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1999 MARSOKHOD FIELD EXPERIMENT: A SIMULATION OF A MARS ROVER SCIENCE MISSION.

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A field experiment to simulate a rover mission to Mars was performed in February 1999. This experiment, the latest in a series of rover field experiments [1-3], was designed to demonstrate and validate technologies and investigation strategies for high-science, high-technology performance, and cost-effective planetary rover operations.

Objectives: The experiment objectives were to: (1) train scientists in a mission configuration relevant to Surveyor program rover missions at a terrestrial analog field site simulating the criteria of high-priority candidate landing-sites on Mars; (2) develop optimal exploration strategies; (3) evaluate the effectiveness of imaging and spectroscopy in addressing science objectives; (4) assess the value and limitation of descent imaging in supporting rover operations; and (5) evaluate the ability of a science team to correctly interpret the geology of the field site using rover observations.

A field site in the California Mojave Desert was chosen for its relevance to the criteria for landing site selection for the Mars Surveyor program. These criteria are: (1) evidence of past water activity; (2) presence of a mechanism to concentrate life; (3) presence of thermal energy sources; (4) evidence of rapid burial; and (5) excavation mechanisms that could expose traces of life.

Rover and Instrument Payload: The Marsokhod rover (Fig. 1) was used for the test. The Marsokhod chassis is an all terrain vehicle developed as a flight prototype by the Mobile Vehicle Engineering Institute (VNIITransmash) in Russia. The chassis is 100 cm wide, 150 cm long, and has a 35 kg unloaded mass. The chassis consists of three pairs of independently driven titanium wheels joined together by a three degree-of-freedom (DOF) passively articulated frame. Two degrees-of-freedom allow the frame to twist, while the third allows it to pitch. The central mast carries a stereo imager consisting of two 3-chip color 640x480 pixel CCD cameras providing 0.30 mrad/pix resolution with a 25 cm stereo baseline at 178 cm height. Monochrome stereo CCD cameras with resolution of 0.9 mrad/pix are mounted on the mast and the front and rear pallets near the wheels. These cameras are used for navigation and arm placement. The rover payload also includes a Near Infrared (NIR) fiberoptic spectrometer operating in the range 0.35-2.5 micrometers. The 1 degree instrument field of view (IFOV, approx. 17 mrad) fore-optic of the spectrometer is bore-sighted with the color stereo mast camera. The files produced by the spectrometer are automatically interpolated by the data collection software from the nominal instrumental spectral resolution to a resolution of 0.001 micrometer over the entire spectral domain. Automated spectral analysis is performed onboard Marsokhod to search for the spectral signature of carbonate minerals[4]. Finally, the Marsokhod is equipped with a 5 DOF manipulator arm and a carousel end-effector. A color camera mounted on the end-effector of the arm resolves 0.08 mm/pixel at closest position. A clamshell scoop occupies another position in the carousel.

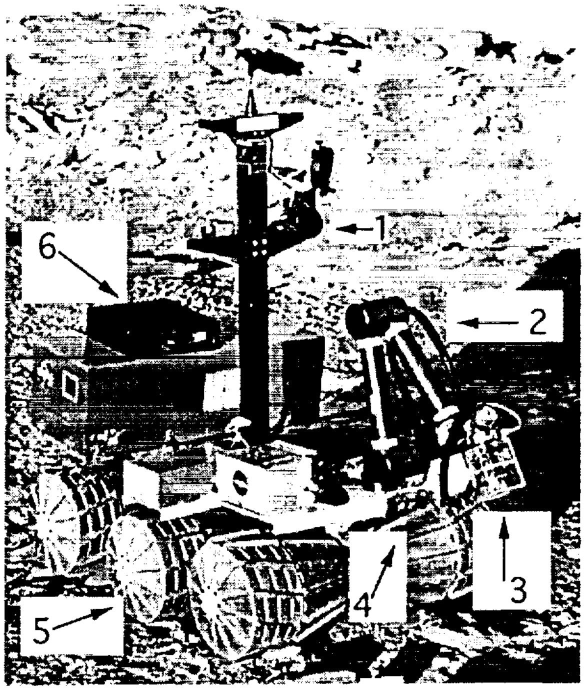

Figure 1. Marsokhod rover with (1) mast carrying stereo color cameras, stereo navigation cameras and NIR spectrometer; (2) five DOF manipulator arm; (3) carou - sel end-effector; (4) front pallet navigation cameras; (5) titanium wheels; (6) onboard electronics and computer.

Three additional instruments are included as part of the simulated payload but operated independently from Marsokhod. A set of simulated descent images were obtained using a helicopter flight over the landing site. The image resolutions and field of view were designed to simulate the Descent Imager camera selected for the 2001 Surveyor mission. Images with 67 degree IFOV were obtained with a Hassleblad film camera at elevations above the landing site ranging from 1900m to 10m. Images were scanned to produce digital image files of 1000x1000 pixels. A portable, battery-powered Fourier transform infrared (FTIR) spectroradiometer operating in the 8-14 μm wavelength range at a resolution of 6 cm^{-1} simulated the Thermal Emission Spectrometer selected for the Mars Surveyor 2001 lander and 2003 rover. A foreoptic gives an IFOV of 15 mrad (FWHM), or 15 cm at a range of 10 m. This spectrometer, mounted on a tripod, is pointed by a field assistant at targets specified by the science team. Finally, simulated arm camera images of a trench dug by a field assistant are obtained using an engineering model of the Robotic Arm Camera selected for flight on Mars Surveyor lander missions for 1998 and 2001. This instrument is mounted on a tripod and pointed by a field assistant.

Science Mission: Twenty participating scientists, unfamiliar with the site, directed the rover science mission for two weeks in February 1999. Prior to the mission, the science team were provided with orbital images with resolutions com - parable to Viking and MOC images, and with Landsat Thematic Mapper images to use for traverse planning and formulating a science strategy. Simulated descent images were provided to the science team at the outset of the rover operations. A portable satellite dish, set up at the field site, enabled communication between mission control at NASA Ames Research Center and the rover in the field. Data volumes were restricted to 40 mbits per command cycle as expected for Mars Surveyor missions. During the primary phase of the mission (Feb. 8-10, 1999) a total of 3 communication cy - cles/day were used by the science team lo - cated at mission control. During the ex - tended phase of the mission, 1-2 cycles/day were used by the science team, many of whom participated from their home institutions via a world-wide-web interface and teleconferences. The science team was asked to: (1) use the orbital and descent data to develop hypotheses that could be tested using rover data; (2) characterize and identify rocks representative of the main geological events at the landing site; (3) identify the main geologic processes that have operated on materials at the landing site using their mineralogy, surface texture, morphology, and context; (4) reconstruct the stratigraphic sequence of events at the landing site; (5) identify rocks and soils that have the highest chance of preserving ancient environmental conditions favorable to life; and (6) characterize and cache samples of rocks which may have preserved evidence of life. Science team interpretations were compared with ground truth as evaluated by a science team in the field.

* The Marsokhod Rover team is the staff of the Intelligent Mechanisms Group and their collaborators in the Computational Sciences Division at NASA Ames Research Center

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