MARS MISSION OPTIMIZATION BASED ON COLLOCATION OF RESOURCES. G. E. Chamitoff[1], G. H. James[2], D. C. Barker[3], A. L. Dershowitz[4], [1]NASA Johnson Space Center (2101 NASA Rd 1, Houston, TX 77058, chamitoff@jsc.nasa.gov), [2]NASA Johnson Space Center, [3]MAXD, Inc. & United Space Alliance, [4]United Space Alliance.

Introduction: This paper presents a powerful approach for analyzing Martian data and for optimizing mission site selection based on resource collocation. This approach is implemented in a program called PROMT (Planetary Resource Optimization and Mapping Tool), which provides a wide range of analysis and display functions that can be applied to raw data or imagery. Thresholds, contours, custom algorithms, and graphical editing are some of the various methods that can be used to process data. Output maps can be created to identify surface regions on Mars that meet any specific criteria. The use of this tool for analyzing data, generating maps, and collocating features is demonstrated using data from the Mars Global Surveyor and the Odyssey spacecraft. The overall mission design objective is to maximize a combination of scientific return and self-sufficiency based on utilization of local materials. Landing site optimization involves maximizing accessibility to collocated science and resource features within a given mission radius. Mission types are categorized according to duration, energy resources, and *in-situ* resource utilization. Optimization results are shown for a number of mission scenarios.

The optimization of planetary landing sites for human exploration missions requires the integration of scientific objectives, mission requirements, in-depth understanding of local geography, and knowledge regarding the accessibility and availability of local resources. Judicious selection of landing sites for the first human missions to Mars is of preeminent importance due to the economic constraints surrounding any early missions. Collocation of indigenous resources that can be utilized on early missions will decrease initial launch mass and overall mission cost. A good example is the production of propellants (methane/oxygen) from the Martian atmosphere, which can be used as fuel for crew return vehicles, surface rovers, and auxiliary power sources. Every kilogram of material (chemical or mineral) that can be obtained from the Martian environment reduces the mass that must be delivered from Earth at substantial cost.

When the landing site for the first human mission to Mars is chosen, it will undoubtedly be based on the most recent remote sensing and surface data available. Organizing, processing, and combining all of this information in such a way that it can be used for mission design and optimization, however, is a major challenge. This problem has motivated the development of a data management and mission optimization tool, called the Planetary Resource Optimization and Mapping Tool (PROMT). This tool (shown in Figure 1) is designed to provide a common platform for managing data from all sources (including remote-sensed or theoretically derived), to process data or images using a variety of functions (built-in or user–developed), and to perform site selection optimization based on various parameters and optimization criteria. The final output from PROMT is typically a global map indicating the relative value of potential landing sites based on the union of all input data, maps, parameters and constraints.

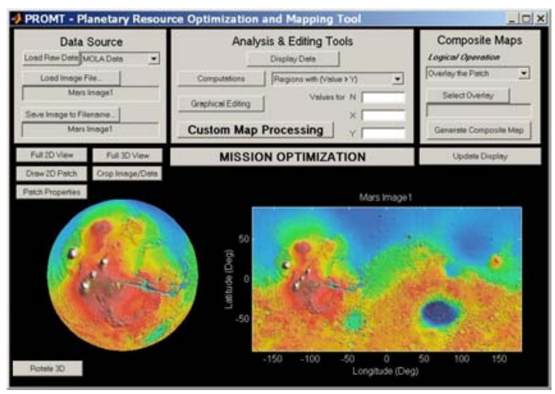

Figure 1: PROMT Main Display

Approach: The meaning of “optimality” for a human Mars mission, depends on many factors which characterize the nature of the mission. In this paper, missions to Mars are described using a three-axis matrix. Each mission scenario can be categorized according to the duration of the surface mission, the power available, and the amount of *in-situ* resource utilization that will be performed. These mission qualities affect a number of other parameters, which, in effect, determine the relative importance of different data in determining the optimal landing site. PROMT enables the user to perform site selection optimization for a wide range of mission scenarios. Some of the important Mars mission scenarios are listed in Table 1 and described further in the paper.

