**Concepts In Maximizing Science Return: Fusing Orbital Datasets To Support Future Mars Surface Missions.**
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**The Challenge:** As NASA considers reformulation of its Mars Exploration Program, including consideration of high pay-off robotic missions beginning in 2018 that include the filling of knowledge gaps for eventual human exploration, the community must focus on leveraging the scientific knowledge collectively expressed in existing and future orbital- and ground-based data sets. The need to fuse data sets for analysis is evident in each near-term Challenge Area (CA), including "*orbital measurements of surface characteristics*" (CA1), requiring optimal use of existing orbital data; "*low cost probes or platforms*" (CA2), requiring targeting and cost-benefit analysis of surface science observations; and "*improved performance in Mars surface mobility*" (CA3), requiring systematic range-rate analyses for mobile platforms. In order to support these requirements, data sets must be registered (geodetically controlled) and geometrically integrated into a common digital environment wherein cross-data queries can be systematically executed and updated based on engineering and science constraints. Data fusion concepts will support mission success by making it easier to analyze science and engineering constraints on candidate landing sites and understand the tradeoffs of time, distance and power for possible traverses on the surface across the mission timeline.

Concepts and approaches that frame the exploration of Mars invoke often contradictory perspectives from scientists, engineers, industry partners, government administrators, the tax-paying public, and factions within these groups (e.g., proponents of robotic vs. human exploration). Geoanalytical methods can provide inclusive and systematic approaches to mission planning within this diverse arena. For example, in the Mars Science Laboratory (MSL) landing-site selection process, the mission-defined goals dictated that the relative merits for each site be determined based on the following criteria: (1) strength of evidence for past water, (2) geological diversity, (3) preservation potential for organics based on mineralogic and geologic characteristics, and (4) presence of exploration targets of interest requiring significant traversing. Data sets relevant to candidate landing sites were then evaluated in local to regional settings, based on preferences involving geomorphologic, mineralogic, stratigraphic, and other criteria as interpretable from available data.

**The Approach:** An especially effective way of comprehensively assembling and interrogating multiple, spatially registered spacecraft data sets and thematic maps is with a Geographical Information System (GIS). Such architecture allows an array of maps to be handled in both gridded (where data is represented in quantitative pixels, such as elevation models) and vector format (where data is represented by geometry, location, and attribute, such as geologic maps). Therein, each data layer can be effectively added, removed, or their influence in the overlay analysis weighted based on evolving mission concepts. This approach provides interactive capability for performing complex spatial statistical analyses that cross multiple data sets (Fig. 1).

To develop and test this kind of approach, we performed a concept study for the MSL mission, which automated systematic interrogation of multi-scale, spatially registered data and integrated evolving mission engineering and planetary protection constraints for landing-site selection and rover trafficability using a GIS model (Fig. 1) [1]. Therein, users of this platform had the ability to search for locations that met chosen values for input parameters based on engineering constraints and scientific requirements.

The geologic data sets included (1) image-based geologic mapping of Mars, (2) preliminary maps of recent gully areas and the extent of the mid-latitude mantle, (3) geologic epoch based on stratigraphic mapping deduced from geologic maps and crater-density data, (4) an impact crater database providing detailed information on >42,000 craters, (5) hyperspectral mineral maps, and (6) neutron and gamma-ray spectrometer $H_2O$ and elemental concentration maps [2-6]. The goal for this landing-site model was to use the data sets to help address mission landing-site selection analyses such as:

- Evaluate science criteria and engineering constraints in a global manner
- Assess characteristics of candidate landing ellipses
- Optimize safety, science, and roving ability

This method allowed us to easily change parameters and their weighting to assist in judging targetability for defined landing-site ellipses (Fig. 1).

**Application:** For future Mars surface exploration, an enhanced geospatial model could comprehensively determine what landing sites, rover traverses, and payload capabilities meet mission-defined engineering

