SURFACE OPERATIONS FOR MISSION CONTROL DURING ANALOGUE HUMAN LUNAR DEPLOYMENTS TO MISTASTIN AND BARRINGER IMPACT STRUCTURES. J.E. Moores[1], R. Francis[1], G.R. Osinski[1] M. Mader[1], E. McCullough[1], L.J. Preston[1], L.L. Tornabene[1] and the KRASH Operations and Science Team[2], [1]Centre for Planetary Science and Exploration, University of Western Ontario, London, ON, Canada N6A 3K7, [2]KRASH Operations and Science Team (see [1]) (john.e.moores@gmail.com).

Introduction: Two analogue deployments were held as part of the ILSR program in the fall of 2011 [1]. The first deployment (KRASH) consisted of two one-week human sortie missions and two one-week robotic missions. During the first week of both human and robot deployments, the humans and robots worked cooperatively to explore a site on the northeast rim of Mistastin Lake (Kamestastin) Impact Structure, Labrador and to determine what samples were appropriate for collection and return to Earth. During the second week, the astronauts relocated to Discovery Hill, on the southwest rim of the impact structure while the robot remained behind at the first rim site to conduct follow-on investigations.

The second deployment (BLAM), consisted of a analogue three day human sortie on the southwest rim of the Barringer Impact Structure, Arizona. While the geology of this crater is less appropriate to a lunar environment than Mistastin [2,3], by using the same tools and techniques in an environment that has been well studied [e.g. 4], we were able to perform validation on the investigations conducted at other impact structures [5,6,7].

Pre-Deployment Structure of Mission Control for KRASH: The structure for Mission Control used to support field operations at Mistastin was derived from the highly successful structure employed during the June, 2011 robotic-only deployment to the Sudbury Impact Structure (SLAM, [8]). To the Planning, Evaluation, Science Processing and Science Interpretation processes [8] was added a fifth process called Tactical. The Tactical process was tasked with directly supporting astronaut EVAs and was led by a Flight Director assisted by a team of personnel to monitor communications with the astronauts, manage their resources and adjudicate modifications to the day's plan. The addition of the Tactical process was necessitated by the anticipated ability to perform two-way communications with astronauts in real time.

Additionally, KRASH benefited from having access to precursor data from a previous Analogue Deployment to Mistastin in August of 2010 [9,10,11,12]. This precursor data was combined by mission control prior to deployment in a traverse planning exercise [13]. In this exercise and during the mission, the use of Geographic Information Systems (GIS) was anticipated to play a large role in understanding the site and planning the traverses that were to be performed. A GIS group was therefore formed with representatives in each process and was led from the Science Interpretation process.

Evolution of the Structure for KRASH: Unfortunately, conditions in the field at Mistastin did not permit effective two-way communications when the astronauts were located outside of their base camp. This severely reduced and restricted the role played by the Tactical process. At best, the Astronauts carried out a plan which had been produced the night before by Mission Control with occasional check-ins [14]. As such, several personel from the Tactical process were repurposed to other tasks.

Simultaneously, the Planning process was undermined by four significant factors. First, due to the difficult terrain at Mistastin, it was impossible to make reliable estimates of astronaut traverse time or resource usage at Mission Control. Secondly, during the first week, it was difficult to effectively prioritize the sites of interest which made it impossible for Planning to adjudicate tradeoffs. Thirdly, the need for planning was reduced by the pre-existing traverses [13]. Finally, by centering the GIS team within the science interpretation process, it became simpler to define new traverses in that process rather than to deliver science desires to planning for assembly into traverses.

Within three days, the Planning process was entirely disbanded and its personel redistributed to other tasks. Thus, for the remainder of the mission, Mission Control consisted mainly of a large science back room and a smaller tactical group. The science back room performed planning, interpretation and processing functions as a group and led science discussions with the astronauts before and after their EVAs. Daily plans were not the fine-scale directives used in SLAM [8] but instead consisted of a document containing a suggested path, science questions to be answered along the way and suggested activities. This allowed a great deal of flexibility to the astronauts – partly a required aspect, given the communications difficulties.

As for the robotic operations, there was little to no input from mission control during week 1. Astronauts spent time joysticking the rover out to what they judged to be sites of interest at which point a pre-canned sequence of observations would be conducted [15]. During the second week, a separate robotic planning process was convened. However, this process was hampered by two factors. First, unbeknownst to Mission Control, the terrain at the robotic site was at the limit of traversability of the rover. Secondly, more science was being generated by the astronauts compared to the rover and it became difficult for the Science Back Room to divide its attention between what were effectively two separate mission scenarios running simultaneously.

Structural Lessons Learned: Several conclusions can be drawn from the evolution of mission control: (1) The communications atchitecture is a key driver of the organization and task flow in Mission Control (2) GIS and traverse planning must be primarily situated within the Planning process for a division of responsabilities similar to SLAM to be effective (3) the effectiveness of the planning process is directly related to the degree to which the traversability and resources consumed by various activities is known (4) when two missions are operating in parallel, separate and adequate personel must be assigned to each, and (5) in an analogue scenario where many of the engineering aspects of a real mission are not simulated, the Science Processing and Interpretation processes take on central importance and therefore have a tendancy to absorb the functions of other processes; this tendancy needs to be held in check for maximum efficiency at Mission Control.

However, the structure which did evolve was effective at directing astronaut operations. The restrictions on communications forced the astronauts to take on responsibility for their investigations at the fine scale with Mission Control supplying (1) large scale direction and (2) monitoring astronaut products for sites of interest that might have been missed by astronauts in the moment. This was aided by the rejection of a long list of competing objectives in the second week, in favour of a single testable hypothesis [16]. We found that the science team was much better able to prioritize and tackle the problem when it was focused on a single objective. However, a real challenge of planetary missions is answering a complex set of related and disparate problems with limited resources. This thus remains one of the key challenges for future analogue work not addressed fully here.

Application of Lessons to BLAM: The final deployment to the Barringer Impact Structure in Arizona was helpful as a calibration for the tools and techniques. However, it also allowed us to test some of the lessons learned from KRASH. Two-way communications were anticipated to be much more effective in Arizona and thus the tactical process was retained and enhanced. However, as traversability and resource utilization were not well understood, traverse planning was left incorporated with the Science Back Room.

This two-process setup worked well. The communications were largely effective and gave both the science and tactical teams greater situational awareness. However, planning proved to be a very time-intensive activity for the Science Back Room which required up to five additional hours each night to construct their plans. Had personnel been available, this would have been aided by breaking out Planning as a separate process. Such a Planning shift would begin in the middle of the afternoon and use a portion of the overnight period to finalize the next day's plans. This scheme is currently used within the operational architecture of the Mars Exploration Program [17].

An additional feature of the operations structure in BLAM was the presence of roles which tracked work in a temporal fashion between processes. These traverse science leads (TSLs) followed a traverse all the way through its lifetime. This began with inception in the traverse planning session prior to the start of the mission. The TSL then oversaw tweaking of the traverse in the Science Back Room on the day before the traverse was to take place. During the traverse, these leads sat in the tactical room and were available to answer questions and advocate for the objectives of their traverse. Finally, on the day after the traverse the TSL would sit with the Science Back Room to help with the processing and oversee the interpretation of the data collected while developing follow-on traverses.

This structure prevented a problem which was forseen in SLAM that with complete division of responsability, information passage between processes became critical. If that information specifically resides within a defined role, this transmission becomes much more effective.

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