Future Mars Landing Site Selection Activities

Submitted to Planetary Science Decadal Planning Group, MEPAG, and NASA HQ

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Abstract:
Mars landing site selection activities help to define the science potential and engineering risks associated with landed missions and utilize existing orbital assets to make discoveries that shape future priorities for the integrated program of Mars exploration. Currently orbiting missions, including Mars Odyssey and Mars Reconnaissance Orbiter, have proven outstanding in identifying and characterizing candidate landing sites for future missions. As demonstrated by the loss of Mars Global Surveyor, however, these orbiting spacecraft have finite lifetimes, and there are currently no plans or resources available to replace them or their instruments. We recommend that a process for identifying and characterizing candidate landing sites for a range of future mission scenarios be undertaken as soon as possible. This process should be accompanied by creation of funding to support landing site characterization activities via the peer review process and the associated program would allow proposals that include suggesting targets for imaging and the use of unreleased data. NASA should also provide sufficient resources to existing missions to enable these activities, especially during periods of high data return from Mars. Finally, NASA should consider including instruments with site-characterization capabilities on future missions.

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This white paper has been widely circulated throughout the Mars Science Community and received widespread verbal and written support. The current submission incorporates the comments from all of the listed coauthors as well as written comments provided by the following contributors:

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Introduction and Charter:

Landing site selection activities are critical to the success of landed missions to Mars and form an important part of a program for exploration of the planet. The process of collecting and interpreting data from orbital missions in support of future landed missions, which might include rovers, fixed landers, and networks, is an excellent example of the integration between components of the Mars Exploration Program. This integration enables ongoing discoveries to shape the goals of future missions and helps to ensure their success. Achieving the science objectives of each landed mission and landing safely on the surface requires careful consideration of a variety of orbital data sets.

Currently operating orbital assets at Mars include Mars Odyssey (ODY), Mars Reconnaissance Orbiter (MRO), and Mars Express (MEx). Together with Mars Global Surveyor (MGS), these assets and the discoveries gleaned from their data have helped to focus the search for the optimal landing sites for the Mars Exploration Rovers (MER), Phoenix, and the Mars Science Laboratory (MSL). Data from these spacecraft enable unprecedented evaluation of the science and engineering merits of candidate landing sites and each has been exemplary in support of site-selection activities. The demise of MGS, however, serves notice that these assets have a finite lifetime.

Recent discoveries from MEx, ODY, MRO, and MER identify many locations where rocks and sediments emplaced in aqueous and potentially habitable settings may be preserved. Some locations may preserve sequences suitable for resolving overarching questions about past habitability and life on Mars. These potentially habitable environments can be evaluated in advance of future landings, but there are potentially thousands of candidate sites that may preserve an appropriate rock record. Very few sites, however, have been characterized to a fidelity (e.g., sub meter scale for rocks) needed to fully document science questions and assess landing hazards. Mid-resolution data sets from MEx and ODY are nearly global and can assist in site characterization and defining targets for MRO, but their spatial resolution is not sufficient to define scientific return and certify landing safety. Hence, a process for identifying and characterizing candidate landing sites for future missions is needed to enable eventual peer review of mission objectives after existing orbiter operations have ended.

There is currently no planned replacement for any of the high-resolution remote sensing instruments being flown on any spacecraft orbiting Mars. Nevertheless, multiple landed missions are anticipated over the next ~15 years that might include ExoMars and a Mid-Range Rover (MRR) in 2018, a network mission, and Sample Return (SR). The configuration and goals of these future landed missions or others remains uncertain. With that issue in mind, there is a pressing need to begin the process of identifying, acquiring data, and evaluating candidate landing sites for future missions.

Upon direction from NASA Headquarters and encouragement from the Mars Exploration Program Analysis Group (MEPAG), a group was formed to discuss (via teleconferences) processes for identification of candidate future landing sites that utilizes existing orbital capabilities. Emphasis is placed on data sets needed for characterizing sites and how best to use instruments on ODY and MRO. The group was chaired by John Grant and Matt Golombek and included Michael Meyer, lead scientist for the Mars Program at NASA Headquarters and Rich Zurek, MRO Project Scientist and JPL chief scientist for the Mars Program. Presentations were also made to the MRO Project Science Group (PSG) and MEPAG.

Background:

Landing site selection activities are evolving as improvements in the quality and diversity of orbital data sets enable formulation of specific science questions and accurate site characterization. As one example, the landing site for Phoenix was well-characterized in advance of landing by data that included the Neutron Spectrometer and THEMIS (Thermal Emission Imaging System) on ODY and HiRISE (High-Resolution Imaging Science Experiment) and CRISM (Compact Reconnaissance Image Spectrometer for Mars) on MRO. The site was remarkable in how closely it met expectations. Similarly, the MSL landing site selection process has converged on a handful of candidate sites, each representing an excellent target for addressing questions related to Mars habitability.

