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ARTICLE

Mars Rover Biosignature Recognition and Analysis Simulation

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Since the beginning of time, humans have looked to the stars and wondered if life existed anywhere beyond Earth. Today, the curiosity remains, and now we are able to explore using various technologies such as video feedback and mineral analysis. These technologies require testing and simulating in order to ensure their most productive and efficient function. The most effective simulations take place on terrestrial analogue sites. These sites are Earthly locations marked due to their geological or astro-biological similarities to Mars. The St. Martin crater in Gypsumville, Manitoba (Figure 1), became a terrestrial analogue site due to the various unknowns surrounding its formation and composition. Our project focus was to analyze the target selection and sample triage capabilities of a rover through comparison between data gathered by an on-site team, with equipment similar to that of the Curiosity rover, and data collected by the off-site team, through looking at the photos of the site. When successful, our study would advance space communication technologies by providing an increased understanding the human-rover relationship. This is achievable through comparing the quality of rover-selected samples (chosen by the off-site team) to the quality of what is actually present on site.

INTRODUCTION

The St. Martin crater in Gypsumville was studied, which has a 20 km diameter impact structure with a central uplift of shocked granitic materials, granite and carbonate impact melts, post-impact deposits of evaporites (gypsum), extensive slumping and reworking of impacted materials by surface water, and poorly sorted and partially lithified sediments [1]. This site showed promise in containing searchable "signs of life", similar to those one could realistically imagine to find on another planet in the solar system, such as Mars. Such signs include the finding of water, chemical biosignatures in the soil and rocks, and biomarker gases in the atmosphere.

Purpose of Experiment A

The purpose of Experiment A was to look at target selection and sample triage (ranking the samples in order of importance) using different degrees of imaging and rover relevant analytical instrumentation, and then to compare the sample triages and analytical findings between both the off-site and on-site teams. This was done with the goal of determining improvements to future deployments in regards to information transferring, instrument selection and control methods.

Our Experiment Post-Gypsumville (Experiment B)

The purpose of Experiment B was to simulate Mars exploration by introducing technical challenges and aspects of real rover exploration such as the physical navigation to the targets of perceived quality in the site and implementing a delay in communications between the rover and the controller. This was done by creating a simulation of foreign environments using various materials in the lab and navigating through it under different circumstances.

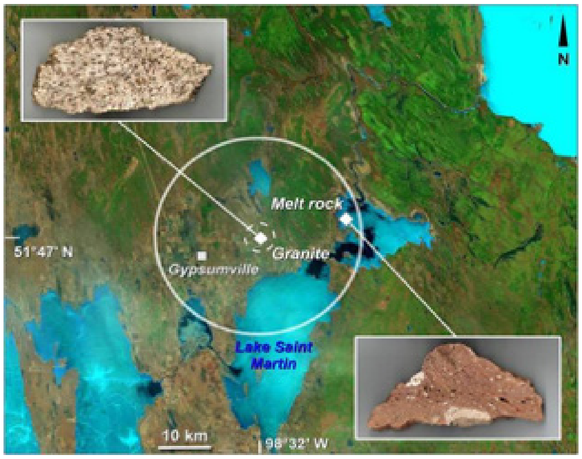


Figure 1: Map of Gypsumville showing the impact site of the meteor along with the melt rock and granite area.

HYPOTHESIS

We believe Experiment A in Gypsumville will depict how difficult it is to quantify the importance of an object when faced with accessibility issues. Such accessibility issues would be communicating with the U of W as we are so far out in the field, much like the actual Mars rover communicating with earth. We further believe that the Experiment B simulation at the University of Manitoba (U of M) will illustrate how challenging it is to control an object when we can only see through a narrow field of vision.

METHODS

Day 1 and 2: For days 1 and 2, large aerial photos were taken of each of the landing sites and sent back to the off-site team at the U of M. Next, the off-site team analyzed the photographs and sent back outlined regions of interest (ROI's) (Figure 2). The on-site team then took close up photos of each ROI and sent them back to the off-site team.

Figure 2: Panorama of the landing site with regions of interest identified

Finally, the off-site teams chose targets of interest (TOI's) for the on-site crew to test with field-portable reflectance and Raman spectrometers. The samples were characterized using X-ray diffractometry and the combination of both X-ray fluorescence and wet chemistry. The sampling equipment and methods chosen were similar to that on the Curiosity rover.

