ISSUES OF GEO-FOCUSED SITUATIONAL AWARENESS IN ROBOTIC PLANETARY MISSIONS: LESSONS FROM AN ANALOGUE MISSION AT MISTASTIN LAKE IMPACT STRUCTURE, LABRADOR, CANADA. I. Antonenko[1], M. M. Mader[1], G.R. Osinski[1], M. Battler[1], M. Beauchamp[1], L. Cupelli[1], A. Chanou[1], R. Francis[1], C. Marion[1], E. McCullough[1], A. Pickersgill, L. Preston[1], B. Shankar[1], T. Unrau[1], D. Veillette[1], [1]Centre for Planetary Science and Exploration & Canadian Lunar Research Network, University of Western Ontario, London, ON, Canada, iantonen@uwo.ca.

Introduction: Historically, robotic missions have been the main method of exploring planetary surfaces (the Apollo program being the one exception) and this trend is expected to continue. However, the situational awareness at mission control is typically much less than that for geologists in the field. This fact has been shown to significantly affect mission control's ability to conduct comprehensive geologic studies [1]. It is, therefore, important to understand the differences and limitations of robot-collected data and to explore ways to mitigate, or compensate for, their adverse effects.

Here we report on a study of reduced situational awareness in an analogue robotic mission conducted in the summer of 2010. This mission was funded by the Canadian Space Agency and conducted at the Mistastin Lake impact structure in Labrador, Canada [2]. A field team of 4 geologists simulated the robot, conducting traverses and collecting data under the direction of a remote mission control team, located some 2000 km away. None of the mission control team members had ever been to the field site, thus faithfully reproducing this aspect of mission operations.

Observations: The mission control team encountered a number of geo-focused difficulties related to situational awareness that the field team did not. These can be distilled into 3 main issues relating to 1) Scale, 2) Relief, and 3) Geological Detail, all of which significantly impacted the ability of the mission control team to effectively direct the robot and interpret the geology of the field site. In turn, all 3 issues shared the common compounding factor of severe time constraints.

1) Scale. Estimating scale in returned image data proved to be much more difficult than anticipated. This is because images with no known objects for scale can be very difficult to interpret (e.g., Fig. 1). Even with LIDAR data providing heights and distances, the numbers did not make the same kind of immediate impression on the mission control team as the simple fact of being there did on the field crew. For example, Figure 1 shows a segment of image data received by mission control. LIDAR data of the same segment indicates that this cliff face is 6 metres at its tallest. Using just these considerations, mission control's selected area of interest (red arrow in Fig. 1) seems reasonable. However, the field team knew intuitively this was not technically feasible and when the same area is viewed in a personal photograph showing a human for scale (Fig. 2), this becomes obvious (even ignoring the unexpected depth of the water). As a result, useful data was not acquired at this site and valuable time was lost in the process. Improved situational awareness would have eliminated this site as a potential target, allowing the focus to shift to more technically feasible sites.

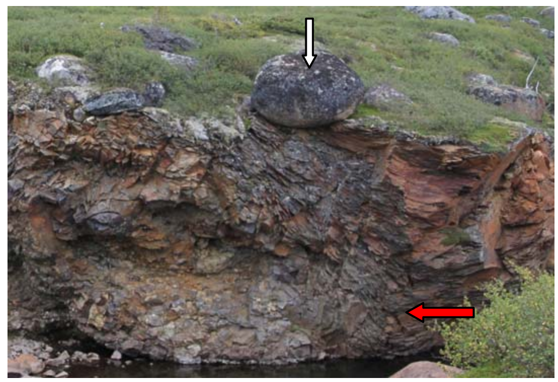

Figure 1: Section of image data from Cote Creek site, looking at north-east bank. LIDAR indicates cliff is 6 m tall and the large dark rock at top (white arrow) is 1.5 m x 2.5 m. Red arrow shows site selected by mission control.

