SEMI-AUTONOMOUS ROVER OPERATIONS: A MARS TECHNOLOGY PROGRAM DEMONSTRATION. M. A. Ravine[1], J. F. Bell III[2], M. C. Malin[1], and D. P. Miller[3], [1]Malin Space Science Systems, PO Box 910148, San Diego, CA 92191-0148 USA, [2]Cornell University, Ithaca, NY, [3]School of Aerospace & Mechanical Engineering, University of Oklahoma, Norman, OK.

Introduction: A niche for a small, solar powered, autonomous, long range Mars rover is created by the following factors:

- Landing errors on Mars will likely remain in 1-10's kilometer range for the foreseeable future, at least for Mars Scout-class missions.
- High resolution imaging of the surface, in-hand from MGS MOC and coming from the high resolution instruments on MRO, allow us to both:
  - Pose important scientific questions that can only be addressed by making measurements at specific locations [1], and
  - Plan traverses to those specific locations that avoid the larger scale (meters to kilometers in scale) obstacles visible in orbital imagery.
- Existing and planned relay assets at Mars provide communication to surface vehicles at comparatively low mass, power and complexity (compared to a direct to Earth link), but at the operational cost of less frequent contacts.
- Rover experiments performed in 2002 by MSSS and OU demonstrated that it is feasible for a 20-30 kg surface vehicle to autonomously traverse long distances by moving between waypoints fifty to hundreds m apart, at speeds of order 400 m per hour, over surfaces similar to those found on Mars, using solar power .

Taken together, these factors define an opportunity, not exploited by the missions currently planned under the Mars Exploration Program, to address key issues in Mars science in the context of less expensive Mars Scout missions. Such rovers could be substantially simpler, lighter and cheaper than the MER rovers, less labor intensive to operate, while still providing capabilities that could not be provided by the MER rovers.

With support from the Mars Exploration Program Advanced Technology Program, the MSSS/OU testbed rover will be modified and used for a series of three additional field tests in Mars analog sites. The principal goal of these field tests will be to demonstrate such a vehicle can be operated in a flight-like manner (traverses planned based on overhead imagery, limited daily contacts, some science data acquisition during the traverses) over cumulative traverse ranges in excess of 10 km. Such a demonstration would mitigate the risk associated with mission architectures that use this strategy to investigate high-science value targets on Mars within the context of “low cost” missions.

Fig. 1. The SR2 rover during the Anza Borrego field test in 2002. For scale, the vehicle’s wheels are 20 cm in diameter.

Background: The MSSS/OU SR2 rover was designed and built to demonstrate long range, semi-autonomous, solar-powered roving capability [2]. It is a four-wheeled, four-wheel drive vehicle with two drive motors (Fig. 1). SR2 deals with obstacles with a simple, reflexive algorithm, and is designed to drive fairly fast (10-20 cm per second), so that the off-heading travel and backtracking resulting from the use of such a simple algorithm did not reduce the net progress toward the next way point below an acceptable level. In June of 2002, the SR2 robot was tested in Mars-like terrain in the Anza Borrego Desert on the western margin of the Salton Sea in Southern California. This site was selected because of its high fidelity as an analog to the most easily accessible of the layered, sedimentary rock sites on Mars. The key results from this field test were:

- A 25 kg, 4-wheeled rover is capable of traversing Mars-like terrain,
- Such a rover can travel in excess of a kilometer/day on solar power, and
- Multi-way-point traverses longer than one kilometer can be done with a single communications cycle (Fig. 2).

Based on this work with SR2, we plan to make several changes in rover hardware and software, as part of this project. These changes are to improve past capabilities or to add new ones, and include communications, wheels, sensors and behavioral tuning. A science payload will also be added to the vehicle, including a color stereo panoramic camera and a point visible-near infrared spectrometer, to help demonstrate the feasibility of science operations on this scale of platform.