Category	Name	Description
000	Sprint	**Robotic, Opposition, Plant the Flag**
111	Robust NASA	High Energy, Limited Resource Utilization
112	ISRU	High Energy, Focus of Resource Utilization
113	Drilling	High Energy, Access the Subsurface
121	All-Solar	Low Energy, Limited Resource Utilization
222	Self-Sufficient	Live-off-the-Land for Power & Consumables
213	Infrastructure	Long Stay, High Energy, Serious Resource Development
223	Independence	Self Sufficient Mission with Subsurface Resources
323	Growth	Independent Mission and Committed to the Planet
333	Colony	Permanent Habitation with Sustainable Resources

Table 1: Mars Mission Scenarios

Although PROMT was initially designed to address human Mars missions, it uses a generalized approach that is equally applicable to robotic missions, or even missions to other planetary bodies for which data is available.

The overall optimization process is outlined in Figure 2. Typically, the inputs to the optimization are a composite map of local resources, a composite map of scientific sites of interest, a mission (or landing) constraint matrix, and additional parameters specific to the mission scenario (such as exploration radius). Various performance functions can be selected, and the optimization is executed. The final output is an intensity map showing the relative value of each mission site. The entire process can be customized to each mission scenario through custom map generating sequences, adjusting the relative weights for each resource or science map, and through the parameters that are used throughout the design. The challenge for the user is to understand the constraints and objectives of a particular mission, and to program the appropriate sequence, specialized functions, and parameters into PROMT.

A wide range of possible input map types are possible, including raw imagery, parametric data on a latitude/longitude grid, or highly processed data that highlights specific features of qualities of interest. For this study, a composite science map was created from the union of scientific points of interest, including regions depicting the Outflow Channels, the Valley Networks, distinct Hematite regions, and regions with "recent" channelized erosion from high resolution photography. This map is shown in Figure 3. Notice that the highest intensity regions are those encompassing the greatest number of adjacent or overlapping sites of interest.

