UK SPACE AGENCY "MARS UTAH ROVER FIELD INVESTIGATION 2016" (MURFI 2016): IN-SITU AND REMOTE OPERATIONS H.J. Walker[1], A. Caldwell[1] S. Kay[1] M.R. Balme[2] M.F. Curtis-Rouse[1] and the MURFI Team[*] [1]RAL Space, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, Oxon, OX11 0QX, UK (helen.walker@stfc.ac.uk), [2]School of Physical Sciences, Open University, UK.

Introduction: The Mars Utah Rover Field Investigation "MURFI 2016" is a Mars Rover field analogue mission run by the UK Space Agency (UKSA) in collaboration with the Canadian Space Agency (CSA). MURFI 2016 took place between 22 October and 13 November 2016 and consisted of a Field team including an instrumented Rover platform, at the field site near Hanksville (Utah, USA), and an operations team based remotely in the Mission Operations Centre of the Satellite Applications Catapult at the Harwell Campus (near Oxford in the UK). A key part of the field trial was that the team in the Mission Operations Centre (MOC) would use only Mars-like data to operate the rover platform in Utah, to simulate operations during a real mission, and send 'commands' back to the Field team in time for the start of the next day's activity. Two main aims of MURFI 2016 were to develop logistical and leadership experience in running field trials within the UKSA, and to provide members of the Mars Science community with Rover Operations experience. It was also an opportunity to train scientists in an operations-like environment.

Overview: [1] gives an overview of MURFI 2016 and describes the mission philosophy, platform and instruments. The remote operations team consisted of 28 scientists and engineers from 10 institutes, with remote support from Joanneum Research in Austria. A small group from the team in Harwell had a few days to set up the MOC, and then two weeks of operations were conducted in the MOC. The MOC was equipped with eight dual-screen workstations, and a very-high resolution video wall operated by a separate computer (Fig. 1). There was a second room, near the MOC, which the team used for strategic science discussions and this was equipped with 3D projection wall. Information, data, documents, and the daily folders containing logs, commanding, reports, etc resided in an FTP site which could be accessed by the MOC, by the Field team and by team members at their home institutes. There was also a folder on one of the workstations which could be accessed by all the workstations, and information generated on one workstation could be placed there to be accessible to the other team members in the MOC.

Fig. 1. *The Mission Operations Centre (MOC), showing some of the workstations and the video wall.*

Since one of the main aims of MURFI 2016 was to build expertise for ExoMars missions, the team members were frequently moved from role to role, to give them an understanding of the different jobs involved in operations. The MOC team used only data which was sent by the instruments in the field or overhead images degraded to the resolution of Mars-orbiting satellites (in-sim). Only the Mission Manager was in direct communication with the Field team (out-of-sim), to alter the day's scenario in the light of weather conditions, instrument/expertise availability, and other constraints.

The team in the field was much smaller and consisted of rover platform experts, geologists, instrument engineers, and logistics support. They camped at the site agreed by the UKSA and CSA, and moved the rover platform and instruments each day from the secure storage to the correct location for the day's operations. The rover platform was relocated to the position at the end of the previous Sol's drive as identified by GPS and bearing angle, to mitigate potential inaccuracy. There was no internet connection in the field and poor satellite phone access, so trips were made regularly to Hanksville for communications.

Operations: Several roles were easily identified, and in consultation with advisers from NASA's MSL mission and CSA trials in previous years (eg [2]), other tasks were identified (Fig. 2). Once the objectives for the next day's operations were identified by the science team, the Mission Manager generated commands for the people in the field to follow and sent them to Utah.

[*] The MURFI Team is listed in LPS Abstr. 1837

When operations in Utah finished at the end of their day, data were sent to the team in the UK. The commanding for the next day needed to reach the team in Utah by sunrise (around 1200 or 1300 GMT, depending on daylight saving), and this time constraint governed the discussion and decision making for the science team.

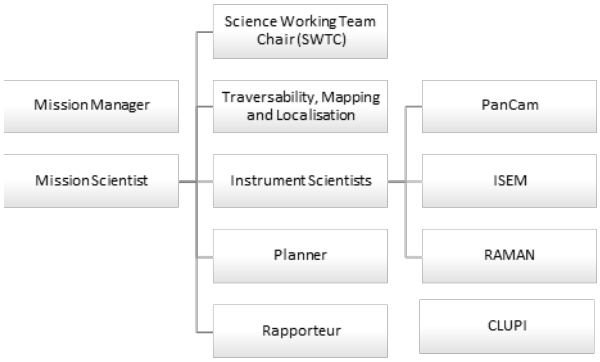

Fig. 2. *MOC roles used in MURFI 2016.*

When the Field team first arrived at the UKSA's proposed site, the position was checked by GPS. The geology team conducted an initial survey of the local area (out-of-sim) to use as a benchmark to compare with results from the MOC scientists. Once the MOC had been set up, and the roles defined, the first two days were used for Operations Rehearsals. AUPE [3] [4] was used to provide panoramas and images for the Traversibility, Mapping and Localisation team. The initial panorama from AUPE (after the platform had 'landed') was used to plan operations for Sol 001 on both days, first to confirm the necessary tools were available, and refine their operation, and second to identify gaps. The tactical planning was executed on the third day (Sol 000), commands generated and sent to the Field team, within the time allowed for the task.

During the morning of a nominal operations day, the processed images and data from the Field team were studied by the full science team, regardless of their allocated role for the day. Rapid and efficient planning was required to make the tactical decisions for the next day's activities in the limited time available (Short Term Planning). These decisions and objectives were listed by the Planner and priorities set. The Rapporteur recorded key elements of the discussion, which could be used by the Mission Manager, out-of-sim, to clarify the objective for the Field team, if there was confusion. The Mission Manager translated the Planner's list into 'commands' and sent them to the Field team with a report from the Planner which (since this was a trial using 'real' geologists in the field) included images and sometimes fuller descriptions of the objective.

Members of the Field team drove to Hanksville each morning and downloaded the command files, using the internet there, then did a sanity check to ensure they understood the objectives while they could seek clarification in case of confusion. After that they returned to the camp and briefed the rest of the team.

The science team in the MOC had strategic scientific discussions in the afternoons (similar to a Science Operations Working Group session) to plan for two or three days further ahead (Medium Term Planning). The PanCam (AUPE) instrument scientists had an important role in the tactical planning, and all the instrument scientists and the TML scientists participated in the SOWG sessions.

The MOC at Harwell was situated close to the reception area and had a glass wall, so visitors could see the activity. There were more than a dozen official visitors (or groups of visitors) to MURFI 2016 at Harwell, and there was a blog, with posts from several team members, and also twitter activity.

Conclusion: The people in the team learned very quickly to work together, due to the time pressure and common goals, and the changing roles meant there were new challenges for the team members every day. Objectives, priorities and constraints needed to be very clearly laid out, to avoid confusion and wasted time (of vital importance in the short period allowed for the trial). While primarily a 'trial for future trials', the ExoMars-like mission part of MURFI 2016 was a vital training activity for the science team. The emphasis on asking the scientists to perform tactical operations with a tight deadline, was a particularly important activity, and one they will need in the future. With more time, planning tools could have be created, but the objectives were met, and much learned about what is required for a more useful operations centre environment.

References: [1] Balme, M.R. et al. (2017) *LPS Abstr. 1837* [2] Moores, J.E. et al. (2012), *Advances in Space Research* 50, 12, 1666–86. [3] Harris, J.K., et al. (2015) *Icarus*, 252, 284-300. [4] Coates, A.J., et al. (2016), The PanCam instrument for the ExoMars Rover, *Astrobiology, in press.*