The landing site selection process for the Mars Pathfinder (MPF), MER, and MSL missions has included open workshops well attended by a broad cross section of the science community. The workshops continue to be a forum for the discussion of how the science objectives of a mission could be addressed at candidate landing sites and how well the engineering constraints could be satisfied. This discussion allows the sites to be prioritized and down-selected as new information is acquired and rapidly made available to the science community (and commonly before official release to the PDS).

The experience with MSL has shown that MRO data, consisting of co-located HiRISE, Context Camera (CTX) and CRISM data, along with ODY THEMIS data provide synoptic, high-resolution morphologic and mineralogic views of the surface at best pixel-scales of 25 cm and 18 m, respectively, that allow studies at unprecedented detail. Such studies are required to accurately assess the science potential and engineering hazards of a site. In addition, because MSL landing sites are relatively small (~20 km long), the full stereo HiRISE coverage required for site certification is modest (~4-6 stereo pairs). The MSL and Phoenix experience confirms that existing orbiters are ideally suited for site selection for missions with similarly sized or smaller landing ellipses. Other data sets are also critical for site evaluation and especially certification (e.g., atmospheric modeling), but these activities might not require high resolution MRO data. Some activities, such as atmospheric monitoring, should be ongoing as instruments permit, whereas other may be initiated for candidate sites once a mission design matures.

Given the critical role of MRO and ODY, and HiRISE and CRISM data in particular, in site certification, the Mars Exploration Program recognizes these orbiters should be used to collect data for future landing sites while able. In the absence of a new MRO class orbiter in the future, one scenario is that only sites for which MRO data exist could be selected, leaving the program with a suite limited to those identified during the MSL landing site activity. Using MRO now to collect data (including the use of Mars Climate Sounder and radio science) to characterize potential future landing sites and enable subsequent certification might lessen the impact of losing this capability in the future. We cannot predict all locations of potential interest and this effort cannot replace real-time support by orbital remote sensing, such as monitoring the atmosphere, but it is prudent to plan ahead for a program that might lack high-resolution orbital support.

These considerations fuel the desire to conduct a landing site selection program that would acquire the data needed to select and certify future landing sites. Landing site selection centers on the safety of the site (derived from the engineering constraints from the entry, descent and landing scenario) and on science objectives (derived from the mission definition and selected payload). Both science and safety issues must be constrained in some fashion to enable a selection activity that is more than just an academic exercise.

Broad Aspects of Future Landing Site Selection

Most engineering constraints for future U.S. Mars landings would likely be generally based on the "sky-crane" design being used for MSL. Using this design, a 10-15 km long landing ellipse for a 2018 MRR or a future SR is anticipated. In addition, owing to the similar landing concept, other engineering constraints would likely be similar to MSL (except perhaps elevation, latitude, and maybe small-scale roughness). A landing ellipse with a 10-15 km long axis only requires 2-4 stereo HiRISE pairs for nearly complete topographic characterization at the meter scale, which would be needed for site certification. As a result, the number of MRO images required to certify a particular landing site is modest and many sites could be characterized with minimal impact to MRO (based on experience imaging candidate MSL sites), provided that a high data rate continues to be supported.

The science objectives of future missions are not fully developed in advance, so it is preferable to leave science objectives open for refinement and cast a wide net for potential future missions. The result should be a process that includes debate of the value of particular science objectives for future missions, including MRR, SR, and network missions, and could contribute to their definition. The goal is to develop a matrix of prioritized landing sites for missions with different objectives. Discussion of candidate sites at open workshops would help prioritize within each type of landed mission.

A Process for Soliciting and Prioritizing Sites:

A widely publicized process for identifying future candidate landing sites is anticipated and would solicit sites for a variety of missions. The call for candidate sites and directions for submission of requisite data was made at the MEPAG meeting held in July, 2009, and will be followed by e-mail solicitations using the LPI and MEPAG e-mail distribution lists. Future special sessions are also envisioned at AGU and/or LPSC that would include invited updates on aspects of Mars science deemed critical to some future missions and their potential landing sites. The deadline for submission of the first round of candidate sites to be targeted initially by orbiters will be in the fall of 2009.

In order to streamline submission of candidate sites, web-entries at existing publically accessible websites will be required (e.g., at the USGS and Marsoweb at NASA Ames). Web entries will include abstracts modeled after those used for LPSC, but with a template that will require: a description of the site, associated mission objective, a figure including precise placement of 10 and 15 km long ellipses (and the latitude and longitude of the co-located ellipse centers to assist in targeting), discussion of whether the science objectives for the site could be met within or require traverse outside of the proposed ellipse (referred to as a "go to" site), location of preferred initial imaging and existing images (e.g., HiRISE, MOC, THEMIS), and characteristics relative to several likely engineering constraints (e.g., elevation, slopes, and thermal inertia).

Proposed sites will be sorted, reviewed, and assigned to prioritized categories by a NASA-appointed landing site steering committee and a prioritized list of sites will be provided to the MRO and ODY instrument teams (and will also be made available to MEx) for use in targeting an initial set of images over the following Earth year.

