CREWED MARTIAN TRAVERSES; BUILDING ON LESSONS LEARNED FROM APOLLO, ROBOTIC MISSIONS, AND PLANETARY ANALOGS. M. C. Bouchard, Missouri University of Science and Technology (319 Shady Meadows Drive, Ballwin MO 63011, mcbmv4@mail.mst.edu)

Introduction: The process of planning a planetary traverse is a delicate balance between engineering, science, and operations protocol. An effective planetary traverse will maximize the science return and engineering proof-of-concepts while operating within the mission constraints; studying previous extra-terrestrial traverses can lend insight into how to best continue the process.

Human missions to Mars will include many of these complex and detailed traverses. Studying the only historical crewed extra-terrestrial traverses, those of NASA's Apollo program, can lend insight into future exploration. Much can also be gained from current robotic traverses of Mars, as well as studies and demonstrations here on Earth. For example, the Desert Research and Technology Studies (D-RATS) seeks to test procedures, technologies, and traverse concepts in order to inform and progress the future of planetary traverses.

After summarizing the traverse planning method as specifically used by D-RATS and presenting some of the significant changes in culture that must occur for the execution of a crewed Martian traverse, this report will introduce a high level architecture for a new mission operations concept.

The Traverse Planning Model: The primary goal of exploration traverse planning is to maximize the science return of an Extra Vehicular Activity (EVA) within the greater mission objectives [1]. Each traverse targets a series of science objectives as well as engineering and flight operations objectives [2]. The process begins with a detailed analysis of high resolution satellite imagery of the traverse region [3]. From this imagery, detailed photogenic maps are created, and the areal extents of geologic formations are interpreted. Science objectives are created from this information and then ranked in order of priority. Sites where these questions can be addressed within the traverse region are identified and it is from these sites that the traverse is determined.

In the context of D-RATS 2010, this pre-work was done by the USGS. A planning workshop formalized the science objectives and specified the first order operational constraints [1]. Using communication constraints such as the deployment of equipment on topographical highs, a series of preliminary traverses were determined. During the process, several operational questions arose that could not be answered with remote sensing such as the location of gates, fences, and property lines [1]. In order to address these issues a field survey was tasked with all mission critical operations represented. Major revisions in a few traverse paths led to time tables with specified actions in 5 minute increments [1].

Mission Control vs. Mission Support:

Communication and Control: The largest difference between the current experiences and future human missions to Mars will be the operations control structure. The Apollo mission style set the standard for how crewed missions are currently run: directly connected to the Mission Control Center (MCC) in Houston, with every step broadcasted and followed by a team of support scientists and engineers. D-RATS missions concluded that having well-trained geologists in the field supported by a science backroom helps to maximize this science return [4]. However, the time delay between Mars and Earth exceeds 20 minutes. The D-RATS analog missions experimented with different communication architectures and discovered that even a few second delay was nearly prohibitive to real time mission assistance from Earth. Lessons learned from the D-RATS missions suggests that having team members with these specific skills as well as major automation of these tasks would be of measurable benefit [5]. A centralized geo-referenced data portal for Martian traverse information should be developed and made accessible to the field crew, the Earth Base, and the general scientific community.

Choreography vs Flexibility: Apollo mission traverses were completely choreographed and directed by MCC. Due to the complexity of the mission and limited durations there was no time planned for deviations from the EVA schedule [4]. However the nature of field science is an evolving exploration science, and as insights are gained the new knowledge informs the next decision. This lead to situations on Apollo where the crew took actions that were not pre-approved by MCC [4]. An understanding of the broad science objectives allows the field crew to respond to unexpected developments appropriately. “Flex-time” in a traverse plan can help maximize science return by allowing sufficient time for the field crew to perform the scientific process [4].

Strategic vs Tactical: The Mars Explorer Rover (MER)-model of operational accounts for delayed mission control. The MER team separates their operations into tactical and strategic levels. The tactical team has direct fine detail control of the rover, and the strategic team is responsible for the long term high-level planning [2]. The tactical team focuses on operating the daily scientific tasks, while the strategic team completes long term planning for the totally mission duration [5]. Future crewed Mars missions will require a delicate balance of real time tactical support and long term strategic planning. The solution is placing most of the tactical duties, and emergency response, in the hands of the local crew and relying on MCC to fill the role of strategic planning.

