Mars Society at Georgia Tech

Final Report to Crew Rotation 2011 at the

Mars Desert Research Station

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1. Executive Summary

It has been a successful seventh rotation at the Mars Desert Research Station for a Georgia Tech crew. Our history at ‘the hab’ has enabled us to prepare for this rotation for many months, utilizing the advice of many people who have already performed a rotation; but, at the end of the day, it all comes down to what we’ve done while here.

We’ve had our challenges; but, overall, this crew has had a wonderful two weeks on ‘Mars.’ Personnel selection for Crew 101 began in October 2010. From a relatively large pool of student applicants, a crew of ten participants was eventually chosen. The crew prepared by holding weekly meetings to update one another on then-evolving research goals, and by participating in team building exercises, including a day hike, and a cold-weather camping trip. These activities obviously pale in comparison to the preparations real astronauts must make, but the experience allowed the crew to grow close before making the trip to ‘Mars.’

By the time the final station crew of six was selected in early February, the crewmembers had spent hundreds of hours together, ensuring an unsurprising rotation, at least with respect to team dynamics. The remaining four crewmembers remained at Georgia Tech to act as a secondary mission support team (behind Mars Society support, of course); they updated the Georgia Tech MDRS website, and provided support on experiments that were being run at the hab. They have remained an important part of Crew 101 and will likely form part of next year’s ‘hab crew’ (two members of Crew 101 were part of the mission support for Crew 93). Together, the ten members of Crew 101 have been working hard for five months in preparation for this rotation.

An important part in our preparations was planning for the various research endeavors that would take place ‘in sim’. Georgia Tech crews have a history of experiments spanning across multiple years; as such these were the first source for inspiration in planning for this year. Crew 101 inherits two heritage experiments from previous crews. The longest running research activity is the incorporation of HAM radio into the rotation, which has been tracking Georgia Tech crew members since Crew 37. Also, areohashing, an exploration plan generator was imported from Crew 79. New experiments included a bacterial analysis and nucleic acid base study, as well as development of a polymerase chain reaction protocol led by Chief Scientist Christina Graves, and a geological survey of surface composition that was orchestrated from Atlanta by mission support lead Whitney Henderson. An EVA stress study and a dust contamination study rounded off the active experiments, while serious work was put towards both a wind turbine and an astronomy study with no avail. The crew has been pleased with the full scientific output of the mission.

The radio experiment had another successful year. During past rotations, the repeater (which extends radio coverage) has been set up on Skyline Rim, an ideal location for boosting signal, but the location is unreachable during sim. The crew this year decided to place the equipment on Radio Ridge, several hundred feet lower than Skyline Rim. This allowed the crew to set up the equipment in sim. The location further proved to be a good decision, when extremely high winds forced several repair EVAs. After the full extension of the antenna (eight meters), EVA crews were able to establish two-way communications to the hab from over five kilometers away. This allows crews to confirm experimental
procedures and report results in real time, ensuring smooth field operations, while also providing a significant safety boost during EVAs.

The geology and contamination experiments also went smoothly. The intention of the geology experiment was to characterize movement difficulties through various soil types and attempt to find a correlation between qualitative and quantitative test site properties and satellite imagery of the area. This would allow more robust EVA planning at the hab with more data of the environment at targeted areas. EVAs were taken by crew members to set up a test area, in which soil samples and qualitative descriptions of the area were collected.

While some collection EVAs were hampered by poor weather, a total of 10 samples were collected for analysis in the hab (a characterization of mass distribution between different sized particles). This analysis allows cross comparisons to be made with the contamination experiment, which tracked the amount and type of dust returned to the hab by crew members on the EVA. Based on soil characteristics of the target site, the amount of contamination to the hab can also be estimated. After further analysis of results, we hope these experiments can be elaborated on in future years to gather more data to help with EVA planning.

For previous crews, wet lab research has been limited, with most of the “pure science” research focusing on the geology and geography of the Hanksville area. Most of the limitations to wet lab research while in sim at the MDRS in Utah have arisen due to limited access to instrumentation commonly found in a university or private lab (such as a PCR thermocycler and gel electrophoresis equipment). As such, the development of protocol that can be performed without these types of equipment is crucial to scientific productivity while in sim. While on site, Crew 101 Chief Scientist Christina Graves developed a polymerase chain reaction (PCR protocol) that could be performed on site, in sim, and without a thermocycler; this development will without doubt be useful for future crews.

In addition to the development of protocol, cultures were grown of microorganisms found in the soil of 8 different sites of interest. Several bacterial staining experiments were performed, and DNA was isolated from the soil samples. Both colony PCR and PCR using purified DNA was performed. Further analysis will be performed upon return to Georgia Tech. Chromatography experiments (TLC) were also implemented during this year’s rotation. While it is unlikely that there is any macrobiotic life on Mars, it may be useful to develop protocol to search for nucleic acid precursors (such as nucleobases) that may signify the correct ingredients are present for the “soup of life,” as well as to help understand the evolution of such systems on Earth.

In addition to scientific output, Georgia Tech crews are also very involved in scientific outreach with the community at large. In an effort to expand our impact, the crew hosted a live web chat with NASA INSPIRE students. NASA INSPIRE is an internet learning community of high school students, of which several Crew 101 members are alumni. We were excited to share our MDRS experience with these younger students, and they responded with many questions about the concepts involved in Mars-analog simulation.
Outside of scientific and outreach pursuits, life at the hab was fairly easy-going compared to the hectic and busy lives we all lead as full-time students. Cooking with shelf stable foods was a challenge, but fortunately, our crew had a number of capable chefs, so life was quite comfortable. The crew worked its way through a number of movies and all of “Firefly,” and in a GT crew tradition, several episodes of “The Twilight Zone”. By the end of two weeks, the crew will be thankful to escape the strict confines of the hab into the world of burgers and the humid air of the South, but crew dynamics allowed a relaxed atmosphere.

Overall, it has been a great two weeks at MDRS. Crew 101 had its challenges, including inclement weather and equipment failure, but the best was made of each situation. After all, without these challenges, it would not be much of a Mars simulation. These months of planning and two weeks in ‘sim’ have been an invaluable supplement to our technical educations, and we hope that Georgia Tech crews in the future can gain from this experience as much as we have.
2. **Station and Crew**

2.1. **Mars Desert Research Station**

The Mars Society, an international association of space scientists, engineers and others interested in advancing the case for sending humans to Mars, has built two Mars-analog stations in remote environments. These facilities are privately funded, through contributions from Mars Society members and corporate donors. The Flashline Mars Arctic Research Station, FMARS, was built in 2000/2001 and is located on Devon Island in the Canadian Arctic ([2], [3], [4]). The Mars Desert Research Station, MDRS [5], is the second station to become operational. It was built in 2001/2002.

2.1.1. **Site**

MDRS is located in the deserts of southern Utah near Hanksville [6], about five hours by car south of Salt Lake City (Figure 1). Figure 2 shows the site’s very Mars-like look and gives a first impression of the station’s exterior. Its design reflects current thinking about the first Mars bases ([7], [8]). In addition to the large habitation module (“hab”) described in the next section, the base features an experimental greenhouse, several unpressurized rovers (All-Terrain Vehicles, ATVs), a power plant with fuel-powered generators, and an external water storage tank.

![Figure 2.1: Mars Desert Research Station location south of Salt Lake City, Utah, USA (adapted from [9], left) and aerial view (right)](image-url)
2.1.2. Habitat Module Layout and Equipment

Two floors accommodate research-related areas (lower floor) and crew habitation space (upper floor). Figure 3 (left) shows the lower floor’s layout. It features primary and backup airlocks, a room for EVA suit and equipment storage, a large work area with laboratory equipment for biology and geology research, a small workshop for the station engineer, and crew hygiene facilities. A central column provides support for the upper floor. Small round windows are provided in the airlock doors, in the EVA preparation room, and above the laboratory work table. A steep flight of lapeyre stairs next to the primary airlock leads to the upper floor.
Figure 2.3 (right) shows the upper floor.

It is divided into two main areas: the northern half contains six crew quarters (CQs) of approximately equal size, each providing a bunk and a shelf/desk for crewmembers to work and store their personal belongings. The southern half contains a galley for food storage and preparation, a long work table for crewmembers to set up their personal computers, and a communications desk with the main computer, receiver for the Direcway satellite Internet connection, and a low-power “Family Radio System” (FRS) radio base station for communication with EVA crews.

Computer infrastructure includes a Local Area Network (LAN), with PC acting as fileserver and interface to the hab’s satellite Internet terminal. This PC also hosts instant-messaging software for direct communication with the local support contractor before and after the closed simulation phases of MDRS rotations and in case of emergency. Additional laptops control webcams that send updated pictures from the interior of the hab to a Mars Society website. This arrangement is augmented by crewmembers’ personal laptop computers which can be connected to the LAN at the work table in the crew quarters, or through a wireless connection.

Figure 2.4: Panoramic views of MDRS lower (bottom) and upper (top) floors
For Extravehicular Activities (EVAs), MDRS provides seven Mars suit simulators. Each such EVA suit consists of the following components:

- A coverall-type garment made from heavy white fabric
- A spherical helmet with a Plexiglas visor and a low-powered FRS FM radio with speaker/microphone for crew-to-crew or crew-to-hab communications
- A backpack providing ventilation and cooling (by means of two battery-powered fans blowing filtered ambient air into the helmet through redundant hoses) as well as hydration (by means of a Platypus® water container connected to a bite valve inside the helmet)
- Heavy ski gloves and super-insulating boots with gaiters
- A wrist-mounted mirror

The laboratory area is equipped with microscopes, a refrigerator/freezer for biological samples, an incubator, and a supply of tools and reagents for both biological and geological research. Outside the habitation module, a large water tank provides a water source for the station systems, while a generator supplies electrical power. MDRS features two military-surplus diesel generator sets designed for long-time use, which are gravity-fed from a 200-gallon diesel tank nearby, thus minimizing the need for refueling and maintenance activities. During nominal operation, MDRS runs off a battery bank, with the generators only running to charge the batteries. A Xantrex inverter set converts power between AC and DC and controls the generators.