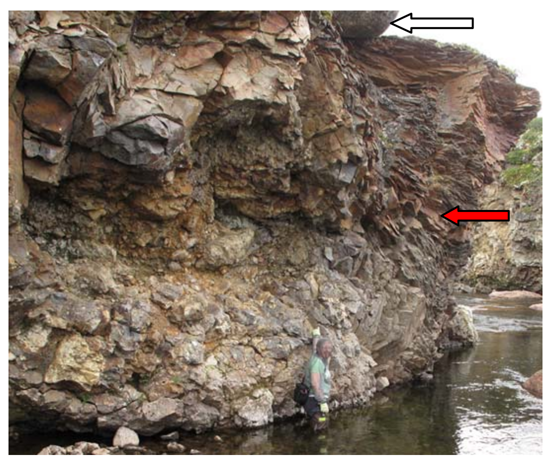

Figure 2: Personal field team photograph of the approximate area in Figure 1. Note how inclusion of field member communicates the scale of the cliff more effectively than numbers. The white and red arrows indicate the same features as they do in Figure 1.

2) Relief. Image data tends to flatten features. This is an issue, since geological information at a variety of scales is intuited from relief information, which geologists acquire by examining areas of interest from multiple angles [e.g., 1]. Understanding this concept, our mission included a mobile Scene Modeler (mSM) stereo camera [3] in the instrument package. However, our team found that even stereo data (Fig. 3) did not always solve the problem. First, proper relief was often not represented, because the stereo data was collected from one location. For best results, additional stereo pairs from vastly different angles of observation should be acquired. Secondly, the spatial resolution of the mSM images (1280x960 - 1 Megapixel) was not sufficient to distinguish relief at the cm scale. A flat area 1 cm square in size was required to obtain X-ray fluorescence (XRF) spectrometer measurements. The mission control team's difficulty in determining relief certainly affected the collection of good quality XRF data.

Figure 3: Data from the mSM stereo camera. Additional data from other angles would have shown that the top rock (red arrow) overhangs the underlying rocks by significantly more than is apparent here.

3) Geological Detail. Issues of time and data resolution all prevented the mission control team from finding and identifying many details of geologic interest and significance, both at the micro and macro scale. For example, Figure 4 shows a 'fresh', clean surface of granodiorite (a target rock of the Mistastin Lake impact structure) from a small area (~1 m x 0.5 m), that was devoid of lichen and the effects of weathering, on a flat surface above the outcrop in Fig 3. The mission control team never saw this fresh surface, because it was beyond their field of view. Meanwhile, the field team identified this spot easily by a quick survey of the site. At the macro scale, Figure 5 clearly illustrates the regional geology at the Mistastin River site. Mission control requested one such image, but their collection point proved to be less than optimal, showing only the rock underfoot and distant horizon. Re-acquiring this data from a better location had low priority, due time constraints. Conversely, the field team identified this optimal vantage point on their first day's walk around.

Discussion: From these initial studies, it is not clear if geologically focused issues of situational awareness can be easily addressed with more or better instrumentation. For example, scale seems to be more difficult to determine in remote data, even when dimensions are provided. This is of great concern in robot-driven planetary exploration, since personal experience with Earth analogues cannot be relied upon when extraterrestrial features may have vastly different scales. One solution is to use scale bars on all visual data; however, it is not clear how this will work for distant features. A similar problem exists for determining relief remotely. In this case, stereo was not completely effective unless stereo pairs were collected from several look directions, effectively forcing the robot to mimic the behaviour of a typical field geologist. Increased resolution of the cameras and better use of lidar data may address this issue. Issues of missed geologic details are a purely operational problem. All these factors are compounded by time constraints.

Figure 4: Personal field team photograph of granodiorite, showing beautiful potassium feldspar phenocrysts with reaction rims. The mission control team discovered a 'fresh', clean surface.

Figure 5: Personal field team photograph of geology across the Mistastin River.

It is important to be aware of these geo-focused situational awareness issues in planetary missions, so that operations can be planned accordingly.

References: [1] Yingst R.A. et al. (2010) Submit. to *JGR Planets*. [2] Osinski G.R. et al. (2010) LEAG 2010, Abst. #3047. [3] Osinski GR. et al. (2010) *PSS*, *58*, 691-700.

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