Objectives: Three field tests of the upgraded SR2 rover will be conducted, each with realistic geological and technical challenges to our robotic system. The sites span a range of block size, abundance, and distribution, vehicle-scale relief, and large-scale topography, and present a progressive increase in obstacle negotiation difficulty for a vehicle the size of SR2. The three sites are:

- Anza Borrego Desert, California: For the initial field test, we will return to the Borrego Desert site. The principal goal of the test will be to extend the cumulative autonomous distance traveled to >10 km.
- Amboy Crater, California: Amboy Crater has been used as a Mars field analog study area for decades, because it displays in a relatively small area a wide range of volcanic and eolian landscapes very typical of many locations on Mars. As with the Borrego test, the goal will be to log in excess of 10 km on the rover.
- Jökulsá á Fjöllum, North-central Iceland: The most scientifically interesting places on Earth AND Mars are those where a large amount of energy has been deposited into the geological system, creating large-scale relief, fragmenting bedrock into large boulders, and distributing these effects over large areas. One place that is demonstrably the worst possible combination of such phenomena is the path of catastrophic floods along the Jökulsá á Fjöllum in North-central Iceland. There, a series of floods reached magnitudes in excess of 400,000 m^3/sec, creating cataracts, boulder bars and streamlined craters. While we do not anticipate adding substantially to the rover's total autonomous cumulative distance traveled in this field test owing to weather constraints on solar powered operation, it is important to attempt such a test across a surface formed in a catastrophic flood, given the importance of this type of terrain on Mars.

After each field test, analysis will include an assessment of lessons learned, including analysis of the science payload data. Those lessons will be used to determine if the vehicle needs additional modification prior to the succeeding field test.

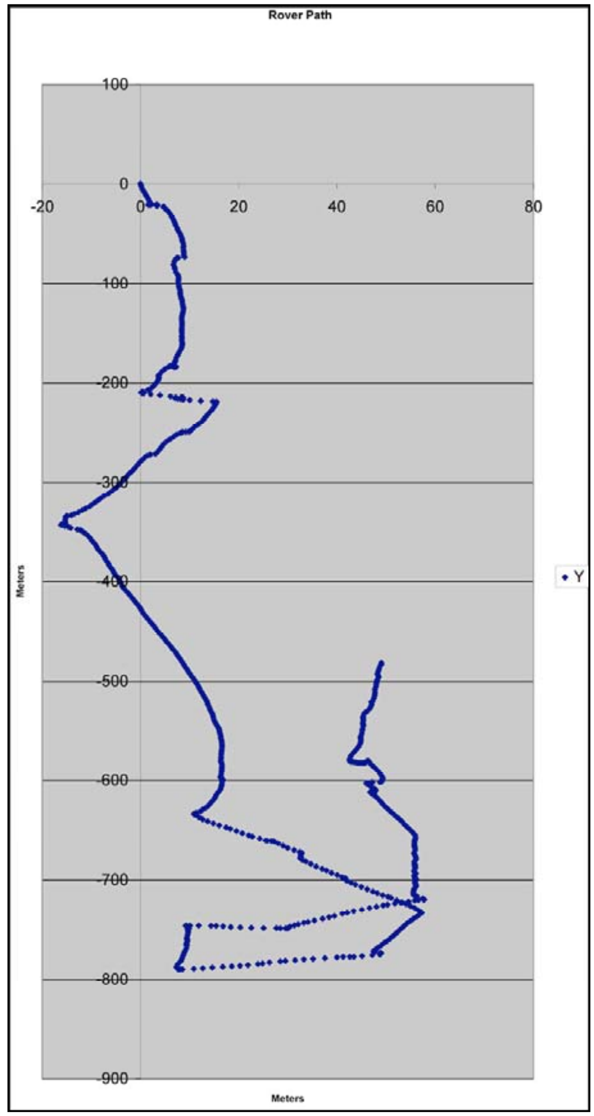

Fig. 2. 1.3 km traverse of SR2 during the 2002 Anza Borrego field test. This traverse was executed in a single afternoon, at an average speed of ~400 m/hour.

References: [1] Malin, M. C. and Edgett, K. E. (2001) *JGR, 108*(E10), 23429-23570. [2] Miller, D. P. et al. (2003) *7th International Symposium on Artificial Intelligence, Robotics and Automation in Space*.