An experimental greenhouse (“GreenHab”) supports plant growth experiments and filters moderately-polluted “gray water” (from sinks and the shower) for re-use as toilet flush water in a high-efficiency macerating toilet. Crew mobility during EVAs is provided by four-wheel All-Terrain Vehicles (ATVs) that simulate unpressurized rovers. An observatory dome houses a 14-inch computer-operated Celestron telescope for astronomical observations.

### 2.1.3. Organizational Structure

The Mars Society owns MDRS, finances its operation and provides general organizational support and mission rules within which the crews operate. The Mars Society also coordinates public outreach and pre-selects crew volunteers. This framework provides broad latitude to the individual crews for defining their own mission objectives and management styles. Crew commanders are tasked with preparing and executing a crew rotation and, in the case of self-organized crews such as the Georgia Tech, Mars Society Canada, and FLAME crews, crew selection. This season, for the first time, Georgia Tech will not be the only crew from a single university, with a Belgian university team joining for two weeks. During an MDRS mission, all communications between the crew and the “outside world” take place by e-mail via the Direcway satellite link. It is generally routed through an off-site Mission Support center staffed by Mars Society volunteers.

Local support (resupply of ATV and generator fuel and water, ATV maintenance, waste disposal) is done by volunteers. A motel in Hanksville [10], about four miles from MDRS, accommodates crewmembers for occasional pre-/post-mission overnights and also serves as a base for Mars Society support staff upgrading MDRS systems or performing major repairs between crew rotations (regular maintenance and repairs are each crew’s responsibility).
2.1.4. **Scope of Simulation**

Crewmembers are subject to strict mission rules aimed at making the operation of MDRS as similar to a real Martian surface habitat as possible ([11], [12]). This includes leaving the only while wearing the EVA suits, no resupply, thorough planning of operations, etc. The station’s design, however, does require some compromise with respect to the fidelity of the simulation: handling fuel for the ATVs and the generators, for example, has to be performed without an EVA suit for safety reasons. Another limitation arises from the fact that crewmembers are volunteers who for the most part have to take personal time off from work for the duration of their mission; therefore, joint pre-mission training and post-mission debriefing is usually done via telephone, and mission durations are limited to two weeks. However, since Crew 101 was recruited from a single organization, extensive in-person pre-mission training is taking place.

Overall, MDRS provides for a reasonably accurate first-order analog of planetary surface base operations, mission support procedures, EVAs and field science. Due to the remote location of MDRS, confinement, isolation and risk also affect the crews, adding to the authenticity of the simulation.

2.2. **Crew 101**

A call for applications was issued by MSGT in September 2010. From the respondents, nine candidates were selected by MSGT for the available five station crew and four mission support slots. As with a “real” space mission, all candidates are undergoing the same mission-related training and preparation, enabling Mission Support crew members to act as backup station crew. In addition to the research described in Section 2, the several operational roles will be covered by the crew members, including:

- Commander
- Executive Officer
- Health and Safety Officer
- Chief Engineer
- Radio Specialist
- Journalist
- Astronomer
- Biologist
- Mission Support Lead
- Mission Support Specialists

Final crew selection and assignment of roles took place in early 2011. Commander and crew members are introduced below.
2.2.1 Tommy Caillouet, Commander

Tommy Caillouet is a fourth year Aerospace engineering student at Georgia Tech. He was born and raised near Huntsville, Alabama, and somewhere between writing his first for-loop for an astronaut training program and seeing the Saturn V frequently, the space industry rubbed off on him to the point of inspiring a potential career. Tommy is also an avid builder of flying machines, an Eagle Scout, a part time employee in the Georgia Tech Craft Center and occasional undergrad assistant at the Aerospace Systems Design Lab. His past activities have included participating in the AIAA Design Build Fly competition, Mars Society’s University Rover Challenge, and the ongoing aspiration to build a steam and/or turbojet powered car. In what spare time remains, Tommy enjoys playing soccer and following Arsenal FC, as well as cheering on the Yellow Jackets as a Goldfella. He hopes to eventually escape Georgia Tech and gravity.
2.2.2 **Jonathan Kosh, Executive Officer**

Jonathan Kosh is currently in his last year pursuing an undergraduate aerospace degree from Georgia Tech. He was born and raised in Las Vegas, Nevada. After being introduced to the then nine planets and attending space camp in 3rd grade, Jonathan developed a passion for all things outer space. He very much wants to see science fiction become reality—namely in the form of orbital shipyards, permanent space colonies, and lunar mining facilities. Jonathan has previously worked at Tech's High Powered Electric Propulsion Laboratory designing and fabricating test apparatus. More recently he has co-oped at the Jet Propulsion Laboratory, assisting in the assembly, integration, and testing of the propulsion system for the Mars Science Laboratory descent stage. On campus, Jonathan is an active brother in the Delta Sigma Phi fraternity, building better men through commitment to living out the core values of culture, harmony, and friendship. On the side, Jonathan loves to read books (sci-fi and fantasy) and learn traditional style martial arts like wushu and kung-fu and has currently taken up a budding interest in astronomy and robotics.

2.2.3 **Cody Hall, Chief Engineer & Astronomer**

Cody Hall is an Aerospace Engineering undergraduate student at the Georgia Institute of Technology. Set to graduate in spring 2011, he hopes to get his MS in the same field. Before attending Georgia Tech, he received an Associate's degree in Physics from Middle Georgia College through the GAMES dual-enrollment program. He spent two years alternating semesters between work and school, co-oping with Southern Research Institute in Birmingham, AL. Cody loves college football, playing video games with friends, and calls the GT library home. He hopes to play a part in the first human colonization of another planet.

2.2.4 **Christina Graves, Chief Scientist**

Christina is a senior in the School of Biology at Georgia Tech. She is a member of the Honors Program at Georgia Tech, and has research experience in prebiotic chemistry. She is currently conducting her senior research with Dr. Eric Gaucher, investigating the translational features and limitations human uricase. Her other research interests include the concomitant roles of dietary restriction and viral activity in the etiology of autoimmune disease. In her free time, she plays classical guitar.
2.2.5 Mitesh Agrawal, Radio Specialist & Biologist

Mitesh Agrawal is a second year Biomedical Engineering student with a minor in Biology at Georgia Tech. He was born and raised in India and is an international student at Tech. His current research endeavors include study of embryonic stem cells and genetic engineering along with his interest in the study of extremophiles and astrobiology. Mitesh is an Undergraduate Petit Scholar for his research and also a member of iGEM (Georgia Tech’s first synthetic biology team). He is also actively involved in the Georgia Alpha chapter of Tau Beta Pi - an engineering honors society. He is an avid reader and also loves to play tennis and racquetball. Mitesh is really excited about being selected for MDRS Crew 101 and hopes to gain a lot through this experience.

2.2.7 Christine Redmond - Health & Safety Officer & Journalist

Christine Redmond is a freshman at Georgia Tech from Brighton, MI. She is studying Aerospace Engineering and is hoping to pursue a minor in Earth and Atmospheric Sciences. Her interest in engineering was first sparked after watching the movie October Sky in the fourth grade. Competing in the Sally Ride Toy Challenge throughout middle school and spending a few weeks at Space Camp in Huntsville Alabama locked her heart on NASA. She has spent the past two summers at NASA’s Goddard Space and Flight Center working in the Mechanical and Advanced Manufacturing branches. She is extremely interested in developing and using resources on the moon to make life on earth better. She hopes to work for NASA after finishing her formal education.

2.2.6 Whitney Henderson - Mission Support Lead

Whitney Henderson is a second year ME student at Georgia Institute of Technology, and is from Athens, GA. Ever since the fifth grade she has been interested in robotics, and has a self portrait entitled “I Want to be an Astronaut” from when she was four. She’s perusing her dreams at Georgia Tech. Whitney is an active member of social and professional engineering sorority, Alpha Omega Epsilon. She is also an official Georgia Tech tour guide. She has had experience in undergraduate research, having worked in the Socially Intelligent Machines Lab under Andrea Thomaz. There she did research on artificial intelligence systems. Outside of school she enjoys running, reading, drawing, hiking, ultimate Frisbee.
2.2.8  **Jordan Bell - Mission Support**  
Jordan Bell is a first year Aerospace Engineering student at the Georgia Institute of Technology from Northern Virginia. She is a member of the Society of Women Engineers and plays the double bass in the Georgia Tech Symphony Orchestra. She is currently participating in Mars Society’s University Rover Challenge. In High School she interned at the NASA Langley Research Center and participated in the NASA VASTS (Virginia Aerospace, Science, and Technology Scholars) program.

2.2.9  **Jacqueline Alexander - Mission Support**  
With hopes of one day being an astronaut, Jacqueline Alexander applied to Georgia Tech and successfully entered the class of 2014 as an aerospace engineer. She is on scholarship through Naval ROTC, and a member of Mars Society, and African American Student Union (AASU). She is very interested in aviation and astronomy. An interesting fact about her: She had the opportunity to fly a plane with the help of a co-pilot through the Organization of Black Airline Pilots (OBAP) Aviation Career Education (ACE) Academy. Jackie grew up as a military brat. She was born in Georgia, moved to Hawaii, moved back to Georgia, then the North Carolina, South Korea, Virginia, and now proudly resides in Georgia again. In her free time, Jackie likes to play the piano, work-out, and socialize on Facebook.

