FUTURE ORBITAL MEASUREMENTS NEEDED TO UNDERSTAND PRESENT-DAY LIQUID H_2O ON THE SURFACE OF MARS. A. McEwen[1], S. Byrne[1], V. Chevrier[2], C. Dundas[3], C. Hansen[4], M. Masse[5], S. Mattson[1], S. Murchie[6], L. Ojha[1], D. Paige[7], E. Schaefer[1], N. Thomas[8], J. Wray[9] [1]LPL, U. Arizona (mcewen@lpl.arizona.edu), [2]U. Arkansas, [3]USGS, [4]PSI, [5]Space Research Centre, Poland, [6]JHU APL, [7]UCLA, [8]U. Bern, Switzerland, [9]Georgia Tech.

Introduction: Pure water will rapidly evaporate (often boiling) and/or freeze on the surface of Mars, but salts can dramatically lower the freezing point and evaporation rates, thus salty water is much more stable [1]. The discoveries of perchlorate [2] and other hygroscopic salts on Mars dramatically change the prospects for liquid water today. In fact, some salts must form small quantities of water at certain times of day, especially at higher latitudes [3]. The discovery of recurring slope lineae (RSL) [4] suggests that enough water may be present at certain times and places to flow down steep slopes, and points to key places for focused investigation.

This new paradigm of water on Mars today raises the exciting potential for extant life near the surface [5], but also raises issues of planetary protection that complicate lander/rover exploration and especially sample return. This is even more critical to potential human exploration, as water is needed for drinking, growing food, oxygen to breathe, and fuel to return home. A live human body contains about 10^{14} bacterial cells and cannot be sterilized. We must understand the surface water and present-day habitability of Mars from orbital observations before attempting a landed mission to a "special region," defined as any region that might experience temperatures above 248 K and water activity >0.5 for a few hours per year [6]. A mission concept focused on this objective is described in a companion abstract [7]. Here we summarize recent results and discuss the critical measurements that can be achieved from orbit.

RSL: Recently discovered recurring slope lineae are relatively low-albedo features that extend down steep slopes from bedrock outcrops, often associated with small channels, and hundreds of them may form in rare locations [4]. RSL in the southern mid-latitudes appear and lengthen incrementally during the late southern spring through summer, favoring equator-facing slopes--times and places with peak surface temperatures from ~250 to 300 K. MRO's High Resolution Imaging Science Experiment (HiRISE) provides the primary dataset for observing these meter-scale features. RSL are recurring: forming and growing in the warm season, then fading and usually completely vanishing in cold seasons, and new features then form and grow in the next warm season.

Until recently, 15 confirmed RSL sites were found only from 52°S to 32°S latitudes [8]. Confirmation requires that we see new lineae form in the same places in more than one Mars year, so we can distinguish RSL from episodic dry mass wasting triggered by impacts, seismic events, or wind. In April 2012 HiRISE confirmed RSL in a crater on the floor of Coprates Chasma (14.1 S, 296.9 E). This suggests that there may be more special regions near Mars' equator than previously suspected. A number of other equatorial candidate RSL are being monitored for activity.

Intensive monitoring during the past southern summer has revealed new details, best seen in a set of animated GIFs at http://hirise.lpl.arizona.edu/sim. These observations show that individual flows fade at different rates, and may fade even in the summer while others are growing. Fading of individual flows may occur in only 2 weeks, even while adjacent flows do not fade. There are significant interannual variations in the abundances, lengths, and exact locations of the RSL.

Liquid brines near the surface might explain the RSL activity, but the mechanism and source of water are not understood. The very specific behaviors of RSL with respect to season and the incremental growth strongly suggest the action of a volatile, and the temperatures are far too warm for CO_2, making water the best candidate. The source of water must be either the atmosphere or the subsurface.

So far, no water bands have been seen in CRISM observations of RSL. Laboratory measurements [9] have shown that this can be explained by the combination of resolution that is often an order of magnitude larger than lineae widths, and weakening of absorption bands at 1.5 and 2 µm as the RSL dry out in the mid-afternoon when MRO observes Mars. Ongoing analyses focus on the strongest absorptions near 3 µm.

Key Future Measurements:

High-Resolution Stereo and Color Imaging. Imaging is needed to identify and monitor RSL and to map slopes. A scale of 1 m/pixel or better is essential for definitive identification of RSL. We have seen that interannual variability can be large, so we cannot assume RSL will be present in the same places seen during MRO operations. Equally essential is a high signal-to-noise ratio (SNR), especially through the dusty air of southern summer when most RSL are active. High resolution topography is needed to understand RSL slopes and model flow processes. Color data are need-

needed to help distinguish RSL from other types of slope features, and overlapping detectors for color imaging also enable measurement of pointing jitter that must be corrected for precision topography. A scale like the ~0.3 m/pixel of HiRISE or better would undoubtedly continue to be very informative about RSL, but is a lower priority than other measurements needed to understand these features in a cost-constrained mission.