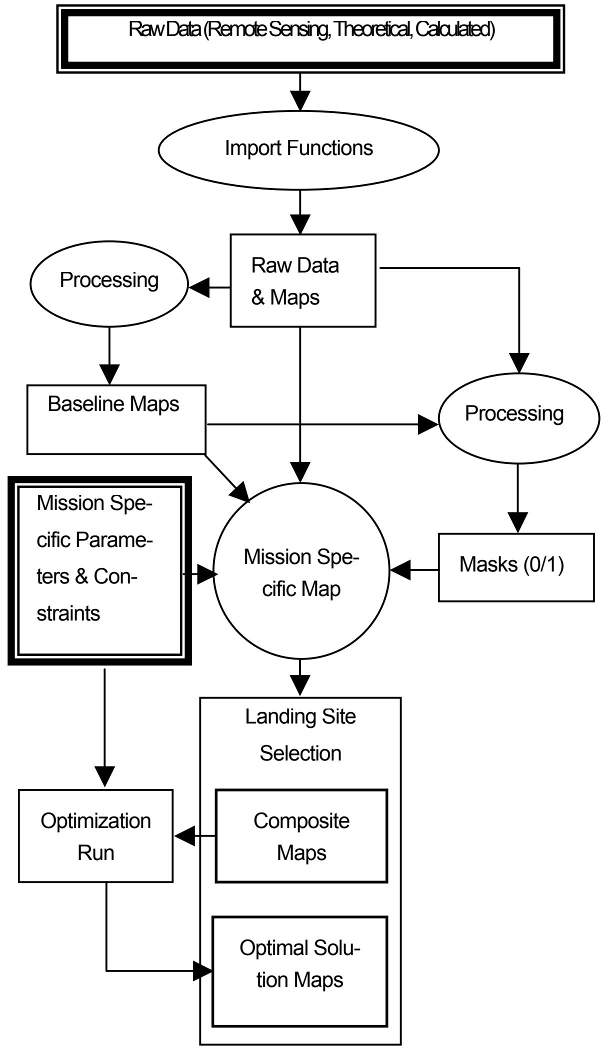

Figure 2: PROMT Optimization Flow Chart

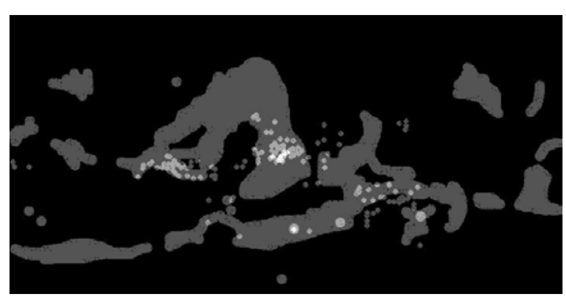

Figure 3: Science Composite Intensity Map

An example of a highly processed input map for the optimization is the Safe Landing Constraint Map as shown in Figure 4. This map is based on the constraint of landing on a low slope region (< 3 degrees in this case), away from the polar caps (+/- 75 degrees latitude), and accounting for a landing error uncertainty (assumed to be 100 km). The admissible landing locations, shown in white, are computed by applying the above constraints to slope data derived from planet-wide altimetry data.

Figure 4: Safe Landing Constraint Map

Typical resource maps are show in Figures 5 and 6. The Composite Water Intensity Map indicates the collocation of indicators for the presence of accessible water on or near the surface (based on latitude and neutron emission data from the Odyssey spacecraft). The High Atmospheric Density Map indicates the potential for atmospheric mining of Oxygen, Carbon, and Argon in order to produce breathable air, and to provide oxidizer and fuel for launch vehicles, rovers, and power generators. Atmospheric processing in these regions would require the least amount of energy to extract a usable supply of these resources.

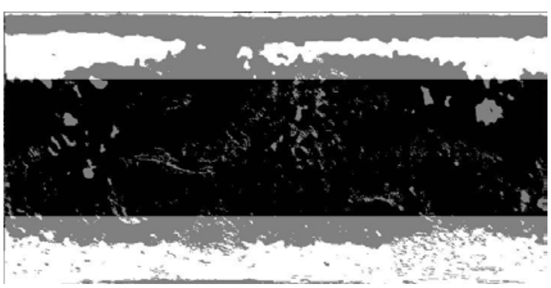

Figure 5: Composite Water Intensity Map

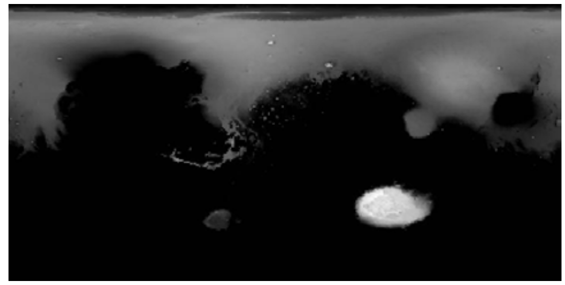

Figure 6: High Atmospheric Density

Similar constraint or intensity maps can be generated for all types of resources, including solar or surface-based energy, consumables, building material, minerals, launch-site compatibility, radiation protection, etc.

Results: Mission optimization includes an appropriate set of resources and constraints consistent with a given mission scenario (from Table 1). This is combined with scientific or mission objectives to generate a final "mission performance" map. The final step in the optimization process is to examine every admissible site on the planet surface, and determine its relative merit on the basis of mission performance (science return and resource utilization). Associated with each mission scenario is an assumed exploration radius. The optimization integrates the performance map within this given radius of every potential landing site. An example of the resulting map is shown in Figure 7.

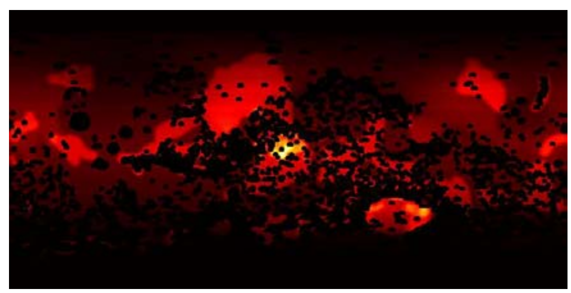

Figure 7: Landing Site Optimization for the NASA Robust Mission Scenario

The brightest points on this map correspond to the best landing sites for the parameters and input maps associated with one specific mission scenario. Similar results can be obtained for a wide range of mission scenarios, while taking into account the constraints, science objectives, and resource requirements specific to that mission. As new planetary data is obtained, and as mission parameters become better defined, this information can be readily incorporated into a new mission optimization using PROMT.