2.2.10  **Jason Baron - Mission Support, Radio Specialist**  
Jason Baron is a second year Material Sciences & Engineering student at Georgia Tech from South Carolina. He is an amateur radio enthusiast and is a member of the Georgia Tech, Atlanta, and Charleston Radio Clubs.
2.2.11 **Jillian Lewis - Mission Support**

Jillian Lewis is a recent Georgia Tech grad and veteran of MDRS Crews 79 and 93, performing the duties of Radio Specialist, Chief Engineer, and Executive Officer. Her family is originally from Nebraska but moved frequently and she has spent time living in Kansas, Georgia, Missouri, Pennsylvania, Norway, and China. Jillian was a co-op for Delta Air Lines as a member of the B737/MD88/MD90 Fleet Management Team at Technical Operations, where she served as operational engineering support. Originally slated to be commander of Crew 101, Jillian left Tech for the much greener pastures of Navair and will provide mission support and coordination advice for this mission.

2.2.12 **Eric van Gehuchten - Mission Support**

Eric van Gehuchten is a Masters student in Aerospace Engineering researching at the Aerospace Systems Design Lab. He was born in Caracas, Venezuela and raised near Pittsburgh, Pennsylvania. Eric has been involved in the Georgia Tech University Nanosatellite Program entry in the Attitude and Orbit Determination and Control subsystem as well as the Mars Society's University Rover Challenge. Outside of engineering, he works part time at the Georgia Tech Craft Center helping others cultivate their artistic sides. In his spare time, Eric enjoys participating in the arts himself from pottery to woodworking and music. Additionally, he enjoys automotive engineering, tuning and amateur autosport. A veteran of Crew 93, where he served as Chief Scientist and Journalist, Eric will provide mission support for Crew 101.
3. Research Objectives and Plans

3.1 Engineering

3.1.1 Radio-based Voice and Data Communication Corrections and Enhancements

This proposal seeks to continue the effort of previous Georgia Tech crews by providing reliable communications between an EVA team and its base. Crew 101 will use prior studies from past crews to determine what worked well and what fell short of the MDRS crew needs. This crew will attempt to improve the communication system previously established by ensuring power is maintained and also experimenting with placement of equipment and its range. This experiment is being led by Mitesh Agrawal, with support being provided by Andrea Hartledge, as well as by Jonathan Kosh while on rotation.

Based on the experience gained from these prototypes, Crew 101 will use the same set-up as previous crews in order to correct previous issues and establish a reliable communication system. Interviews held with members of previous missions will outline the needs for modification of the communication system. Aspects of the system that performed well will be kept in the new system as much as possible unless, through the course of a redesign, an improved method is found. The interviews will also allow mission members to provide useful insights and input into the redesign so that their needs and desires are included. The basic set up of the system follows in Figure 6.
This crew will test links established between Kenwood TH-D7A APRS enabled radios and attached GPS units on each space suit, a pair of deployable APRS and voice repeaters using a Kenwood TM-D700A for the digital repeater, and two Icom IC-W32A radios for a cross band repeater. Figure 1 diagrams the previous and current system. The system, as designed, will help establish improved surveying and mapping missions of the terrain through the automatic position reports forwarded to the habitat module via the APRS data links. Figures 7 and 8 show the mapping possible, especially with the combination of the data and Google Earth in Figure 8.

![Figure 3.2: Surveying and Mapping](image)

No additional radio equipment is necessary; however, a voltmeter will be secured in order to keep a log of battery power to ensure power is not lost during an extra-vehicular excursion (EVA). Interviews with past crew members indicated that equipment had failed due to a lack of necessary power. The goal is to have less dependence on only battery power, which requires an exploration team to retrieve the batteries at regular intervals for charging. A combination solar and battery power system will be constructed to provide long service time for the repeater. A solar panel from the Hab will be used to aid this generation of power on the hilltop. Battery power will be tracked and recharged as needed.

As seen in the past, placement and power supplies may limit operation and range. The digipeater will be placed strategically and range will be measured to see how far the explorers can go before communication is lost. Equipment may be moved to different locations for testing. This will provide data for future missions.
Sponsorship was secured in past years with the Kenwood Corporation, Amateur Radio division, which produces the TM-D7A handheld and TM-D700 mobile data radio. These units have been used at MDRS in the past, and are directly compatible with the Amateur Packet Reporting System (APRS) as designed by Robert Bruninga, WB4APR, of the United States Naval Academy. The Kenwood radios and APRS system has seen extensive use at MDRS during several crews for tracking of EVA teams, digital messaging and voice communication.

The APRS protocol allows for arbitrary data transfer formats in addition to position and message formats. This is suitable for adding telemetry devices in the field that can report back to the mission members and beyond. Some remote sensors suggested for use are sunlight intensity sensors, temperature sensors, and radiation sensors. These can be interfaced to the APRS system by way of an OpenTracker APRS telemetry interface from Argent Data Systems, a BASIC Stamp from Parallax (if needed by the sensor to digitize the data), and an inexpensive handheld radio such as the Kenwood TH-K2AT. Together, a full one-way telemetry system can be added to the many tools available to mission members for remotely monitoring their environment.

Crew 101 will be investigating updating current equipment, if funding allows. The crew will also be looking into adding a live video feed component to the communications network to enhance location identification and to add another layer to outreach activities by having at least one crew member answering questions from the field. Finally an updated Google Earth output (similar to Figure 8) will be used to track crew movements and store radio reception information for future crews.

Figure 3.3: Visualization in Google Earth
3.1.2 Contamination Study
The purpose of this project is to develop, build, and test methods to deal with the issue of contamination on Mars. This project will consider both the problem of contaminating the habitat with Martian contaminates and the contamination of the surface of Mars with earthly contaminates. Both living and nonliving contaminates will be considered in this project. Eliminating both living and nonliving contaminates are important in order to retrieve accurate data about the possibility of life on Mars. Additionally, it is important to eliminate contaminates entering the habitat to prevent harm to the astronaut crew. This project will involve constructing an air shower unit at the entry of the air lock. This project will serve to further the realism of the Mars habitat and demonstrate the functionality of at least one possible method of dust mitigation. This experiment is being organized by Christine Redmond.

3.1.3 Wind Turbine Verification and Integration
Over the past three crews, MSGT has been investigating the integration of wind power integration into the hab power system. During Crew 93, the prototype wind turbine underwent load testing and verification. Crew 101 will continue this investigation and expand to searching for an ideal location for such a set up. This experiment is being coordinated by Jonathan Kosh, with support being provided by MDRS veteran and experiment initiator Dan Crowley.

3.1.4 General Engineering Maintenance and Upgrades
MDRS crews are responsible for the maintenance of station systems. Crew 101 will continue this as needed. In addition to maintenance, one or more upgrade projects may be undertaken, depending on crew time availability and skills. The Engineering Team webpage maintains a database of currently needed maintenance and upgrades [15], from which projects will be selected.

3.2 Scientific Studies
3.2.1 Mineral Analysis and Extremophile Study
The chief investigator of the experiment is Christina Graves.

Introduction and Background
Water is a necessary component for life, as we know it, on Earth. Although not currently stable in liquid form, the discovery of water on Mars, as well as the evidence suggesting that Mars once held vast amounts of liquid water, opens up the surface of Mars as a suitable arena for prebiotic chemical analysis ([16], [17]). The discovery of amino acid synthesis from prebiotic-like reducing conditions conducted by Stanley Miller in 1962 sparked interest in prebiotic synthesis, and this, along with other discoveries, led to the formation of the RNA world hypothesis ([18],[19]). More recently, the Hud Lab at Georgia Tech has proposed that intercalators (or, so called “molecular midwives”) may have served an important function in the polymerization of nucleobases to form oligonucleotides ([20]). The small prebiotic molecules (adenine, purine, guanine, etc.) are abundant in all life on Earth, were most likely some of the first molecules formed on prebiotic earth, and are also found in interstellar media, making them good candidates for analysis on the Martian surface. In addition, the presence of mineral compounds such as phyllosilicate minerals, sulfate minerals, as well as olivine makes the Martian surface an optimal area for catalytic mineral prebiotic studies. Also, the large amounts of sulfate and ferrous minerals and on the Martian surface open up the possibility of catalytic vent activity leading to the
formation of prebiotic chemicals deeper underneath the surface. Drilling down into the soil at various depths to search for plausible nucleobases or even extremophiles could yield important data.

The prebiotic synthesis of nucleotides is an exciting area of research, and investigations into the potential mechanisms on the Martian surface may yield important insights into the potential formation of life (either currently or in the past) on Mars, as well as to lead to a better understanding of the evolution of life on Earth. For the purposes of our experiments, we will use the RNA world hypothesis as a model for probable nucleobase formation on Mars.

On December 2, 2010, researchers at the NASA Astrobiology Institute announced the discovery of a bacterium, GFAJ-1, that substitutes arsenic in place of phosphorous in the biomolecules, including DNA, of the bacterium ([21]). This deviation from the 6 molecules thought to be essential for life (carbon, hydrogen, nitrogen, oxygen, sulfur, and phosphorous), provides new context surrounding the search for relevant biomolecules on alien surfaces. In addition to expanding the scope of biomolecules searched for, the discovery of alternative-use organisms such as GFAJ-1 also serves to expand the locational and regional constraints typically placed on alien-life form searches.

**Experiments**

During our tour, we will conduct mineral and soil analysis at various sites and depths to search for plausible nucleobases, intercalators, as well as potential extremophiles and alternative-use bacteria. We will focus on visualizing the nucleobases, adenine, purine and cytosine from prepared stock solutions using thin-layer chromatography (TLC) and paper chromatography to develop a standardized Rf (retardation factor) which we will use throughout our experiments for the remainder of the trip.

If extremophiles or alternative-use organisms are found, we may consider performing an onsite polymerase chain reaction of the genetic material of the organisms. If no analytical methods are available for the reactions described, samples will be purified and retained for analysis when we return to a facility with appropriate analytical capabilities.