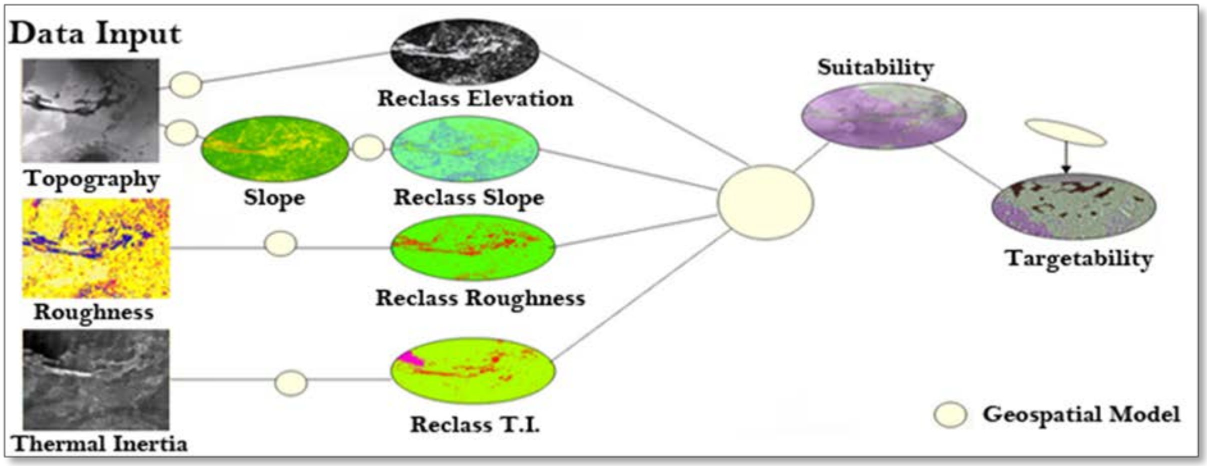


*Figure 1. Simplified flow chart of an geospatial model designed for MSL landing-site selection that illustrates how multiple datasets can be processed through user-defined reclassification parameters to derive maps showing suitable sites to meet engineering constraints (the suitability map). Here, the reclassified stage shows a simple non-weighted pass/fail of the user-defined constrains for the given layer (e.g. elevation low enough to support spacecraft deceleration, slope map is not too steep). And with knowledge of the precise ellipse shape and size as a function of latitude, etc., locations where suitable ellipses can be fit resulted in a targetability map.*

constraints and scientific goals. At a higher/earlier level of planning they could also be used to examine engineering constraint trade-offs. Such a model could also effectively rank candidate landings sites and rover traverses relative to one another, given sets of available data, adjustable criteria, and analytical tools. The first model step (Fig. 1) would be to assemble and merge appropriate surface data sets and thematic maps into a geospatially controlled database. This would involve incorporation of data products from NASA's Planetary Data System as well as those derived by planetary researchers (the spatial accuracy and resolution of the input data and defined parameters would be addressed in the model). Next, using these assembled data, geospatial models would be constructed and would be mission critical parameters defined to produce a global or regional suitability map. Finally, potential landing-site ellipses fitting within the suitable zones would be determined, yielding promising targets for which additional data collection may be needed for optimal landing-site selection.

Once a landing ellipse is chosen and the spacecraft arrives, this same database could be used to organize, plan, and direct surface operations and observations. The local datasets (high-resolution orbital and lander images, geologic mapping, instrument data), along with planned observations, science objectives, and engineering constraints would allow for improved planning of traverse/extra-vehicular activities to maximize science return given time and distance constraints. This model would not replace engineering models for the rover but would take them into account while narrowing the focus of the traverse as time, power, distance, and other constraints to the target reduces the explorable area.

**Conclusion:** By quantitatively measuring science-based parameters in a controlled, spatial environment, GIS technology provides a rapid yet comprehensive methodology for determining potential areas of interest that meet engineering, science, and other tangible mission requirements, including resource needs and safety certification for human exploration, using a set of evolving user-defined parameters that applies equally to the entire planetary surface. This approach would assist in the planning and execution of future Mars (and other planetary) surface missions, enabling optimal use of innovative capabilities, instruments, and investigative approaches.

**References:** [1] Tanaka, K.L., J.A. Skinner, Jr., and T.M. Hare, A geoscience-based digital mapping approach for MSL landing-site selection (abs.), First MSL Landing-Site Workshop, Pasadena, CA, 2006. [2] Skinner, J.A., T.M. Hare, and K.L. Tanaka, (abs.), LPSC XXXVII, #2331, 2006. [3] Balme, M. Et al., J. Geophys. Res., 111, doi:10.1029/2005JE002607, 2006. [4] Mustard, J.F., C.D. Cooper, and M.K. Rifkin, Nature, 412, 411-414, 2001. [5] Tanaka, K.L., Proc. Lunar Planet. Sci. Conf., 17th, Part 1, J. Geophys. Res., 91, suppl., E139-158, 1986. [6] Barlow, N.G., Icarus, 75, 285-305, 1988.