The Crewed Martian Traverse Model:

Mission Hardware: Planning a crewed Martian planetary traverse will involve all areas of expertise and experience. Once a landing site has been selected the traverse region can be defined. This region is limited by operation constraints such as consumables, power, communication, and the available equipment. Having a pressurized rover increases the amount of terrain coverable as well as the safety of the mission. In order to best perform the preliminary remote sensing of the region, an array of polar-orbit survey and communication satellites will need to be tasked. Similar to the 2010 D-RATS experience, the preliminary remote sensing may leave outstanding questions about the region. These can be answered by a field study conducted by robotic rovers. Sending robotic rovers ahead of a human mission will ensure that the maximum amount of information is known about the region's conditions, resources, and terrain. These rovers should survey the landing site, the base station, and the aproximate traverse course. Once the crew arrives they can service and continue to use these rovers for their surface operations. Air-breather exploration may serve the same purpose. The Mars base will be important as a staging and return point for the traverses, and should include more specialized experimentation equipment as well as facilities for sample cache and curation.

Standardization of Traverse Procedures & Training: Whereas in Apollo missions the astronauts could rehearse every minute of the traverse before arriving [5] the added complexity of several multi-day traverses with pressurized rovers that may occur weeks apart makes this practice impractical. Instead astronauts must train in regional geology and to perform standardized traverse procedures, and then apply these skills to the variety of traverses. Training will increase the onsite value of the field crew, who will become the subject matter experts on that region of Martian geology. Later traverses will end up being edited, altered, and potentially even generated by the field crew.

Mission Operations Concept: The field crew will operate out of two pressurized rovers that will provide the crew with a shirt sleeve lab environment while between traverse sites. The field crew will include at least one trained Geologist, and one crew member with more familiarity with EVA and/or the rover systems. The rovers will stay in direct, real-time communication with the Mars Base via a communication satellite array or repeater stations. The Mars Base, which can be on the surface, on a Martian moon, or in Martian orbit, will act as the real-time, human-in-the-loop, tactical team for the field crew. The Mars Base crew will also provide safety monitoring and mission opertions support to the field crew.

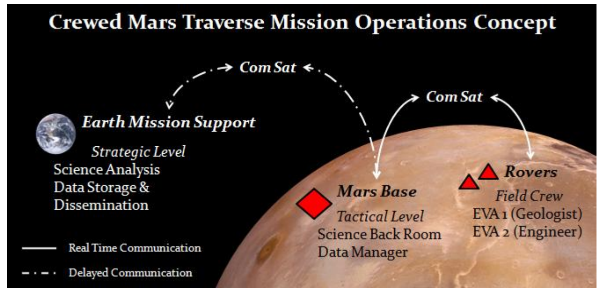

Figure A: The communication/command operations concept of a crewed Martian traverse

The tactical team should include a trained physical scientist(s) to provide science support, as well as a crew member to capture all of the data produced by the traverse, pictures, locations, transcripts, etc, and package it for transmission to Earth. Automating processes will increase crew efficiency. In incremental amounts the Mars Base will transmit the data packages, comments, and results back to Earth. Once received these data packages will be reviewed, cataloged, and disseminated. The Earth Base will follow the model of Mission Support, providing extra information or expertise when requested and will participate in the strategic level of traverse operations (Fig A).

After the traverse is completed the returning field crew will meet with the Mars Base crew and they will review the mission. Together they will create a formal finalized report for Mission Support, much the same way an exploration Geologist would for a resource company or research institute. Based on the discoveries and new information Mission Support may draft sequential traverse plans, but these will be sent to the crew who will edit, and adjust the traverses to their own specifications. This process will repeat for the duration of the mission.

References: [1] Science Team of the Traverse Planning Group, Internal NASA project documentation (2012). [2] F Horz, et al., Acta Astronautica (2012). [3] F El-Baz, Geological Society of America Special Papers (2011). [4] RA Yingst, et al., Acta Astronautica (2011). [5] D Eppler, et al., Acta Astronautica (2012).

Additional Information: Interviews with: Dean Eppler, Friedrich Hörz, Farouk El-Baz, and John Gruener, as well as guidance from Lee Graham and David Melendrez of NASA's JSC.