**Sites of Analysis**

Soil samples will be collected from the areas of the Mars surface most likely to currently or recently have liquid water, such as in the inner channels of the Nanedi Valles or the gulleys of the crater Newton. In addition, the team will identify regions on the Mars surface likely to harbor pools where nucleobases and intercalators may have had the ability to accumulate, polymerize, and potentially lead to the evolution of extremophiles. The most appropriate areas for investigation will be determined and coordinated when the Crew is on site in the spring. In addition, sites will be well photographed prior to sample retrieval. All samples will be marked according to date, location, and time of day collected.

Due to limited analytical instruments on site, analysis of minerals and plausible nucleobases will be performed using thin-layer chromatography (TLC) and paper chromatography. Permitting resources, on-site DNA extractions from extremophiles or alternative-use bacteria found, and polymerase chain reaction (PCR) may also be performed.
### 3.2.2 Areohashing as an Exploration Pattern & Low Altitude Photography Survey

Exploration patterns generally focus on choosing an interesting portion of terrain to focus study upon; however, some extremely interesting features can easily escape even the most comprehensive exploratory plan. This proposal suggests using a randomly generated, yet verified coordinate to be the focus for exploratory parties. This experiment is being organized by Tommy Caillouet.

The coordinates are generated daily with the input of the date and the most recent opening of the Dow Jones Industrial Average. These numbers are run through an MD5 cryptography algorithm, which generates two hexadecimals that are then are converted to decimal. An exploratory boundary is defined, and the decimals determine the point by modifying the normalized latitude and longitude from the base value. This technique was adapted from that of geohashing, an exploration technique devised by Randall Monroe. The benefits of using the Dow and date as inputs for coordinates are that each coordinate is verifiable at any point in the future, while still being completely random. The randomization term could also be changed in order to remove reliance on communication for the excursion attempts.

To augment these expeditions, low altitude aerial photography will be performed at each site and at any geologically significant site passed along the route. The previous rig to capture low altitude photos was a simple camera on kite set up, with the camera modified with the Canon Hackers Development Kit to program in desired function. The crew plans to augment this with a hand thrown UAV that carries a similar camera in order to test the feasibility of such a scouting tool on Mars. These photos could be used to create a higher definition topological view of the MDRS site, and if compared between missions, used to observe significant amounts of erosion at the site due to wind. This portion of the experiment will require at least one kite to mount a modified camera on, though more would be ideal in order to be prepared for varying wind conditions. The camera would be modified to run CHDK, an alternative firmware, so the photographer could use one of a number of scripts to take ideal photos for the day of the expedition.

In addition to these photos, firsthand accounts will be recorded describing the journey to the generated destination. These accounts would illustrate ideal or attempted methods of bypassing obstacles, notes on geologically significant regions, and any other useful anecdotes. The ultimate goal is to create an electronic mash-up any presently available MDRS maps that could be enhanced with these notes and photographs.

### 3.2.3 Astronomy

Crew 101 plans to make use of the observatory at MDRS if given the opportunity. Unfortunately, previous years’ plans have been marred by technical failure or cloud cover, giving rise to ‘the legend of the cursed astronomer.’ It was decided to route research planning onto other subjects. A prospective plan will be formulated by the crew astronomer once equipment is verified operational and seasonal weather is confirmed to be mostly cloudless, as typical. The crew is currently working to cooperate with the Georgia Tech Astronomy Club to design an experiment so the telescope and relatively light pollution free sky can be a resource for other students at Tech. The plans are being coordinated by Cody Hall, with support from Jackie Alexander and Jordan Bell.
3.3 Human Factors

The new space exploration agenda of the United States will lead to humans engaging in long-duration space exploration missions within a decade. These pioneer crews will be subject to an unprecedented combination of isolation, confinement and risk in their quest to explore the Moon, Mars and destinations beyond. Even though none of these challenges is likely to be a “showstopper”, the perceived and actual success of their missions will depend on their ability to sustain a constant, high level of performance under taxing environmental conditions and high workloads. Therefore, understanding the factors that influence crew performance and behavior during a mission is an important prerequisite for the successful implementation of the nation’s new policy of manned exploration and discovery.

Analog simulation facilities like MDRS play an important role in this context since they allow the operational, hardware, and human sides of key mission-related elements to be combined, and thus enable the capturing of interactions among these elements. The crews of such stations are also exposed to workloads, external stressors and other conditions similar to those encountered during space missions.

3.3.1 Food Study

Crew 101 will be participating in the food study as it has during the past two rotations. This experiment is organized by investigators Kim Binsted and Jean Hunter, of the University of Hawaii and Cornell University respectively. This will entail consuming only shelf stable foods for the duration of simulation in order to increase mission realism as well as monitor psychological impact of such a diet.

3.4 Mission Support

After the final positions have been selected, mission support crew members will each be designing an experiment of their own for personnel in the Hab to carry out. This will simulate the interaction between distant astronauts and scientists on the ground with a much more intimate knowledge of an experiment. Mission support will also aid in preparing the NASA INSPIRE experiment, a to-be-determined activity proposed by students taking part in the NASA INSPIRE program. Experiments lead by mission support crewmembers follow.

3.4.1 Life Support Resource Sizing and EVA Stress Study

When de-scoping experiments and activities from a Martian habitat to conserve resources, it is important to know if or how the activity affects environmental conditions and life support system. The crew will begin preliminary characterization of necessary resources by monitoring oxygen consumption by crewmembers. This will be accomplished by tracking heart rate and correlating this metric to other bodily functions such as breathing. Heart rate monitoring will also be used during EVAs to characterize stress experienced by crewmembers during various activities.

3.4.2 Topographical Survey of Geological Distributions

Whether or not a rover or astronaut will have a difficult time traversing particular terrain is a challenging feature to assess without actually evaluating terrain conditions on site. Correlations between aerial photography and geographic rock characterization will enable the capability to produce
plots of terrain accessibility and rock quality. Movement limitations imposed by both suits and ATV
ground clearance are exacerbated by loose top soil or large exposed rocks. The varied topography
surrounds the hab makes planning EVAs with these considerations difficult without documentation of
the sites of interest. During EVAs, crewmembers will make qualitative characterizations of the areas in
which activities take place. Additionally, when manpower permits, samples of topsoil will be collected
and sifted through aluminum mesh, quantifying characteristics of the collections. When available, aerial
photography of surveyed areas pre-sampling will enhance terrain characterization and mapping
capabilities. The chief investigator of the experiment is Whitney Henderson.
4. **Outreach Activities**

Outreach proved to be a difficult set of objectives for the crew to fully meet, due to lofty goals. While early planning seemed to show promise in setting up talks with local K-12 schools through CEISMIC, unfortunately, none could be scheduled. Educational outreach did have an unique success in collaboration with NASA INSPIRE, an online learning community for high school students. The crew made a call for research suggestions from the students several months before the rotation and chose several to investigate while at MDRS. While not every investigation proved successful, the collaboration proved to be a great learning experience for both crew members and INSPIRE students. During the rotation, the participated in a web chat with the students, explaining the purpose of MDRS and answering questions about Mars analog studies. Other internet outreach activities suffered partial setbacks due to inconsistent and limited connection to the web. The GT Mars Society website was not always up to date, but the international Mars Society's page did provide consistent coverage of the crew’s activities. After returning from the rotation, on-campus presentations were given to several organizations. Also, the crew’s exploits were also covered by on campus media to the greatest extent in years. While Crew 101’s ambitious objectives were not fully met, especially in terms of educational outreach, the final results were still quite successful and provide a great starting point from which future Georgia Tech crews can build.
5. Selected Daily Reports from the Trip

MDRS policy requires the submission of several reports on a regular basis. Both the Commander and Journalist give a brief narrative of the day, while reports also follow extravehicular activities (EVAs) and summarize scientific efforts for the day. Daily Chef’s and Engineering reports were also submitted, but they have left out of this compilation since their rather technical nature makes them only of interest to the food study investigators and engineering mission support respectively. The best picture from each day has also been included.

5.1 March 12

Commander’s Report - Tommy Caillouet reporting
We have finally made it to Mars. After being greeted by Crew 100B and being given a thorough debrief, we seem to have a full red planet to ourselves. We’ve spent the entire afternoon unpacking, organizing, and cleaning for our stay. Tonight, we continue preparation of our experiments and sorting our massive food stores. Tomorrow, we begin our first full day on ‘Mars.’

Journalist Report - Christine M Redmond reporting
Today crew 101 landed on Mars! We were greeted by crew 100B. Each 101 crew member broke off to be brief by their respective counterpart crew member on 100B. After receiving our briefing from crew 100B the two crews got together for a group picture outside the hab. Crew 100B handed over the keys to the hab, wished us luck and were ready to make their return trip to earth!

Crew 101 had a busy afternoon planning and sorting the food we will be eating for the next two weeks. We broke up the afternoon with a nice hike with a beautiful view. Crew 101 is very excited for a great mission!
5.2 March 13

Figure 5.2: On the top of Skyline Rim. Normally, Georgia Tech radio repeaters are placed on this ridge, but the lack of trails to an ideal location to set up the equipment forced a change of plans.

Commander’s Report - Tommy Caillouet reporting

It has been an eventful first day on Mars, though not one in full sim quite yet.

Much of the effort this morning was directed towards the food study. Each crew member read through the full instructions and filled out the initial survey. Afterwards, we continued inventory and sorting efforts from yesterday. We begin the study today with a cooking day, and the tantalizing smell of the salmon patties that are being cooked now doesn't make eating on Mars sound that bad.

Our radio experiment, an investigation that has been running for seven years now, has been traditionally been placed on Skyline Rim for ideal coverage of the entire MDRS site. After spending the morning ensuring proper functionality, we traveled to the Rim in the ever reliable V'Ger, but upon reaching the access roads, we found that the trails had significantly changed from previous years. After mapping out the new area, it was determined that the trail did not come within a near enough to the repeater site to carry the equipment by hand, since off-roading is explicitly forbidden in that area. In the end we returned to the hab with the repeater equipment still in tow, but at least we captured several pictures of the awesome view on the Rim.

