SHIFT HANDOVERS FOR REAL-TIME LUNAR OPERATIONS: METHODS FROM THE CANMOON ANALOGUE MISSION. C. L. Marion[1], Z. R. Morse[1], J. D. Newman[1], E. A. Pilles[1], P. J. A. Hill[1,2], G. R. Osinski[1], E. A. Cloutis[3], C. M. Caudill[1], S. L. Simpson[1], T. Xie[1] and the 2019 CanMoon Team. [1]Deptartment of Earth Sciences / Institute for Earth and Space Exploration, University of Western Ontario, London, ON, Canada. [2]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada. [3]Department of Geography, University of Winnipeg, Winnipeg, MB, Canada (cmarion3@uwo.ca)

Introduction: In preparation for future lunar robotic missions, the University of Western Ontario, with funding from the Canadian Space Agency and partnered with the University of Winnipeg, conducted the CanMoon lunar analogue sample return mission to Lanzarote, Spain [1]. In addition to providing a training platform, the primary operations objective was to determine the best mission control operations structure for 24/7 real-time lunar surface operations. Our design was adapted from real missions, such as NASA Mars Exploration Rover (MER) missions [2], as well as past analogue missions run by Western [3, 4], to address the real-time increase in communications and data exchange between Mission Control and the Rover. Mission Control was split into a Planning team [5] and a Science Team, including both a Tactical Science Team [6] and a Science Interpretation Team [7]. Each team consisted of very specific hierarchy of roles and responsibilities with a series of procedures and flight rules by which to operate.

Objective: To develop shift handover procedures and documentation templates to be applied to future 24-hour lunar missions, particular attention was given to designing CanMoon's Mission Control shifts and shift handovers. "An effective shift handover is one in which the outgoing workers have effectively communicated the relevant information to the incoming workers." [2]. The execution of this objective was completed not only by executing the specific mission scenarios and shift design, but in applying lessons learned throughout the mission by modifying and improving the shift handovers every day based on results of leadership meetings and daily surveys from the entire mission control team.

Scenarios: The two-week mission comprised two scenarios:

1) Week 1: the entire Mission Control team (~40 people) worked the same 10 hour shift (4AM - 2PM EST) during which most roles were double-occupied for the purpose of role and operations training through mentorship.

2) Week 2: Mission Control was divided into 2 human shifts and one ghost shift, lasting 5.5 hours each, with a 30 minute overlap. Shift A ran from 3:45 AM to 9:15 AM; Shift B from 8:45 AM to 2:15PM EST. No operations were run during the ghost shift.Shift lengths were chosen based primarily on the limitations of daylight in the field as well as effective use of mission length [1]. Where possible, the rover was given a series of commands to complete during the handover to avoid rover idle time.

Shift Documentation: The mission was documented extensively using team documentarians, audio recordings, archived inter-team communications, current rover location using the software Slack®, automated reporting by the Rover Operator terminal etc., records which could be consulted at any time by any crewmember. In addition, specialized End-of-Shift documents were completed by each role at the end of each Shift Week 1, and a Shift Handover document was completed by each role throughout their shift Week 2 and uploaded to a communal CanMoon Mission server. The template for both the End-of-Shift and Shift Handover document templates were identical, and were designed to act as a shift summary of the most important information to be archived and passed on from the outgoing to the incoming shift. The identical document template served a training purpose, to increase the quality of reporting for the Week 2 handovers.

The Shift Handover template was designed to be used by any role, where each role may have very different information to convey to the incoming shift. Required information included the name and role of the crew member, date, mission date and shift e.g. Lunar Day 1, Shift A. There are then 4 main field headings: Shift Summary, Near-term Objectives (1-2 shifts), Long-term Objectives (2-3 days) and a Comment Section. The template also shows examples under each heading from a previous mission. These documents have no character limit, and insertion of tables and figures where necessary was encouraged.

Shift Handovers: Two types of handovers occurred Week 2, a document-only handover from Shift B to Shift A; and an in-person handover from Shift A to Shift B. All Shifts were required to complete the Shift Handover documents, regardless of handover type. Hard rules were in place so the Shift Handover reports were complete before the next shift began.

Document-only Procedure: The morning crew Shift A, started their shift by immediately reading the handover report from their role's previous shift. Once this was done, they started a new report for the current shift and filled it out continuously throughout their shift. Approximately 15 min into the shift, or when operations allowed, the Planning and Science Leads gave a summary presentation to their respective teams. A Lead Meeting followed to make sure all were on the same page.

In-Person Procedure: The incoming shift enters the room and has a face-to-face meeting with the crewmembers whose roles they are relieving for approximately 15 min. It is the responsibility of each crewmember to confirm they are confident in understanding what occured during the previous shift before the outgoing shift crew may depart. Most of the crew completes their handover within the first 15 minutes. The second half of the handover consists of each of the incoming shift's Planning and Science Leads giving a summary presentation to their respective teams. During which the outgoing Shift Leads remain in the room to correct any misunderstandings, make precisions and answer questions from the team. After which the outgoing Leads depart and the new shift Planning and Science Leads would have a tag-up Lead Meeting.

Further questions are then answered by consulting the Shift Handover documents as well as other archives as needed.

Results: In general the In-Person handover was more effective than the document-only handover, particularly for the Team Leads and handovers between experienced and inexperienced personnel. The Document-only handovers improved with time as adjustments were made based on crew-to-crew comments as well as survey results. Each person's writing style and attention to detail varied. Hence, the summary presentations were extremely beneficial in getting the whole team on the same page and able to continue operations seamlessly.

Because of the nature of the Planning Team's operations, there is very little ambiguity in information transfer during handovers. The information transferred in the Science Room is less straightforward. For this reason, the Planning Team's handover was generally completed much more timely and efficiently. Shift overlap time was adjusted on a role by role basis. As 15 min was adequate for most handovers, the outgoing crew were permitted to depart the second half of Week 2 before the Team meetings began. The Science Lead and Science Interpretation Manager needed the most time, as the allotted 30 min wasn't always adequate, we had the Science Lead start Shift B 10 min earlier than the rest of the crew, with positive results.

The biggest challenges were when in-progress rover operations demanded the attention of the team at the same time as the shift handover. This occurred during multiple handovers where the team was in the midst of troubleshooting or creating new rover commands. The team worked through the chaos, and completed the handover on time.

Recommendations: Prompt and properly completed Shift Handover documents were essential in both handover types, and must include summary figures. We recommend pre-mission training be provided in completing these documents. It is also far more effective to complete the Shift Handover documents throughout the shift rather than at the end, particularly in the case of long shifts where end-of-shift operations may be otherwise demanding.

Generally, In-person handovers, in agreeance with the MER surface operations [2], are the most effective as questions can be answered immediately and subtleties such as degree of confidence can be relayed. Document-only handovers may be appropriate for particular roles, whereas other roles may need 15 minutes of in-person handoff time. More handover time should be allotted to the lead roles, 30-40 minutes, particularly for the Science Leads.

Optimal shift length should be no more than 8.5 hours. Shift lengths in real missions can be up to 10 [2]. Contrary to Martian surface operations, with few exceptions, each role should be a manned at all times as lunar surface activities operate real-time, activities are planned and completed on a shorter timescale.

Handover and shift design may benefit from further analogues to test optimal shift offsets, that is where different roles may start and end their shift at different times. This may eliminate chaos and errors in information transfer. Planned handover offsets of 1-2 hours difference for certain roles were successful in the MER missions but what would the optimal offsets be for the more fast-paced lunar surface operations?

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