REAL-TIME MISSION CONTROL TRACKING OF ASTRONAUT POSITIONS DURING ANALOGUE MISSIONS. M. C. Kerrigan[1], B. Shankar[1], C. Marion[1], R. Francis[1], A. E. Pickersgill[1], R. D. Capitan[1], G. R. Osinski[1] and the ILSR Team [2] [1]Centre for Planetary Science and Exploration, University of Western Ontario, London, ON, Canada N6A 5B7 (mkerrig@uwo.ca)

Introduction: Analogue missions simulating human exploration of planetary bodies often make use of the global positioning system (GPS) to track the positions of the astronauts and to record the locations of sites visited (e.g. [1]). However, recent analogue missions led by the Centre for Planetary Science and Exploration (CPSX) at the University of Western Ontario (UWO) were carried out under the assumption that human explorers on the Moon or Mars would not be aided by a GPS network similar to that available on Earth. Bearing in mind that the tracking of astronauts during a mission is vital not only for logistical reasons but also for maximizing the scientific return of a mission, we present a simple and reliable method of real-time tracking of astronaut positions developed and implemented during these analogue missions.

Mission Overview: In August and September 2011, astronaut-only and joint astronaut-robotic analogue missions took place over 10 days at the Mistastin Lake (Kamestastin) impact structure in Labrador, Canada. This was followed by a 3 day astronaut-only analogue mission at Barringer Crater in Arizona, USA in November 2011 (see [2] for overview of the mission and scientific objectives). For all three missions, Mission Control (MC) was based at UWO and split into three teams – tactical, planning, and science (see [3] for overview of MC).

Communication: The astronauts were equipped with ultra-high frequency (UHF) radios networked and relayed by voice over internet protocol (VOIP) with a satellite connection using an Inmarsat Broadband Global Area Network (BGAN) terminal. In short, live communications were maintained between the astronauts and MC for the 5-8 hour duration of extra vehicular activities (EVAs). Prior to each deployment, MC supplied the astronauts with maps and instructions of planned traverses for each day [4]. While the astronauts followed these plans, the open lines of communication allowed for discussion and flexibility during EVAs based on the ground-truth information relayed by the astronauts.

Tracking Method: The astronauts used visual and radar satellite images in conjunction with digital elevation models to position themselves using digital mapping tools in the form of ruggedized computers and PDAs [5]. They then relayed their positions (in UTM coordinates) to MC where they were recorded by the Situational Awareness Officer (SAO) and displayed on a map (using ArcGIS during the Mistastin deployment and Google Earth during the Barringer deployment). This allowed all MC members to know how the EVA

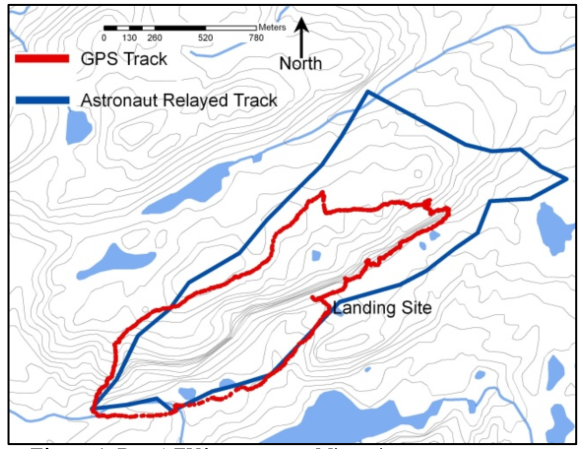

Figure 1. *Day 1 EVA traverse at Mistastin.*

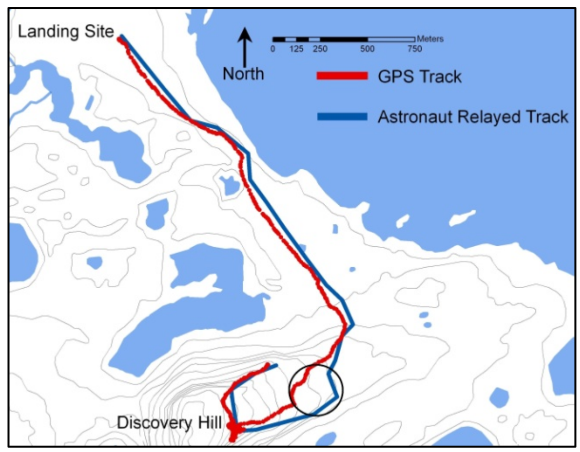

Figure 2. *Day 7 EVA traverse at Mistastin. Note the closer match of the two tracks compared to Fig. 1. Black circle highlights area of largest discrepancy.*