Upon returning to the hab, the entire crew was put through ATV training. Each crew member took turns in demonstrating proper ATV handling and safety, and after not too long, I am confident in sending out ATV EVAs.
We also learned that our wind turbine would not be reaching the hab due to a communications error. While the crew is disappointed to lose a heritage experiment (the wind turbine has been at the hab for three years now), we are confident that our scientific output will still be significant.

With regards to Crew health, Christina was ill for most of the day, but appears to in good condition tonight. I, too, have felt poorly since late in the afternoon, but hopefully these are both steps of acclimatization.

Tomorrow, we transition to full sim. The first EVA planned is a delivery mission: repeater equipment will be placed on the less than ideal, but much more reachable, Radio Ridge. This will allow the equipment to be more easily accessed in case of electronic failure (a nagging problem in previous Georgia Tech rotations). We will also begin EVAs for sample collections for the geology and biology. The real fun is soon to start...

**Journalist’s Report – Christine Redmond reporting**
Today crew 101 woke up with one less hour of sleep than we all would have liked. Did you know that daylight savings is observed on Mars too? We all had a busy day of final preparations prior to entering sim tomorrow morning. As health and safety officer, I ran through typical protocol checking to make sure the hab is in safe condition. Jon and Mitesh were very busy setting up our radio equipment we will be using for the remainder of the rotation. This involved fixing a broken connection and setting up the solar panel to recharge the battery which powers the repeater. Cody spent the morning working on checking off items on our crew’s “fix it” list. Tommy was busy planning for sim and preparing our food study which each crew member started today.

Crew 101 had a very memorable afternoon. We loaded up V’ger with our radio equipment and headed to Skyline rim to set up our repeater. We ran into many road bumps (quite literally) and do to change in the path locations were unable to set up the repeater in the same location as past crews. We decided that it would be best to set up the repeater on radio ridge while in sim tomorrow. We spent the remainder of the afternoon receiving ATV training. The entire crew had a blast learning to maneuver the ATVs on the rough Martian terrain.

Tonight Christina is making salmon patties for dinner as part of our food study. Rough I know, but crew 101 will do anything to further human space exploration!

**EVA 1 Report – Tommy Caillouet reporting**
15:00 – 16:30
Crew members: All Crew Members
Location: Skyline Rim
Transit mode: V’Ger
Objective: Placement of Radio Repeater
Results: Traveled to Skyline Rim using access road from highway. Found that trails leading to the edge were substantially changed from previous years. Legal trails did not lead close enough to an acceptable repeater placement. We held discussions on placing in a less ideal location and determined that the
reduced effectiveness of the signal along with the increased risk of Skyline Rim placement (no mid-sim repair EVAs possible) made Radio Ridge a preferable location, despite it providing far less coverage.

**EVA 2 Report - Tommy Caillouet reporting**

1645 - 1800

**Location:** Near the Hab

**Transit Mode:** ATV and Walking

**Crewmembers:** All Crewmembers

**EVA Objectives:** Crew members were to demonstrate proper ATV handling and safety to prepare for future EVAs.

**EVA Results:** Crew members successfully demonstrated competence in vehicle usage.

**5.3 March 14 – Day 1 in Sim**

Figure 5.3: Jon, Cody, and Mitesh carrying radio equipment up to Radio Ridge.

**Commander’s Report - Tommy Caillouet reporting**

After waking up this morning still feeling quite ill, the day only seemed to go upward. Fortunately a large quantity of water and some food has left me in better health, and Christina appears completely recovered from symptoms she was experiencing yesterday. Hopefully the crew's health will continue to be good throughout the remainder of the rotation.

Most of the day was spent focusing on our first in-sim EVA: placing the radio repeater. After yesterday's failed attempt to set up the equipment on Skyline Rim, it was determined that Radio Ridge, a much closer and much lower location, would provide a decent enough location for set up. Jon and Mitesh spent much of the morning verifying radio performance again, but technical issues resulted in a much longer than anticipated EVA preparation time, about two hours. The crew finally embarked at 1330, but
with only two active radios amongst the four crew members. The repeater was successfully deployed, and the full team returned around 1600. Being the first real EVA, there were many lessons learned (as detailed in the EVA report), and another EVA is being planned to improve the antenna height. However, the overall results are positive, and our most physically demanding EVA has been completed.

The crew has been relaxing since then with episodes of the Twilight Zone (a favorite show of my previous rotation, Crew 79) and Firefly. It is a non-cooking day, which complements our shifted eating schedule caused by the long EVA time. Should the crew get hungry, we have several meals to choose from (just add water!), but most of us seem far more interested in sleep.

*Journalist’s Report - Christine Redmond reporting*

Crew 101 had a very active first day in sim! Today’s EVA involved setting up the radio repeater on top of radio ridge. This was a challenging EVA which took more time than any of us were anticipating. This EVA involved two separate trips between radio ridge and the hab. Four of us headed out on this EVA while Tommy and Christina stayed back at the hab to communicate with us via radio. Suiting up took us much longer than we had anticipated. We could only get one of the radios to work fully, while the second one worked partly allowing the astronaut to speak but with fuzzy reception from base. Usually all astronauts participating on the EVA have a radio on them. Since we were all staying together and only two roles needed communication we headed out with the equipment we had working.

Climbing up the ridge in full suit with two car batteries, the case and the antenna was extremely challenging. Luckily as journalist, my only responsibility was to carry up a camera! It was fun taking pictures though it may not have been fun at the time for Jon, Cody and Mitesh but it will definitely be fun for them to look back on the pictures! After we reached the top of the ridge we had to turn back down to carry up the solar panel. Mitesh and Jon took care of this part since they were responsible for setting up the equipment. Cody and I headed back into the hab to brush off the dust for our contamination study and depressurize. Jon and Mitesh spent a few more hours out there setting up the equipment. Once they arrived back at the hab the entire crew was ready for a relaxing evening. Crew 101 had a great day and is very excited for the days to come!

*EVA 3 Report – Jon Kosh reporting*

1330 - 1550

**Crewmembers:** Jon, Mitesh, Cody, Chrissy

**EVA Procedure:** Transport radio repeater equipment to the top of Radio Ridge. Crew journalist Chrissy took pictures while Mitesh, Cody, and I carried equipment. Maintained radio contact with remaining crewmembers at the hab.

**EVA Results:** A radio repeater was placed at top of Radio Ridge with telescoping antenna extended to approximately 10 feet.

**Lessons Learned:** Previous Georgia Tech crews placed the radio repeater at the top of Skyline Ridge - which is accessible by a fifteen minute long drive using V’ger out of sim. This year, it was found in the first EVA that roads led either too far north or too far south of the habitat. Therefore, this is the first time a GT crew has placed the repeater this close to the hab and while under sim.
For an activity as involved as on-foot equipment transport (primarily uphill), this EVA required thorough preparation and equipment check. The EVA was slow to start today as crews suited up for the first time and the radio communications crewmembers struggled to figure out placement of radios and experienced trouble adjusting radio settings. Clearly, a radio operation refresher was needed. Additionally, the crew, being fully suited and ready to depart, still had to prepare equipment needed for travel (tape down dangling wires and gather tools required, etc). It would have been a much quicker egress if Mitesh and I had prepared repeater equipment and radios the night before for quick access as we suited up.

Another EVA is planned to acquire the GPS coordinates at the repeater site and increase the height of the repeater. Another possible EVA involving relocation of the repeater to Olympus Mons of Phobos Peak is under heavy consideration.

5.4 March 15 – Day 2 in Sim

Figure 5.4: Christina during an EVA. Suits worn during sim are very restrictive on movement and have a very limited walking range.

Commander’s Report – Jon Kosh reporting
This morning the crew awoke seemingly more comfortable with their new home, ready to begin a new sol on the Red Planet. Jon and Mitesh had radio communications fully prepared for the planned expedition and experiment specific equipment preparations went smoothly. Tommy and Christina suited up, depressurized and moved to the vehicular landing area.

After attempting to start all 4 ATV’s, and following several minutes of technical diagnosis, the EVA team entered the airlock much sooner than expected. Temporarily extending SIM boundaries to include the ATV landing area, engineering crewmembers were sent to investigate. After another round of evaluation, the crew realized more specific knowledge and expertise was required to surpass this off-nominal technical challenge and promptly notified mission support.
The vehicular sampling EVA quickly evolved into a walking distance EVA that resulted in sample returns from three different geological sites. Radio contact was maintained for the expedition and a time based event log was kept detailing GPS coordinates and accuracies as well as site descriptions. This data log will grow to include sample analysis and visual evidence of sample sites.

The crew spent the next part of the afternoon relaxing with more episodes of the Twilight Zone and Firefly while enjoying a nice warm bowl of clam chowder. Feeling under the weather, the crew commander passed on the report to the executive officer. Today is a cooking day, and just before heading in for some rest, the commander kneaded some fresh bread and set it out to soak in sunlight and rise. The crew is currently enjoying the fruits of this labor along with what smells like a fantastic spaghetti dinner. While still typing the report at the dinner table, the XO is glad to report that the crew commander seems to still have a healthy appetite. The crew's vehicular EVA's are on hold until the crew is able to receive technical consul from mission support-which we have recieved word may happen tonight or tomorrow morning.

**Journalist's Report - Christine Redmond reporting**

Last night was close to a tragedy for any Tech student. The hab lost all internet connection! We ruffed through it though. I repeat crew 101 will do anything for the advancement of human space exploration! The outage lasted approximately 1.5 hours. The outage occurred exactly at the time of our mission support window for submitting our daily reports. Crew 101 managed. We notified mission support immediately of the outage and they were able to get it back up and working fairly quickly so we could submit our reports before calling it a night.

