1 Identification

ITA #: 03-004-I	
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Short Title: Mars Exploration Rover (MER) Flight Operations Report	
Description: In September 2003, the NESC Chief Engineer at JPL forwarded requests to the NESC Board for technical experts to support the MER review process in two key areas, Human Factors and Entry, Descent and Landing (EDL) operations.	
Date Received: 11/3/03	Date ITA/I Initiated: 11/06/03
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Date ITA/I Concluded:	

2 Executive Summary

The MER's Spirit and Opportunity were sent to Mars for geological exploration, especially to search for evidence of the presence of water on or near the surface in the past. Spirit successfully landed on January 3, 2004, followed by Opportunity on the opposite side of the planet on January 24. Over many months prior to the landings, and in the period between the landings, the MER Project and JPL sponsored numerous critical readiness tests and reviews to maximize the chances of mission success. The MER missions are very important and visible from an overall Agency perspective, especially in light of the fact that about 2/3 of all prior missions launched to Mars have failed.

In September 2003 the NESC Chief Engineer at JPL forwarded requests to the NESC Board for technical experts to support the MER review process in two key areas, Human Factors and Entry, Descent and Landing (EDL) operations. Surface Operations staff and mission scientists must cover work periods around the clock that steadily shift in start time each day because the Martian day is 40 minutes longer than an Earth day. This poses potential risks to staff performance, due both to fatigue and to personal stresses related to the loss of synchronization with the daily cycle of human activity on Earth. Such issues are best addressed by Human Factors experts. NESC sponsored the participation of two, Dr. Cynthia Null from ARC and Dr. John Caldwell from Brooks Air Force Base, in the MER Operations Readiness Review (ORR), December 3-5, 2003. Dr.

Null paid a follow-up visit to JPL on March 3, 2004. For the critical EDL phase NESC provided two experts in Flight Sciences, Mr. Claude Graves from JSC and Dr. Dean Kontinos from ARC. They served on an independent Red Team whose function was to evaluate the EDL performance of Spirit and to recommend any steps that might be taken to enhance the probability of Opportunity's successful landing.

Conclusions drawn by the ORR Board and by the EDL Red Team, including the observations of the NESC experts, were briefed to JPL senior management and appropriate implementation steps were taken by JPL. Several areas of particular concern to the NESC representatives emerged.

Human Factors. Regular monitoring of operations staff for fatigue and other deleterious health effects needs to be conducted by medical professionals experienced in these areas. JPL's Safety Organization and Medical Services resident physician took on this role. Management, in consultation with appropriate experts, should set and enforce objective criteria for the number of hours per day and per week an individual may work before a break is required. Such criteria may be found in NASA Procedural Requirements NPR 1800.1 (October 16, 2002), pages 202-209. It is not clear that this NPR has been widely promulgated within the Agency. In any event the MER Project has successfully enforced a 10-12 hour workday limit for critical engineering operations personnel. However, no such limit appears to be in effect for mission scientists. Although the latter do not have duties critical to the health and safety of the flight system, their decisions about operational strategies directly impact the scientific success of the mission. It is very important that the scientists also recognize the need to minimize fatigue.

Entry, Descent and Landing. Deviations from the expected angle of attack of the entry vehicle during EDL's for Spirit and Opportunity raised several issues potentially relevant to other planetary missions as well as future missions to Mars. Is the aerodynamic model used sufficiently accurate, particularly in the regime from Mach 6 to Mach 2? Did the late design change to the aeroshell, which was not considered significant enough to warrant a revision in the aerodynamic model, contribute to this deviation? Instrumentation currently flown (or planned for future missions) on such vehicles is not adequate to distinguish the separate effects of density and drag coefficient errors on the aerodynamic forces encountered during EDL. Such instrumentation - accelerometers, temperature and pressure sensors - should be considered for use on future planetary missions to determine entry performance. The MER Project has initiated studies that are expected to resolve these issues. It is fair to say that NESC involvement helped identify or reaffirm these problems and is contributing to the formulation of solutions.

In summary, there is value added for the flight program and for the Agency in having an independent perspective on mission implementation and operations, even if it does not take the form of a formal independent assessment. This can include inputs to the planning or implementation of anomaly resolution, as well as to the scope and content of follow-on studies.

(The remaining sections of the report will be provided upon completion of the work in progress.)