Day 3: On day 3, the off-site team visited the site and assessed their accuracy in choosing TOI's and re-evaluated their previous sample triage and compared their results.

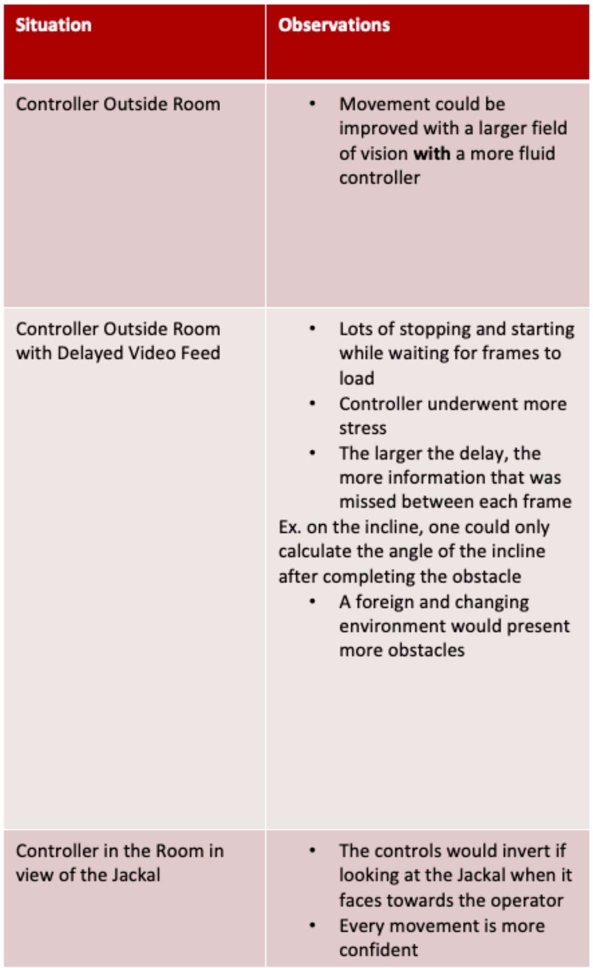
These rules were imposed on the off-site science team: A maximum of 20 high priority targets, defined as being important enough for sample return, could be chosen. As well, a "no going back" rule was applied, for cases where a TOI in a subsequent ROI was found to be more scientifically valuable than a previously identified TOI sample in a previous ROI; the previous samples priority ranking would not be affected. This was done to reflect the reality of sample acquisition. Finally, the "ROI Rule" meant that data for the TOI's within a single ROI could be compared with each other for prioritization prior to moving to another ROI.

This was implemented to reflect the ability of a rover to linger within an ROI. Table 1 was used as the baseline for our experiments in the U of M for controlling the Jackal drone using each situation and recording our observations.

Materials

- 1 Large drone equipped with camera
- 1 iPhone camera
- 1 Field-portable reflectance spectrometer
- 1 Field-portable Raman spectrometer
- 4 rock picks
- 1 laptop
- 1 Jackal unmanned ground vehicle
- Office supplies to build barricades

Table 1: Situations used during the use of the Jackal drone in UofM to simulate different scenarios for rovers on mars.



Situation	Observations
Controller Outside Room	• Movement could be improved with a larger field of vision **with** a more fluid controller
Controller Outside Room with Delayed Video Feed	• Lots of stopping and starting while waiting for frames to load • Controller underwent more stress • The larger the delay, the more information that was missed between each frame Ex. on the incline, one could only calculate the angle of the incline after completing the obstacle • A foreign and changing environment would present more obstacles
Controller in the Room in view of the Jackal	• The controls would invert if looking at the Jackal when it faces towards the operator • Every movement is more confident

RESULTS

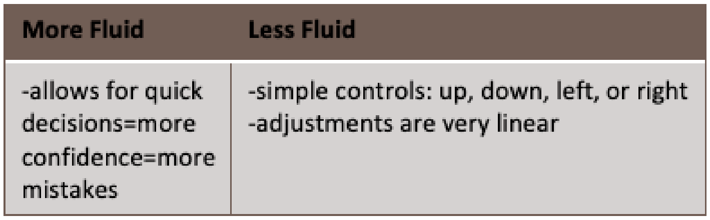
Results (Experiment A)

The onsite team identified numerous geological deposits along the site, and ROI's were quickly identified by the field team. Generally, 1-3 ROI's were identified by all team members onsite, with the rest supported by <50% of the off-site team. The tonal and textural diversity of the site could be captured by the first few high priority ROI's, and, as such, less TOI's were identified in less important ROI's. TOI's were identified for priority via a down select process which goes as follows: The panoramic color imagery, the ROI color imagery, the TOI color imagery, and the Raman and reflectance spectra of the TOI's. The number of TOI's became less numerous as their priority increased. Lower priority TOI's were more often discarded, as there was much more overlap in similarities between them than higher priority TOI's, unless they showed distinct textural differences with similar spectral characteristics compared to earlier TOI's.