This morning was Christmas morning for Christina! We woke up to find the final shipment of our lab equipment sitting in the air lock. Christina was extremely excited to finally get all of her biology equipment. Christina and Tommy headed out for our Geology expedition mid morning. We ran into another road block. We could not get the ATVs to start for this EVA. So Christina and Tommy headed out on foot. This EVA involved observing the terrain of three separate 6 foot square areas and taking samples. The ATVs failing to start was another unanticipated problem to add to our list of many after only two days of sim. We have all learned these past few days that on Mars things don’t always go as planned and you need to be able to work with the limited resources you have to ensure a successful mission.

Today is a cook day! Tommy baked bread this afternoon. Christina and Mitesh are busy making pasta right now. We are all looking forward to a pasta dinner and a busy day tomorrow!

**EVA 4 Report – Christina Graves reporting**

1300 - 1315

**Crew Members:** Commander Tommy Caillouet and Christina Graves

**EVA Procedure:** Commander Caillouet and I went out at 1300 to board the ATV's in order to collect samples for the geography experiment.

**EVA Results:** Due to mechanical failure (or human error) in the operation of the ATV's, both of us were not able to utilize the ATV's for the EVA, therefore the vehicular EVA was cancelled.

**Lessons Learned:** Ensure all crew members know how to troubleshoot the ATV's prior to mission.
**EVA 5 Report – Christina Graves reporting**

1347 - 1419

**Crew Members:** Commander Tommy Caillouet and Christina Graves

**EVA Procedure:** Commander Caillouet and I set out on foot to 3 predetermined sites for soil sample collection. At each site, a 6’ x 6’ area was marked, photographed, and soil samples were collected. Each site’s location was also recorded by GPS. The soil samples were set aside for analysis on 3/16/11.

**EVA Results:** Soil sample sites marked and photographed, and soil samples all collected successfully.

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**5.5 March 16 – Day 3 in Sim**

![Figure 5.5: Jon and Cody filling out the daily Engineering Report. Engineering lies outside of the hab, but it is considered a ‘pressurized’ environment, so no suit is required.](image)

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**Commander’s Report - Tommy Caillouet reporting**

Today has been a bit slow of a day. After yesterday’s issues with the ATVs, outside help was due to arrive at some point in the day. A small break in sim, but now our science collection will be far more sample sites available. Unfortunately, this lead to a cancellation of all EVAs planned for the day (more geology sample collection). This left us with plenty of time to analyze EVA 4’s samples and continue to improve the reliability of the radio system. Tomorrow, we return to our regularly scheduled sample collections and begin the areohashing scouting.

A note on crew health: All crewmembers besides me remain in good health. I am still not 100%, but hopefully whatever this was is finally kicked.

**Journalist’s Report – Christine Redmond reporting**

Today there was a wind storm on Mars! The crew remained grounded at base due to the ATVs being down and the windy conditions. However, crew 101 made a productive “in hab” day. This morning we prepared for our outreach chat with the NASA INSPIRE students. We did a test chat and measured the
bandwidth usage after the chat. Crew 101 has been especially careful with our internet usage since the outage on Monday. We are all very excited for the chat tomorrow night!

Jon had a busy day tweaking the radio equipment. Christina and I classified the geological samples from yesterday’s EVA. Tommy had a busy afternoon updating the website for our friends back on earth to enjoy. This afternoon Don made a visit and helped us get the ATVs back up and running. We are all excited that they are back in working order and we are ready to head out on some exciting EVAs!

### 5.6 March 17 – Day 4 in Sim

![Figure 5.6: Mitesh sets up the geology experiment in the field.](image)

**Commander’s Report - Tommy Caillouet reporting**

It has been another successful day on Mars. After a full morning of preparation, Jon and Mitesh took out the ATVs for sample collection. This was also our first chance to do range testing of our radios. While they successfully gathered samples, imaged the test site, and confirmed radio operation, the weather turned against our plans, and it began to rain. This naturally forced us to cut the EVA short, and it also scrubbed the second EVA planned for the day.

With less field activity comes more in hab activity, though. We have spent a large portion of the day preparing a St. Patrick's Day meal of shepard's pie and soda bread and celebrating the holiday with a continuous playlist of Flogging Molly and The Dropkick Murphys. We have also used this extra time to prepare for our NASA INSPIRE presentation later tonight and to prepare for EVAs tomorrow. Hopefully the rain will depart quickly so we can return to full activity soon.

**Journalist’s Report - Christine Redmond reporting**

Happy Saint Patty’s day Earthlings! It has been a great day here on Mars! This morning we mapped out our 6th EVA on an aerial map of the site and Jon and Mitesh headed out to execute this EVA shortly
afterward. The ATVs are back up and running so they were able to gather samples for our geology and biology experiments from a site further from home base. Tommy stayed back and manned the radio station for this EVA. The EVA team had to cut their EVA slightly short due to weather. I was able to collect some sufficient dirt and dust for our contamination study upon their return to base.

This morning I made soda bread for our St. Patty’s day dinner tonight and Christina has been busy making a Sheppard’s pie this afternoon. We are all ready to celebrate St. Patty’s day from Mars! But before the celebration begins we have one more official task for the day, our NASA INSPIRE outreach chat! We have all been looking forward to sharing our experience with the INSPIRE students and answering the great questions they are sure to have for us.

_Biology Science Report - Christina Graves reporting_

On 3-17-11, an ATV EVA (EVA #6) was performed by Mitesh Agrawal and Jonathan Kosh. The purpose of the EVA was to collect soil samples and geological data from a site on the San Rafael Swell (the site of the MDRS) for analysis. The San Rafael Swell is characterized by both anticline and sedimentary rocks. Geological data obtained includes rock morphology, type, and location, as well as Geiger counter readings.

Data obtained from the EVA is found below:

**Site 1**

**Local time:** 13:17  
**GPS Location Data (UTM):** 12N 0519191 4250809 (+/-) 7 m  
**Alt (m):** 1368  
**# of rocks larger than 6 in:** 9  
**Depth of collection:** 0.5 in.  
**Geiger counter (mR/hr):** 0.05-0.1; One spike to 0.2

A 6' x 6' area was marked and photographed at 12N 0519191 4250809 UTM (+/- 7m) at an altitude of 1368m (+/- 7m). A 320.8g soil sample was collected at a depth of 0.5 in. In addition, a Geiger counter reading was taken of the area, with most readings between 0.05 - 0.1 mR/hr. It should be noted that there was one "blip" in the readings which registered at 0.2 mR/hr; however, it is unclear whether this was an accurate reading or a technical artifact. The area was a water run-off area; chosen because of the probability of bacterial variety at the site. The site also serves as a potential model of a "primordial pool," thought to be necessary for life in prebiotic situations.

The sample collected is a uniform sample of fine sand. There were several (9) larger rocks in the area, although none were collected for purposes of this experiment. Larger rocks were classified as those greater than 6 in. in diameter.

Sample collection was limited on this EVA due to inclement weather (rain); therefore, samples were only obtained from 1 site.
Biological soil analysis (EZ N.A. Soil Analysis from Omega and PCR) will be performed at a later time to test for the presence of bacteria.

**EVA 6 Report - Jon Kosh reporting**

1223 - 1350

**EVA Crewmembers:** Jon, Mitesh

**Base Communications:** Tommy

**EVA Procedure:** Sample soil at sites where water flow characteristics are evident. General site locations north, northeast of the hab were selected beforehand based on satellite images. EVA team not to deviate from established paths while on ATVs. Before exploring on foot, ATV helmets are to be exchanged with bubble helmets. Once the sample site is reached, stakes are to mark out a 6' x 6' area. Pictures of the test site will be taken from each stake, then a sample will be gathered from the area. Radiation readings and a count of large (>6" characteristic length) rocks will also be taken. This will be performed at up to five sites.

**EVA Results:** Soil sample returned from a promising site located at 12N 0519191, 4251413 (UTM). After evaluating weather conditions, the team returned to hab, safely inside from the Red Planet rain.

**Lessons Learned:** Start EVAs earlier in the day, stay mindful of weather conditions.

### 5.7 March 18 – Day 5 in Sim

Figure 5.7: Cody inspecting the GPS on a hill top. The crew relied heavily on GPS and radio equipment to increase safety during EVAs, many of which targeted location several kilometers away from the hab.

**Commander’s Report - Tommy Caillouet reporting**

It has almost become routine to be out here. No longer do I expect a loud city around me when I wake up, just complete isolation. Along with this routine, we become more efficient in carrying out our work. Prepping for EVAs has become a much more streamlined process as we grow more comfortable with the suits and radio equipment. We rose a bit late today due to a late St. Patrick’s Day night celebrating with
Irish-themed movies and card games. I had intended to send EVA 7 out at 11 am, but Chrissy and I didn't make it into the airlock until a bit after 11. This caused no output losses on the day, the schedule was merely shifted back an hour.

EVA 7 suffered some setback due to continued power reliability issues with our GPS units. However, even without the antenna at full length, our repeater set up allowed communication, albeit not always very clear, for the entirety of Cow Dung Trail north of the hab. To gain a reasonable signal to the hab, the EVA crew had to climb nearby hills about a mile and a half from the hab, but this is still a great performance and safety gain for the remaining EVA crews. A future EVA will attempt to quantify the radio transmission quality better, so another EVA can test quality with the repeater antenna extended. EVA 8 was accomplished without any major setbacks. Its goal was to gather soil samples for biological analysis. While the targeted area was not reached, several samples were collected from other stream beds, so the target area will be reached in a later EVA.

Other than EVAs, there have not many other scientific efforts today since all previous samples have been analyzed. In hab analysis of today’s samples will begin tomorrow while we send out EVAs to once again map the northern portion of the trail. If that is successful, an afternoon EVA will boost the repeater antenna length. A separate afternoon EVA collecting geology samples is also possible, but dependent on the rate we get through working with today’s samples.

