SOME REQUIREMENTS FOR FUTURE ORBITAL ASSETS TO SUPPORT SAFE AND PRODUCTIVE LANDED MISSIONS. L. Keszthelyi[1], C. Dundas[1], R. Fergason[1], B. Archinal[1], and R. Kirk[1], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (laz@usgs.gov).

Introduction: Landing safely on the surface of Mars in a location that allows productive science requires support from orbital assets. Extensive orbital data already exist, but the most valuable types cover only a small fraction of Mars (e.g., <0.01% for HiRISE stereo). These existing observations have been carefully targeted, but Mars is a dynamic planet; our understanding of its surface is still evolving, and the capabilities of future landers will open up vast areas of the planet that have not been considered before. Thus, it is absolutely essential to maintain capabilities for orbital remote sensing over the coming decades.

Critical Data Sets: In order to accomplish any surface operations, it is first necessary to land safely. Steep slopes and tall rocks pose the primary hazards for landing on Mars. While it is possible to extrapolate the distribution of hazardous boulders from a few m/pixel images with some success [1], it is preferable to actually resolve the rocks. For most landing systems, obstacles ~50 cm tall are of concern. Assessing such hazards requires a ground sampling distance ≤1/3 of a meter and a signal to noise ratio (SNR) greater than 50 [2]. Such images need to cover the entire landing ellipse, the size of which depends on the entry, descent, and landing (EDL) technology.

It is important to note that such images can also be highly useful during mobile surface operations, assisting in navigation and locating targets of special interest. If the landed mission has significant mobility, it can exit the landing ellipse and additional data along potential traverse paths is strongly desired.

High-resolution topographic data, with a spatial resolution of order 1 m and a vertical resolution ≤50 cm was essential for the Mars Science Laboratory to confidently resolve surface features that could impact landing and subsequent surface operations [3]. Stereo-analysis of submeter pixel scale high SNR images is the only existing practical method for deriving topography at the required resolution.

The nature of the atmosphere (density, temperature, wind profiles) also greatly impacts EDL safety. Atmospheric models have proven essential in determining the safety of previous landing sites because it is difficult to directly measure these properties with sufficient temporal and spatial resolution via remote sensing. However, the atmospheric models provide much more robust results if they are constrained by even relatively low resolution observations [3].

A final parameter that has proven critical for landed assets is the seasonal temperature at the surface. Ideally the surface temperature would be observed at the scale of the lander/rover (a few meters per pixel) but this is extremely challenging. It is also possible to use multispectral data to measure the variability within a larger pixel. Co-analysis with high resolution imaging and topography can then identify the likely warm and cold areas at the scale of interest. The success of such a method requires good spatial resolution (<100 m/pixel) and high SNR (<0.5 K NEΔT) [4].

While not critical for the safety, other data sets can provide essential scientific information to select the most fruitful of the safe landing sites and to help plan productive surface operations [5]. In this regard, a very wide range of spectral data (from gamma rays to radio wavelengths) has proven useful. Given a likely emphasis on water and/or hydrous minerals, being able to map out near-infrared spectral features related to hydration would be particularly valuable. Ideally, such data would be able to spatially resolve outcrop scale (a few meter) features. This requires a combination of small ground sampling distance and high SNR.

Also, if a landed mission aims to sample the subsurface some subsurface sounding from orbit is desired. Thermal infrared data taken at different times of day provide constraints on the nature of the upper several centimeters of the surface. If seasonal surface temperature variations are reliably measured, the information is related to the upper several tens of centimeters [4]. For deeper sounding, active radio wavelength instruments are required.

Existing Data Sets: While data from many Mars missions are useful, the Mars Reconnaissance Orbiter (MRO) has instruments particularly well suited to fill most, but not all, of the critical needs discussed above.

HiRISE is the first orbital camera to resolve all boulders large enough to constitute a serious hazard for landing. By taking images on different orbits, HiRISE is able to collect stereo data that can be converted into 1 m/post digital terrain models. These capabilities depend on the combination of very small ground sampling distance and high SNR [2].

MARCI and MCS provide global coverage of the Martian atmosphere at scales that are useful for constraining global circulation models and further understanding seasonal processes around the polar caps. CRISM, CTX, and SHARAD allow detailed science characterization of potential landing sites.

The THEMIS instrument onboard the Mars Odyssey (MO) spacecraft is the primary orbital source of reliable Mars surface temperatures at the scale of interest. THEMIS observes in 9 unique thermal infrared (TIR) bands with a 100 m ground sampling distance with an accuracy of a 1-3 K which is adequate for safety considerations but marginal for high spatial resolution subsurface sounding [4].

