THE VALUE OF CONTEXT IMAGES AT THE MARS SURVEYOR LANDING SITES: INSIGHTS FROM DEEP OCEAN EXPLORATION ON EARTH.

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Exploration of the Martian surface with a rover is similar to investigation of Earth's oceans using remotely operated vehicles (ROVs) or deep submergence vehicles (DSVs). In the case of Mars, the techniques required to perform a robust scientific survey are similar to those that have been developed by the deep ocean research community. In both instances, scientists are challenged by having to choose and characterize a target site, identify favorable sites for detailed analysis and possible sample collection, only being able to maneuver within a few meters of the landing site and integrating data sets with a range of spatial resolutions that span 1-2 orders of magnitude (rover data versus satellite data, or submersible data versus bathymetric data). In the search for biologic communities at Earth's mid-ocean ridges, it is important to note that the vast majority of the terrain is completely barren of life: no microbes live in the thousands to hundreds of thousands of meters that separate the life-sustaining hydrothermal vent fields [1].

In attempts to better understanding the origin and emplacement of geologic and biologic features on the seafloor, techniques have been developed to select sites of special interest (target sites), by combining the low-resolution, high spatial-coverage data with medium-resolution, higher spatial-coverage data [2]. Once individual sites are selected, then a DSV or ROV is used to obtain high-resolution, low-spatial-coverage data. By integrating the different resolution data sets, the individual target sites can be placed into the larger context of the regional and global geologic system. Methods of exploration of the oceans are pertinent to the Mars Lander Missions because they highlight the importance and value of the acquisition of 'context' images.

Over 60% of Earth's mid-ocean ridge crests have been surveyed using multibeam bathymetry. The typical resolution of such data is 100 m in the vertical and 20 m in the horizontal. This data set is comparable to the Viking Orbiter images of Mars. Only 7% of Earth's seafloor has been imaged using side-scan sonar systems which are towed behind a surface ship at an altitude of ~20 m to 200 m above the seafloor. This data set provides textural information on the target surface. The resolution of these instruments varies from 50 m for GLORIA to 1 m across and 2-4 m in the vertical for the DSL-120. Higher resolution is provided by camera sleds such as ARGO II, which is towed at altitudes of ~3 - 15 m above the seafloor. Videos on these instrument platforms can provide continuous real-time video imagery via a fiber-optic tether. Still and video photographic and digital images are typically collected every ~10 - 15 seconds. The typical field of view of images from these cameras is 5 m. Added flexibility is provided when DSVs such as Alvin are used since they are capable of more autonomous exploration and can collect and return samples.

Lessons learned: Detailed site investigations of the ocean floor and of planetary surfaces share the common burdens of being both costly and time consuming, making appropriate site selection and the achievement of science goals vital. The methodology adopted to achieve these tasks and goals is to collect low-resolution but high aerial coverage data, and then to improve image resolution at the expense of aerial coverage as the list of possible sites is reduced. However, selecting the 'appropriate' or optimum resolution is a difficult problem, one dependent on many factors, not least of which is what the goal(s) of the exploration maybe.

On a recent survey of the Puna Ridge [3], the WHOI DSL-120 deep-towed vehicle was used to obtain side-scan sonar acoustic imagery, co-registered fine-scale bathymetry, and high resolution data along the crest of the Ridge and one region on its southeast flank. These data were used to plan the flight-path of the ARGO II sled. ARGO II photographic imagery from seven survey regions was used to provide geologic groundtruth, to understand the detailed morphology of the volcanic surfaces, and to select sites suitable for wax coring and dredging. Analysis of the DSL-120 data was complicated by the nature of the terrain and changes in elevation along the Ridge. ARGO II was configured with four still (two of which were for navigation only and had no recorded data stream) and two video cameras (as well as the necessary illumination), a forward and side-looking sonar, an altimeter as well as standard sensors for attitude, heading, pressure depth, acceleration and navigation. Cameras used where: 1) a color camera with a 4.8 mm lens positioned to be down-looking; 2) a Silicon Intensified Target (SIT) black and white camera with a 8.4 mm lens, mounted to be forward-looking; 3) a 35 mm still camera with a 28 mm lens synchronized to a

400 watt/second strobe, mounted to be down-looking; and 4) an Electronic Still Camera (ESC) with a 16 mm lens mounted adjacent to the 35 mm still camera. Due to the changing altitude of AGRO caused by ship motion on the tether, the field of view (FOV) was variable but at 5 m above the seafloor the horizontal FOV for the ESC was 4 m and the vertical FOV was 2.8 m. During 139.5 hours of explorations ARGO II covered 31.3 nautical miles, acquiring 29,320 images along with 125 hours of color and black and white video.