Results and Comparisons (Experiment B)

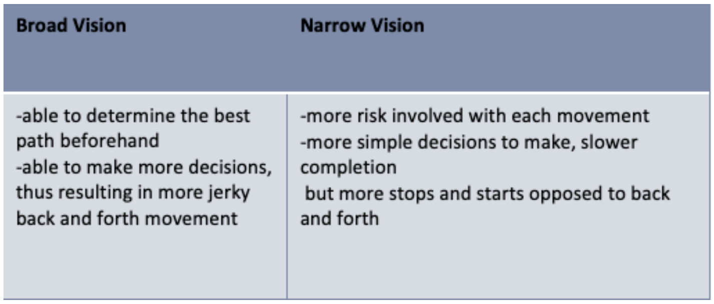
While the controller is outside the room to simulate controlling the Mars rover, the lack in fluidity in the drone's movement and the narrow field of vision becomes more frustrating (Figure 2). Although, when we compare fluidity in the drone's movement and field of vision, we find many differences and aspects as outlined in Tables 2 and 3.

Table 2: Results found from when the jackal was used with differing fluidity of control.



More Fluid	Less Fluid
-allows for quick decisions=more confidence=more mistakes	-simple controls: up, down, left, or right -adjustments are very linear

Table 3: Results found from when the jackal was used with a broad or narrow view point.



Broad Vision	Narrow Vision
-able to determine the best path beforehand -able to make more decisions, thus resulting in more jerky back and forth movement	-more risk involved with each movement -more simple decisions to make, slower completion but more stops and starts opposed to back and forth

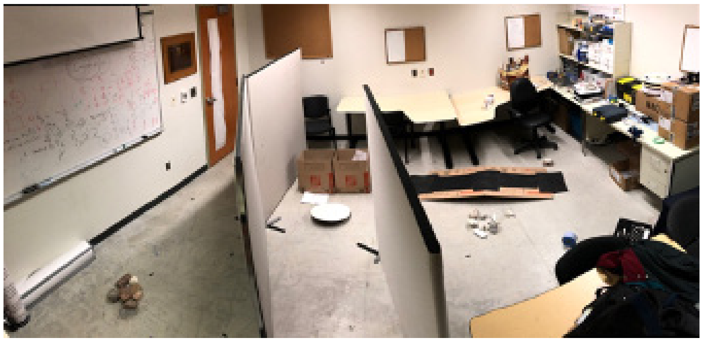


Figure 3: Photograph of an office space set up to create an obstacle course to be navigated by the jackal drone. In our situation, unlike on Curiosity, we had a stationary camera which hindered our field of vision.

DISCUSSION

The field-based rover-relevant deployments provide invaluable operational experience, help to identify potential pitfalls and issues, and inform best practices for future space deployments. Some of the lessons we learned were: A narrower field of vision results in more collisions, the ideal scenario for piloting a rover would include complete camera coverage and the controls would be suited towards the controller in both fluidity and style. The jobs of the controller are much simpler when the topography ahead is well understood; the larger the delay, the more information that is missed, and a foreign and changing environment would present more challenges.

Slow downlink-uplink between the field and off-site teams impeded quantitative spectral analysis, which can be used to provide important information about the chemical composition of targets tested. Related to this, we were unable to confidently search for or identify small differences in absorption band positions, which could be indicative of important mineralogical variations.

Even if communication issues were not present, the analysis would have benefitted from the availability of spectral libraries and easy to apply and rapid spectral analysis tools, such as a ramen spectrometer and reflectance spectrometer that can be used to acquire a chemical fingerprint of materials tested. The use of imagery at the three different scales (L.S, ROIs, TOIs) resulted in changes in sample prioritization, with potential TOIs being both upgraded and downgraded. Target selection and geological interpretation was hampered by the lack of scale bars in the imagery. Stereo imagery and other techniques (such as Lidar) could help to mitigate this issue.