Composition at High Resolution. In order to confirm the presence of liquid, we need clear identification of water (or wet soil), and associated minerals, at the scale of the RSL (up to ~5 meters wide). Anhydrous chlorides have featureless spectra [10], and hydrated salt may not have time to form given diurnal freezing and desiccation in the Martian surface environment [3], so observing in the morning when liquid is most likely may be essential. Laboratory measurements [9] show that the spectra of wet soils should change as a function of time of day, season, salt composition, salinity, and degree of wetness. The spectral range should be at least 1-3 µm and the minimum wavelength coverage needs further study.

Temperatures at High Resolution. We need to know the surface temperature when and where free water or hydrated minerals are detected. This is essential to determining salt concentration, a constraint on habitability. Measuring temperatures at scales of ≤10 meters and ≥200 K can be accomplished by a near-IR instrument that is sensitive to 5.1 µm [11]. Alternatively, a microbolometer detector could measure temperatures down to the CO_2 frost point, but the instrument would require a large telescope to get to the 10 m scale. Measuring thermal inertia is key to modeling shallow subsurface temperature gradients, and can identify shallow subsurface ice.

Water Vapor. To understand water stability we need to know the relative humidity near the surface at the local scale (e.g., north-facing slope of a 10-km crater), which controls deliquescence and efflorescence and the stability of surface water regardless of source. The near-IR spectrometer can detect water vapor, but is limited by atmospheric dust, and dust opacities are high in southern summer when most RSL are active. Microwave spectra would avoid this limitation and could also measure the atmospheric temperature profile, wind speeds, and shallow subsurface temperatures [12, 13].

Shallow Subsurface Ice and Water. SAR imaging can detect changes in soil moisture in the upper ~1 meter (depending on wavelength and soil properties) from repeat imaging [14]. Adding SAR to the other experiments described here likely requires a New Frontiers class mission.

All of the above need high spatial resolution and high SNR. The way to best accomplish this is to have the visible and IR instruments boresighted and together follow an along-track slew profile like that of CRISM. This can be done either by the S/C (e.g., MGS cPROTO--compensated Pitch and Roll Targeted Observation) or by having all 3 instruments on a small scan platform. This way the instruments themselves do not need mechanisms. This approach also ensures excellent geometric registration of the 3 datasets. Overlay of HiRISE and CRISM is difficult in the presence of rugged topography because of the changing viewing geometry of CRISM and the limited coverage by HiRISE Digital Terrain Models.

Summary. The theme of the Mars program for the last 2 decades has been "follow the water," but with emphasis on ancient water. Now we realize that there should be liquid water on Mars today, and the RSL may mark key locations. Detailed data on these features will determine the presence of liquid water and improve our understanding of habitability in Mars' current climate.

Table 1. Measurement Requirements

Requirement	**Metrics**
Imaging	≤1 m/pixel, 3 colors
Composition	≤3 m/pixel, key wavelengths from 1 to 3 microns
Surface temperature	≤10 m/pixel, ≥200 K
Topography	≤5 m scale; ≤0.5 m vertical
Swath width for all of the above	≥2 km; preferably ≥4 km for stereo (landing sites)
Time of day	≥5 times of day (including 8-10 AM) over key sites within cycles of a few weeks
Atmospheric temperature and humidity	≤1 km scale
Mission length	≥1.5 Mars years (including 2 southern summers)
Data rate	≥50 Gbits/day during S. summer (peak downlink rate in 2019-22)

References: [1] Chevrier, V. and T. Altheide (2008) GRL 35, L22101. [2] Hecht, M. et al. (2009) Science 325, 64. [3] Gough, R. et al., 2011, EPSL, 312, 371-377. [4] McEwen, A. et al. (2011) Science 333, 740. [5] Davila, A. et al. (2010) Astrobiology 10, 617. [6] Kminek, G. et al. (2010) Advances in Space Research 46, 811-829. [7] Paige, D. et al., this workshop. [8] Ojha, L. et al. (2012) LPSC 43, #2591. [9] Masse, M. et al. (2012) LPSC 43, #1856. [10] Osterloo, M. et al. (2010) JGR 115, E10012. [11] Jouglet, D. et al. (2007) JGR 112, E08S06. [12] Encrenaz, Th. et al. (2001) PSS 49, 731-741. [13] Gulkis, S. et al. (2007) PSS 55, 1050-1057. [14] Paillou, P. et al. (2006) JGR 111, E06S11.