Journalist’s Report – Christine Redmond reporting

Last night crew 101 had a blast chatting with the NASA INSPIRE students via live chat! We had fun participating in their “pre-chat poll”, arguing amongst ourselves prior to the chat starting whether fast food and pizza or family and friends is missed more here on Mars. It was exciting seeing the chat map fill with students from all over the United States and Puerto Rico! It was impressive hearing from the INSPIRE students as they described their experiment proposals to the chat group. After the chat we had a great St. Patty’s day celebration complete with Irish soda bread and Sheppard’s pie! We were all impressed with the quality of the Sheppard’s pie considering it was made up of entirely dehydrated ingredients.

This morning Tommy and I went on an exploratory EVA and tested the range of the radios in the process. I had a blast and became much more comfortable operating the ATVs. Last night one of the INSPIRE students ask the crew the question, “What made you want to participate in MDRS?” My quick and simple response was “because it is fun!” Tommy expanded on this by explaining that many of us are aerospace engineers and many of us will never become astronauts. He views MDRS as an opportunity for us as engineers to further understand the environment and limitations in which we are designing for. Today’s EVA further confirmed Tommy’s statement for me. When Tommy and I stopped to take our first GPS coordinate during our EVA we could not get our GPS to turn on. We tried to turn on our backup GPS which also failed. So we were tasked with the daunting task of changing the GPS batteries while wearing our thick, space gloves. After today’s EVA I can say that I am an aerospace engineer who better understands the usability issues astronauts on Mars would face.
Radio Science Report - Tommy Caillouet reporting
Georgia Tech crews at MDRS have used a HAM radio setup for six previous rotations. Crew 101 continues the use of the system to improve EVA efficiency and to study the range of communication of the equipment in the Mars-like environment of MDRS. EVA 7 on March 18, 2011 was a range testing expedition along the main trail next to the hab.

Comms checks were planned to occur about every three minutes. Once the voice quality becomes greatly reduced, GPS coordinates were to be taken at sample spots. Clear main road communications were maintained to about a half mile north of Olympus Mons. Further along the road, hab transmissions could still reach the crew members on EVA, but they could not achieve transmissions directly to the hab. However, by climbing nearby hills, transmissions from the field could be received by the hab. The first location this was accomplished was at 12 N 0518504 4252834. Unfortunately, the GPS lost power after the first reading, but the crew continued to gather rough performance data for the rest of the trail.

As the trail continues, it increases in elevation and eventually surpasses the altitude of the tranceiver on Radio Ridge. Two way road communication was never re-established, but the climbing nearby hills usually allowed consistent communications, even with large geographic features between the crew and the repeater. However, this means in relatively flat areas, EVA crews are incapable of transmitting to the hab. Hab transmissions to the EVA crew were received with quite reasonable strength and clarity all the way to Cow Dung Reservoir, which the EVA crew estimated to be about 3 miles from the hab. At this point, the EVA crew was unable to transmit to the hab, but they were unable to reach a hill top to transmit from. The closest proven transmission point was about a quarter mile away.

EVA 7 Report - Tommy Caillouet reporting
12:17 - 13:58
Crew Members: Tommy and Chrissy
Mode of Transportation: ATV
EVA Procedure: Crew members will travel on ATVs along Cow Dung Road, stopping about every three minutes for a radio signal strength check.
EVA Results: Travelled to Cow Dung Reservoir. Radio signal testing along main trail only partially completed due to GPS failure.
Lessons Learned: Rechargeable batteries do not provide sufficient charge to run GPS for any reasonable amount of time.

EVA 8 Report - Christina Graves reporting
1652-1815
EVA Crewmembers: Cody and Christina
Base Communications: Tommy
EVA Procedure: The crew set out to find Cow Dung Reservoir for soil samples for geology and biology experiments, but was unable to locate the site. Soil samples were taken from alternative locations, instead. The sites were chosen based on characteristics of water flow. General site locations were north and north east of the hab, and were predetermined, and based on a satellite image map of the
area. The team was not to deviate from established ATV paths, and ATV helmets were exchanged with bubble helmets prior to sample collection and on-foot exploration of sites.

**EVA Results:** Soil samples were returned from two sites located at 12N 0518280, 4255774 UTM (Site 1) and 12N 0518175, 4253614 UTM (Site 2). Accuracy of the first GPS location was 4m, with an altitude of 1370m. A third sample (consisting of a 1 lb. rock) was collected at 12N 0518584, 4252862 UTM, with a GPS accuracy of 5m, and an altitude of 1359.

**Lessons Learned:** Accurately map and locate destinations prior to ATV, or take along a crew member who is familiar with the destination of interest.

5.8 **March 19 – Day 6 in Sim**

**Figure 5.8:** Crew members used ATVs to travel relatively long distances, with some EVAs covering over 20 kilometers.

**Commander’s Report - Tommy Caillouet reporting**
'Mars' hasn't been the friendliest place while we've been here. Today, we were planning on having several EVAs to test and improve radio coverage. Unfortunately, high winds cancelled these plans for us. Instead, we decided to run another biological sample return EVA, again attempting to go to Cow Dung Reservoir. I was hoping that having been there yesterday, it would be fairly trivial to find the location. It was decidedly not trivial, though partially this was due to an exploratory urge. We decided to take a branch off the main trail and explore the route to Radio Ridge. After this detour we collected a sample at a place that looked a bit like the reservoir from the road. We'll give it another shot in another day, but at least we had the total success of pancakes this morning.

**Journalist’s Report – Christine Redmond reporting**
Today was another windy day on Mars! This morning I had a little piece of heaven, a warm shower! Oh the smell of Oasis soap! Tommy made pancakes to make the morning an unforgettable one for crew 101!
On a more serious note, despite the windy conditions, Tommy and Christina had another successful EVA during which they collected more biology samples. Jon had a busy afternoon working on the radios. We have been taking full advantage of today’s “cook day”! This afternoon I brought home back to the hab with some toll house cookies! Cody is currently preparing our dinner, mac and cheese!

**EVA 9 Report – Christina Graves reporting**

1350-1514

**EVA Crewmembers:** Tommy, Christina

**Base Communications:** Jon

**EVA Procedure:** The crew set out to find Cow Dung Reservoir for soil samples for geology and biology experiments, but were again (as on 3-18-11) unable to locate the site. Soil samples were taken from alternative locations, instead. The sites were chosen based on characteristics of water flow, including at the base of a dried up river bed. General site locations were north and north east of the hab. The team was not to deviate from established ATV paths, and ATV helmets were exchanged with bubble helmets prior to sample collection and on-foot exploration of sites.

**EVA Results:** Soil samples were returned from three sites located at 12N 0517686 4254622 UTM (Site 1) and 12N 0510979 4251416 UTM (Site 3). GPS data was not recorded at Site 2 (an attempt was made, but the focus of the camera taking the picture of the GPS was too blurry to get a clear reading). Accuracy of the first GPS location (Site 1) was 17m, with an altitude of 1399m; accuracy of the third GPS location (Site 3) was 7 with an altitude of 1378.

**Lessons Learned:** Crew members should take water along on longer EVA’s.

**5.9 March 20 – Day 7 in Sim**

Figure 5.9: Jon reinforces the radio equipment. EVAs on March 20 focused on increasing radio range by increasing the repeater antenna size.
**Commander’s Report - Tommy Caillouet reporting**

Wind looks to be a big problem for us for the second week we are to be on Mars. It seems like we have gotten off alright in losing the wind turbine; the high winds we are expecting to get over the next few days are much higher than it has been run in the past. With this weather, we likely would have had to pull down the turbine for safety reasons. All other science has been going well. Earlier today, Cody and Chrissy rode the length of Cow Dung Road to test radio transmission strength. The afternoon EVAs were climbs up Radio Ridge for Jon and Mitesh to check on the radio repeater and increase antenna height. Inside the hab, Christina has been hard at work testing the biology samples with some help from Mitesh. I even spent some time playing scientist with the geology samples, figuring the percentages of the samples of different dust sizes. It has been a very productive day.

**Journalist’s Report - Christine Redmond reporting**

We all live in a yellow submarine, a yellow submarine, a yellow submarine...Crew 101 is now half way through their mission! Has crew 101 gone crazy? You be the judge. Positive crew dynamics is essential for mission success. I am fortunate to be a part of a crew that works so well together, having many laughs along the way.

Today was a productive day on Mars despite windy conditions and losing power! This morning Cody and I headed out on EVA #10. We traveled the full length of the trail in both the northern and southern direction, stopping periodically for radio strength checks and GPS readings. Cody and I had a blast navigating the rugged Martian terrain! One of the NASA INSPIRE students put together a study for the crew to evaluate the safety of the ATVs. Today was our first day participating in this study. Safety is top priority here in the isolated Maritain environment. Crew 101 always exercises appropriate safety measures.

After a quick lunch break, Mitesh and Jon were ready to suit up for EVA #11. This EVA involved climbing up radio ridge and raising the antenna for the repeater as well as further securing the antenna given the recent windy conditions. Jon and Mitesh were able to raise the antenna to 25 feet! We are all looking forward to testing our increased range during our EVAs tomorrow. We lost hab power during this EVA. Tommy quickly moved to hand held radio communication and notified the EVA team of the outage. Luckily, Cody (our chief engineer) sprung into action and discovered that power would be restored shortly.

Today is a pre prepared day. Santa Fa Beans and Rice...let’s see how this one goes!

**Radio Science Report - Tommy Caillouet reporting**

After a less than completely successful EVA to measure radio signal strength on March 18th, plans were made to once again map signal strength along Cow Dung Road on the 20th. There was concern due to increased wind activity; this could lead to reduced clarity by causing interference in EVA crews' microphones or reduced power by deforming the radio repeater antenna. The morning EVA was, however, successful; wind appeared to have minimal impact on the results.