Once the initial image data have been obtained for each site, a workshop would be held to facilitate discussion of the relative merits and objectives. New candidate sites, some of which might be characterized by pre-existing data, could also be submitted for consideration at the workshop. As has been the case for MER and MSL, votes held at the end of each workshop would determine which sites are deemed of high merit and would move forward for additional imaging and analysis. By requiring presentation and discussion at workshops, each site would be subject to scrutiny by a group with wide expertise. Alternatively, additional data could be obtained for sites not presented at the workshop if they are deemed to have sufficient priority via proposal peer review (see recommendations below).

This process would result in a multi-tiered system, where yearly proposal of new candidate sites is followed by review and targeting of initial images. Simultaneously, a subset of sites proposed earlier and deemed of sufficient merit would undergo additional imaging to provide more comprehensive coverage of the proposed ellipse. Those deemed of highest merit would be targeted for complete coverage.

Support from MRO and ODY:

Involvement of the ODY and MRO instrument teams and Projects are critical in any effort to image candidate landing sites. The images obtained by HiRISE, CTX and CRISM in particular set the new standard for evaluating the science and engineering merits of any proposed site. Hence, the group presented tentative plans at a MRO PSG meeting at the National Air and Space Museum on May 6, 2009.

MRO instrument teams are very supportive of activities geared toward imaging candidate future landing sites. There was agreement that 3-4 targets per two-week imaging cycle (26 cycles per Earth year) is a reasonable burden and would yield 80-100 images of candidate landing sites per Earth year. The Project would be provided a prioritized list of sites to be used to target the candidate sites over a period of one Earth year. None of the sites would be required targets in any particular planning cycle, but each would be targeted at least once.

Initially, candidate landing sites for MSL were targeted by a single set of MRO images that included data from HiRISE, CRISM, and CTX sharing a common center point. The HiRISE image was designed to be 10 km long by 6 km wide, whereas the CRISM data targeted a 10 km by 10 km area as a Full Resolution Target (FRT, other imaging modes also exist). The encompassing CTX image covered 30 km by 30 km. The expectation of a 10-15 km long landing ellipse for most future NASA missions (e.g., MRR or SR) means a similar set of images would cover a significant fraction of each proposed ellipse. In the case where a proposed target ellipse is outside of the prime science region of interest, the proposer would be responsible for identifying prioritized targets within the ellipse and “go to” science area. As sites move forward in the evaluation process, additional images and supporting data (e.g., from the SHARAD sounding radar on MRO) would be acquired for further characterization.

Experience with MSL site selection activities has shown that many of the candidate sites possess attributes that make them interesting targets for study for reasons beyond the objectives of a candidate mission. It is therefore possible that some sites would be imaged more than once by MRO early in the process (e.g., to create stereo coverage or multiple image footprints). Each site would initially be guaranteed only one set of images; however, any additional data sets obtained would be made available to the proposers for use in evaluation of the sites. Landing site data from MRO would rapidly be made available to the community for investigation, before general release, which typically takes 1- 6 months.

A recent shift in the orbit of ODY to a mid-afternoon time will nearly double the signal-to-noise ratio of THEMIS daytime infrared data and significantly enhance the ability of THEMIS to characterize the mineralogy of candidate landing sites. THEMIS will target ~150 candidate sites that will be co-located with those for MRO and extend over ~30 km by 30 km at a resolution of ~100 m/pixel. The resultant set of colorized decorrelation-stretched images, which were instrumental in the discovery of possible chloride deposits, will also be made available to the community.

Recommendations:

- *All parties agree that starting the targeting and imaging of a range of candidate future landing sites is essential and must begin as soon as possible*. Orbital assets have a finite lifetime, there is currently a lull in imaging of MSL sites, and imaging of candidate landing sites for ExoMars has not yet begun, so this process should begin by early 2010 (peak data rate for MRO). In order to be successful, the proposed activity requires all instruments on MRO to continue to operate and to collect and process data at a high rate. It is essential that MRO and ODY receive adequate support to enable these activities to proceed.
- *Funds to support future landing site proposals must be set aside in the Mars Data Analysis or similar NASA program and should be included in NASA's 2010 ROSES omnibus NRA*. A critical aspect of the proposed process involves the participation of the community in landing site activities and workshops. To date, participation in these activities has been widespread and enthusiastic, but most individuals lack funding for related work and travel. Proposals should be allowed that include the targeting or use of unreleased data or analysis of data that have not yet been acquired. For the proposed process to be successful, the planning, targeting and evaluation of unreleased and not yet acquired data should be permitted. We further recommend that process chair(s) and a steering committee be appointed by NASA to help steer the process, prioritize image requests, and report on activities. These activities would provide a head start for future missions that would eventually take over direct funding of relevant portions of the process.
- *Given the critical role played by orbital instruments in defining landing sites that enable the success of future landing missions on Mars, NASA should consider inclusion of instruments appropriate to support landing site selection on future orbiter missions*. All activities geared towards identification of future landing sites would be incomplete to some degree, as ongoing evaluation of existing data would yield new discoveries. If these discoveries occur after the key aspects of existing orbital assets are no longer functioning (e.g., CRISM IR data or HiRISE camera), the ability to characterize related candidate landing sites would be compromised.