Using the data collected during this survey to achieve the science goals of understanding the formation and evolution of the Puna Ridge, a number of difficulties have arisen. It has not been easy to integrate the DSL-120 sonar data which covers a large aerial extent with the high-resolution low spatial photographic coverage from ARGO. The need has arisen for a ‘context’ image data set at a resolution in between that of the DSL-120 data and that from ARGO. This is not a problem that is easily addressed without another survey. A solution has been the design of a different instrument configuration which specifically incorporates the acquisition of context images. This is achieved by attaching an open framed, towed vehicle equipped with a SIT camera at a transition point from the main tow cable to main instrument sled. Typical altitudes for this second and smaller vehicle are between 20 and 30 m, providing context images of the seafloor being imaged by the main instrument sled at higher resolutions.

Mars Exploration: A similar desire for context images for target sites, arose in the analysis of data from the Mars Pathfinder Mission [4]. It proved to be difficult to integrate Viking Orbiter and lander images. Due to unforeseen problems with Mars Global Surveyor, results from the MOC are being released at a slower rate than originally planned. MOC data of the surface of Mars at the highest resolution has not been available for the Mars ‘98 lander, nor for the selection of the Mars ‘01 lander. However, the recent completion of the 100 m/pixel global image set provides a very useful addition to resources available to assist in the selection of suitable landing sites. Both the Mars ‘98 and ‘01 landers have descent imagers. Based on our experience in deep sea exploration, we believe that the images that will be acquired by these descent imagers will be of extremely high scientific value and allow for significantly improved integration of the orbital images with those from the landers.

The Descent Imagers on the Mars ‘98 and ‘01 missions, built by Malin Space Science Systems, will be similar [5]. The Mars Surveyor '98 Descent Imager MARDI will produce panchromatic wide-angle views (3.4˚ FOV) of the Martian surface beginning about 10 seconds after the lander's parachute has been deployed, at approximately 8 kilometers (5 miles) in altitude, until its landing. Image resolutions will span almost three orders of magnitude in scale, from roughly 8 m/pixel to 1 cm/pixel, while covering areas from 8 km to 10 m across. These images will be stored in the spacecraft DRAM for later transmission to earth. It is anticipated that the descent images will 1) provide both a local and regional setting for the ‘98 and ‘01 landers; 2) provide a link between the landing site and orbital data sets; and 3) serendipitously discover evidence of geomorphic processes at scales between those seen from orbit and those from the surface. Based on the value of context images in deep ocean research, we believe that the context images from MADRI will meet all three of these goals. However, the question of the ‘appropriate’ or optimum resolution for context images for the ‘01, ‘03 and ‘05 landers should continually be re-evaluated in light of the current state of knowledge of the most favored landing site.

Consideration: Given the value of context images, we propose that such images could be acquired by a science package on the lander itself and not just during descent through the atmosphere. In a basic configuration, a camera could be sent aloft from the lander by a balloon or small rocket (with cost, engineering and science implications). The time to launch such a package would be determined from the meteorological instruments that are part of each Mars Surveyor Landers science payload. At an added level of cost and complexity, a camera could be sent aloft that is tethered to the lander. If the tether were on a winch, a controller could determine the height at which images were acquired above the lander. Control of a winch offers the further possibility of multiple ascents and descents, allowing multiple spatial and temporal context images to be acquired.

Conclusion: The acquisition of context images during deep ocean exploration, that are intermediate in resolution between that of low-resolution, large-spatial area, and high-resolution, small-spatial area data, has resulted in significant gains in data integration and interpretation. Based on our experiences, we highlight the importance of acquiring ‘context’ images for the Mars Surveyor Landers. We advocate continual re-evaluation of optimum resolution of these ‘context’ images if they are to be acquired on a one-time only basis during lander descent. Further, we propose that consideration be given to a camera package that could be deployed from on-board the lander that could obtain multiple spatial and temporal ‘context’ images of the local and regional terrain around the lander site. Context images will significantly enhance the integration and interpretation of MOC images and MOLA data with lander images, and should be considered a priority task for lander science teams.

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