Limitations of Existing Data Sets: The MRO and MO data sets are augmented by significant data sets from the ESA Mars Express mission, and earlier NASA missions including Mars Global Surveyor, Viking and Mariner 9. It is reasonable to ask why further orbital data should be acquired. There are two fundamental answers: (1) Mars changes and (2) the drivers for selecting landing sites change.

The changes from year-to-year in the Martian atmosphere (especially dust storm activity) are sufficient to significantly alter the timing of EDL events. Not having up-to-date information on the atmosphere will require much larger margins to be built into any landing system. Weather forecasts can also play an important role in planning surface activities. Geologic changes (e.g., avalanches, moving sand dunes, new impact craters) pose a minimal hazard but provide important science targets for surface investigation.

Another important consideration is that our definition of a good landing site changes as both the EDL technology matures and our scientific understanding of Mars advances. In the past, many areas of high scientific interest have been excluded from consideration but as the landing ellipses shrink, latitude and elevation constraints are reduced, the mobility of landers increases, and the ability to land on rough terrain improves, many new areas of interest will need to be considered; in fact, one objective of this meeting is to examine new ideas that would significantly expand the range of sites that could be considered for landing. Perhaps even more importantly, the basic goals for a landed mission evolve with time. When Mars sample return was first seriously studied, the goal was to return rocks much like the Apollo astronauts did from the Moon. This placed a premium on collecting a variety of rocks of known geologic context. At the moment, the greatest desire is to return rocks that might contain fossil life or biomarkers, putting more emphasis on hydrously altered rocks or water-lain sediments. However, very recent results from MRO and the Phoenix lander [6,7] open the possibility that a future sample return mission will focus on returning aqueous fluids or ice – possibly even containing living organisms.

In any case, it is likely that the critical data for safe landing and productive surface operations are not in hand. For example, after 6 years of operations in Mars orbit, and collecting ~19 Terrapixels, HiRISE has imaged only about 1.5% of the surface of Mars. Stereo coverage is only ~10% of this. It is not likely that HiRISE will image the landing sites of the 2030s, even if MRO last into the 2020s.

Future Data Needs: To summarize, there is a compelling need for a new orbiter when either MRO *or* MO cease to operate. The absolute minimum instrument set are (1) an imager with ~0.3 m/pixel ground sampling and high SNR and capable of acquiring stereo data and (2) a thermal infrared imager capable of viewing the surface and atmosphere with high temporal and spatial resolution. An important improvement over THEMIS would be to measure surface temperature at several different times of day and across seasons to reliably measure the surface temperatures a lander will experience [4]. Such data would also allow robust subsurface sounding (especially for volatiles) via thermal inertia, observe seasonal and diurnal process such as frost formation that can greatly affect operations, and provide better characterization of the surface via detailed photometric analysis.

Very strongly recommended are (1) multispectral coverage in the visible, near infrared and TIR and (2) contextual data covering a larger area at lower spatial resolution. The former can provide important information on minerals and volatiles to evaluate the scientific merit of landing sites, and if resolution is adequate, individual outcrops. The latter is especially important for identifying changes for detailed follow-up with high-resolution observations and thus the identification of new potential landing sites.

While a new orbiter could simply refly key instruments from MRO and MO, we encourage consideration of new operational approaches. For example, a highly elliptical orbit reduces high resolution coverage but allows a single instrument to collect both high resolution and contextual data. Similarly, putting the orbiter in a non-sun-synchronous orbit complicates planning but is necessary to observe diurnal changes and best characterize the surface. The ability to quickly point the instruments in a variety of directions (a) allows the acquisition of better stereo data and (b) eliminates the need to carry multiple instruments to observe the surface and atmosphere. Finally, we suggest that the similarity of the required data and that acquired by the NASA-built but USGS-operated LANDSAT Data Continuity Mission could be examined for operational concepts not typical in planetary missions [8].

References: [1] Golombek M. et al. (2005) *Mars, 1*, 1-13. [2] McEwen A. S. et al. (2007) *JGR 112*, E05S02. [3] Golombek M et al. (submitted) *Space Sci. Rev*. [4] Fergason et al. (submitted) *CAME*. [5] Tanaka et al. (submitted) *CAME*. [6] McEwen et al. (2011) *Science, 333*, 740-743. [7] Renno et al. (2009) *JGR, 114*, E00E03. [8] Bergstrom et al. (submitted) *CAME*.