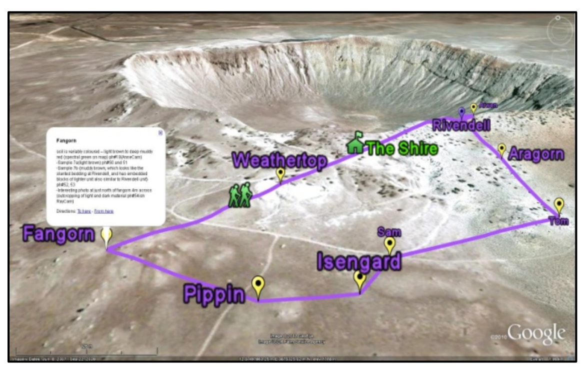

Figure 3. *Day 1 EVA traverse at Barringer Crater. Intuitive and visually appealing, Google Earth was used by the SAO to display information to MC. The astronauts are represented by the green hikers symbol, the purple path is the astronaut relayed track and data is accessed by clicking on the site of interest.*

was progressing. The tactical team used the positional information for logistical purposes (such as the timing of the EVA) while the science team used it along with the relayed field observations to gain a better spatial awareness of the ground covered by the astronauts.

Validation of Method: The astronauts were accompanied in the field by a support team who were equipped with a GPS receiver. The data recorded with the receiver were used to measure the accuracy of the UTM method after the completion of the missions. Fig. 1 is a map of the Day 1 EVA traverse at Mistastin. It shows the traverse as tracked by MC with astronaut-relayed coordinates (blue) and as recorded by the GPS receiver (red). For some points (particularly in the north-east of the map) there is a difference of 500-600 m between the tracked and actual positions. However, of the nearly 5 km traveled on this traverse approximately 50% was accurately tracked to within a few meters.

The reason for these inaccuracies is two-fold; 1) the astronauts had multi-layer maps with aerial and satellite imagery available to them on their PDAs, however due to the exorbitant time it took for these layers to render the astronauts often used only the basic topographic map to position themselves. This led to 2) the misidentification of features and scale due to the low resolution of the topographic map. As a result, general spatial orientation allowed the approximate shape of the traverse to be correctly mapped, but enlarged to an incorrect scale.

Fig. 2 shows the Day 7 EVA traverse at Mistastin and the difference between the two sets of tracks is noticeably reduced. In fact, the point in the south with the largest discrepancy (marked with the black circle) is mostly as a result of the astronauts and the GPS receiver being momentarily separated and not a positional error. Discounting this point the entire length of the traverse was accurately tracked to within a few meters. The main reason for this improvement is the astronauts and MC's growing familiarity with the tracking method as the mission progressed.

Additional Data Recording: In addition to positional information, the SAO also recorded astronaut observations, both scientific and non-scientific (e.g. environmental conditions) over the course of the EVAs. This information was embedded in the map using the attribute tables for point locations within ArcGIS and the description text boxes within Google Earth as shown in Fig. 3. Comparing the software used for this task, Google Earth was more intuitive and therefore quicker to input the data coming from the field. However, the volume of incoming data was such that it was impossible to manually input in real time and thus most of the data was linked to the map after completion of the EVA (see [6] for more details of data management).

Discussion: An important element in the success of these missions was the ability of the astronauts and the back room science team at MC to discuss the astronauts' observations and to re-evaluate the scientific objectives for the day if needed. These discussions allowed for adjustments to be made to traverses, thereby maximizing the scientific value of each day.

Maintaining the line of communication was not only a technical challenge but also one of understanding between the field and MC. The astronauts and the MC science team were often working with information on scales that differed by orders of magnitude. For example, the science team was examining satellite imagery and data that covered large areas with resolutions of perhaps hundreds of meters, while the astronauts were dealing with outcrops at a sub-meter scale. As data was sent back by the astronauts, it was vital that the science team could accurately position this new information in the context of the satellite data to facilitate the scientific discussions between the field and MC.

This technique of tracking astronauts in the field without the use of GPS was developed by trial and error during a series of analogue missions and as such has proven to be an efficient and reliable method. It relies heavily on a steady line of communication with the astronauts during their EVAs. Given the importance of communication to many aspects of a mission, the technology to maintain this line should be readily available. Manual astronaut tracking can be subject to human error but as was observed during these missions, with training and repeated use the margins of error can be significantly reduced. It is suggested therefore that non-GPS tracking be used in future analogue missions to refine the methodology and train those who use it.

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