CONCLUSION

While our simulations for Experiment A and B were done on Earth, the techniques and challenges of finding life on other planets, such as Mars, are no different. The most difficult challenge is that we cannot travel there yet and can only send rovers to search for life in our place, guided by scientists here on Earth. Although the onsite team and the offsite team were 300 km apart in Experiment A, compared to the mere one room away distance from our drone in Experiment B, the same principles and challenges apply to the Earth's 70 million kilometer distance from Mars.

Experiment A in Gypsumville proved our hypothesis that it is difficult to quantify the importance of an object when faced with accessibility issues. The communication between the on- and off-site teams was difficult at best and non-functioning at worst. In other words, this experiment depicts there is a proven discrepancy between the perceived importance and real importance of a sample. Adding the mobility/accessibility component where U of W was unable to access the samples and could only rely on the field team to gather samples, while also factoring in the triage of accessible vs. inaccessible samples, we are able to definitively rank accessibility as a limiting factor for finding biological samples in a foreign environment.

Experiment B proved how challenging it is to control an object when we can only see through a narrow field of vision through the drone itself, again consistent with our hypothesis. As stated before, both simulations illustrate the difficulties of communicating and controlling something over long distances.

Despite the challenges faced with distance, accessibility and narrow field of vision, we were able to find definitive signs of life in the samples we collected with evidence of water content and chemical biosignatures in the rocks. With advancing science, the dream of humans reaching beyond our own planet to find life continues. Acknowledging these challenges and limitations also serves as a reminder protect our own planet Earth, already rich with life supporting diversity.

ACKNOWLEDGEMENTS

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ABOUT THE AUTHORS

RYAN WALKER

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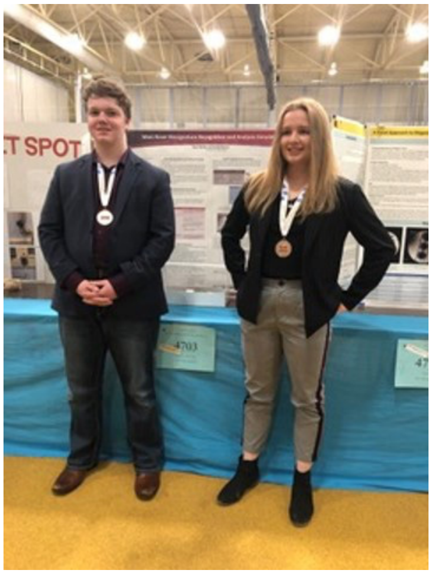
Ryan Walker is a 17 year old graduate of Shaftesbury High School, currently attending the Canadian Mennonite University in Winnipeg. With a passion for science, Ryan was previously published for his work on Climate Change, with www.Winnipeg Weather Warning and traveled to the Japan Super Science Fair in Kyoto, Japan to share his research. Continuing to broaden his experiences, Ryan and his partner Rachel, participated in research with Dr. Ed Cloutis in Gypsumville, Manitoba, one of the oldest meteor sites in Manitoba, which resulted in the publication The Lake St. Martin impact structure (Manitoba, Canada): A Simulated Rover Exploration of a Sulfate-Bearing Impact Crater, June, 2020. This also became the basis for Ryan and Rachels' additional research and current publication.

Ryan is a dedicated volunteer of the Manitoba Museum in the Science Gallery and planetarium. His recent accomplishment with his younger sister and family over the past year was establishing a micro-sanctuary called the Little Red Barn where families develop empathy and compassion towards farm animals, and the environment by interacting with rescued farm animals previously destined for slaughter. This sanctuary was the result of Ryan inspiring his younger sisters research Does Knowledge Increase Empathy and Compassion Towards Animals and the Environment?

In his free time, Ryan enjoys painting, the outdoors, and reading.

If there is one life-lesson Ryan has learned relating to what he has participated in academically, "It is not the destination, but the journey that is important".



RACHEL PARSON
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Rachel participated in a CSA analytical expedition of a simulated Mars rover lead by Dr. Ed Cloutis alongside her co-author Ryan. This study was the foundation to their project. Rachel is currently in her second year of environmental engineering at Carleton University and looking forward to continuing her STEM education in the years to come. Her other interests include hockey, rock climbing, and piano. She is the previous winner of best environmental science and physical sciences award for her project "Phytoremediation and Cattails" at the Manitoba Schools Science Syposium (MSSS). This project on rover biosignature recognition earned a bronze medal at MSSS.