [2] Hecht, M. et al. (2009) Science 325, 64. [3] Gough, R. et al., 2011, EPSL, 312, 371-377. [4] McEwen, A. et al., this workshop.