The procedure was to send ATVs along the trail and pause every couple minutes to report in GPS coordinates and altitude. A radio operator at the hab would record this data, along with a signal
strength and clarity rating between 1 and 5, with 1 being no strength or clarity and 5 being perfect strength or clarity. If the hab could not be reached from the road, the EVA crew would climb a nearby hill to attempt to boost the signal. Ratings for the route follow in Table 5.1, with site 1 being a reading at the base of the hab

Table 5.1: Signal Strength and Clarity along the Main Trail at MDRS. UTM Coordinates for Sector 12N.

<table>
<thead>
<tr>
<th>Time</th>
<th>Easterly</th>
<th>Northerly</th>
<th>Altitude (m)</th>
<th>Accuracy (m)</th>
<th>Strength</th>
<th>Clarity</th>
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The first obvious trend is that the signal strength is perfect for all transmissions. This is due to the radio repeater located above the hab. Any loss in signal power is lost between the EVA crew and the repeater, and then the repeater boosts the signal to transmit to the hab. Therefore, the radio operator at the hab will never detect a signal power fluctuation; the signal strength will either appear to be 100% or completely lost.

Clarity, on the other hand varies rather significantly. There is no apparent loss in clarity within 500 - 700 meters of the hab. Up to about three kilometers north of the hab, there is minimal noise in the transmission. Southern bound crews start to gain additional noise around 2.5 kilometers south of the hab, likely due to interference caused by Kissing Camel Range. Full communications range is around 5 kilometers from the hab, though crews often had to climb nearby hills to gain two-way communications. This is partially because the northbound trail often has small hills just off the path blocking transmission. These seem to have a greater effect on blocking signal than larger features that are further removed from the trail, such as Olympus Mons.

This 5 kilometer radius of transmissions theoretically gives EVA crews 79 square kilometers of radio coverage. Geographic features do clearly disrupt the signals, but positioning the radio equipment in front of or on top of hills allows for contact with the hab. Radio signal on top of Radio Ridge, which
accounts for about half of that area, is also untested at the moment. We hope to test signal strength in
that area tomorrow, if weather conditions permit.

**EVA 10 Report – Christine Redmond reporting**
11:55-14:05

**Crew Members:** Chrissy and Cody

**Mode of Transportation:** ATV

**EVA Procedure:** Crew members will travel on ATVs along Cow Dung Road, stopping about every two
minutes for a radio signal strength check, recording GPS coordinates at each point of communication.

**EVA Results:** Traveled full length of trail in both the northern and southern directions and took radio
signal measurements and GPS coordinates along full length of trail.

**Lessons Learned:** I need to wear the smaller helmet next time I go on a ATV EVA and remember to take
earrings off. Also, for purposes similar to this EVA mission it may be helpful to count steps taken from
road to get a more accurate distance from road approximation to report to base.

**EVA 11 Report – Jon Kosh reporting**
1643 - 1728

**EVA Crewmembers:** Jon and Mitesh

**Base Comms:** Tommy

**Mode of Transportation:** Foot

**EVA Procedure:** Currently the radio repeater height is limited to ~10ft because the length of the coax
cable is shorter than the length of the max fiberglass mast height. EVA 11’s mission was to carry a coil of
HF coax cable to the top of radio ridge and raise the repeater antenna to full height (25’). With high
winds over the past week and increasingly higher winds expected the next, the team also carried a
shovel to set the mast into the ground for more stability.

**EVA Results:** Operation not complete. Equipment successfully carried to the top of radio ridge, but in
the process of breaking down the existing HF cable currently used to insert the longer coax cable, the
repeater wires were removed from the back of their powerwerx connector. A new connector needed to
be fit at the hab. The team promptly returned to the hab for a quick fix.

**Lessons Learned:** Make sure to rigorously test electrical connections created at the hab before utilizing
them in the field.

**EVA 12 Report – Mitesh Agrawal reporting**
1800-1915

**Crew Members:** Jon and Mitesh

**Base Comms:** Tommy

**Mode of Transportation:** Foot

**EVA Procedure:** Team had to fix the loosened wire brought after EVA 11 operation, go
to the top of radio ridge and raise the repeater antenna to the full
height (25 feet)

**EVA Results:** Raised the height of the repeater antenna to the full height (25 feet)

**Lessons Learned:** Always better to take the tools required for some operation even if one suspects it
might be slightly useful. We should have taken a hand drill to the ridge as initially, we could not fit our wires through one of the holes in the radio box but we managed to make it bigger using a screw driver.

5.10 March 21 – Day 8 in Sim

Figure 5.10: Wind gusts during the rotation reached nearly 50 miles per hour, enough to rip the several hundred pound roof off of the engineering area on the other side of the ridge.

Commander’s Report – Tommy Caillouet reporting
We woke this morning to the entire hab shaking from high wind speeds. We had expected bad weather, but it still wasn’t the most pleasant thing to get up to. The gusts were enough to cause a bit of chaos around the hab. A few pieces of metal siding, some boxes, and the roof from the generator area were strewn about outside, so we spent some time cleaning up. The winds died down for several minutes of the time, but never long enough to get an EVA going. We’ll have to have the comms EVAs planned for today tomorrow, and there will be an extra one to check the status of our much more wind-worn radio equipment on the ridge.

Journalist’s Report – Christine Redmond reporting
Today was a quiet day on Mars. Crew 101 was grounded due to a severe wind storm. Luckily Raj was able to keep us entertained on this otherwise slow day. Today is a cook day so the windy conditions has allowed us to take full advantage of our cook day. Christina and Tommy made bread and Mitesh and Jon are cooking us a special Indian dinner. We are all anxious to get back to work tomorrow.

Biology Science Report – Christina Graves reporting
Objectives:
Science objectives for the day is to begin DNA isolation from soil samples collected thus far (8 in al) using the E.Z.N.A. Soil DNA kit (Omega).

**Materials and Equipment:**
1. water bath set to 70C
2. centrifuge
3. 1.5 mL centrifuge tubes
4. 15mL centrifuge tubes
5. 95% ethanol for sterilization

**Preparation and Procedure:**
The water bath was set to 70C. 80mL 95% ethanol was added to SPW Wash Buffer. It should be noted that the kit calls for 96-100% (absolute) ethanol; however, only 95% was available.

For each sample (8), 500mg of glass beads were added to a 15mL centrifuge tube. To this, 1g of soil sample and 1mL SLX Mlus Buffer was added. Solutions were shaken for 5 minutes to lyse samples [note: protocol calls for vortex, but this was unavailable].

100uL Buffer DS was then added and shaken to mix [note: protocol again calls for vortex].

The samples were then incubated for 10min at 70C, and shaken once during the incubation.

The next step called for a centrifuge, which was found to be harboring a lose centrifuge tube. The centrifuge tube down in the centrifuge was extracted, but something seems to be wrong with the rotor itself.

Checked the fuse - it is in good order. Will look for a broken connection or burned out wire.

Incubator was set to 37C, and plates (left out on table top on 032011) were transferred. Waiting for some colonies to grow!
Commander’s Report – Tommy Caillouet reporting
The crew almost seems to be winding down. We can feel that our time here is limited. Biology samples have been completely gathered for days. We could get more geology samples, but the investigator back at Tech is already pleased with the current haul. Radio coverage would have been completely tested today, if it weren’t for uncooperative weather (rain and snow cut that EVA short), but it was still as very successful EVA as the radios demonstrated a marked improvement with a longer antenna. I’m pleased that we’ve reached this point with several days left in the mission. We will be able to use the last couple days to do more exploratory EVAs and use the areohashing algorithm, which has been more or less shelved while we finalize the other experiments. Still, it is disappointing that we have only a few more days in sim, if only because we can’t escape the work that expected of us on Earth for much longer. No point in taking our eyes too far off of our current activities. We’ve got several EVAs and a lot of science and writing to do over the next couple days.

Journalist’s Report - Christine Redmond reporting
This morning started with a repair EVA. During yesterday’s wind storm our repeater antenna snapped at the base cutting communication for our EVAs. Mitesh and Jon suited up and climbed radio ridge to assess and repair the damage. Luckily we only lost about a foot and a half from our initial antenna length.

This morning Cody and I headed out on EVA #11. EVA #11 was quite an adventure! We were gone for approximately two hours and in that time we traveled along a path west off of Cow Dung trail testing radio coverage in these regions previously unexplored by crew 101. These trails are much more rugged
than the nearby trails making this an extremely fun EVA to maneuver. We had to cut our EVA short when dark clouds appeared over head and it started snowing!

Today I really felt like an astronaut when I added one more addition to my space suit, a heart rate monitor. Mitesh is heading a study to relate heart rate during different activities to oxygen consumption. He is hoping by studying this relationship he can determine how much oxygen would be needed to support human life on Mars with relationship to different activities that would be performed on Mars. Christina had a busy day analyzing our biology samples. Raj has been enjoying today’s beautiful Martian view. Tommy has been working on our final report.

I am happy to report an adventurous and productive day. We are all looking forward to another night on the red planet!

**Biology Science Report – Christina Graves reporting**

**Objectives:**
Science objectives for the day is to complete DNA isolation from soil samples collected thus far (8 in all) using the E.Z.N.A. Soil DNA kit (Omega). Also prepare liquid cultures for gram staining.

**Materials and Equipment:**
1. water bath set to 70C
2. centrifuge
3. 1.5 mL centrifuge tubes
4. 15mL centrifuge tubes
5. 95% ethanol for sterilization
6. ice bath
7. 91% isopropanol
8. LB mix
9. dH2O
10. pressure cooker
11. sterile inoculation loops

**Preparation and Procedure:**
The water bath was set to 70C. Prepare an ice bath using a styrofoam bucket and ice.

Each sample was transferred to sterile 1.5mL eppendorf tubes, and were centrifuged at 3000rpm for 3 min (Eppendorf Minispin plus centrifuge). The supernatant was then transferred to a new 1.5mL tube, and 270uL of Buffer P2 was added. The samples were then incubated on ice for 5 min, and centrifuged at full speed (13000 rpm) for 5 minutes [note that the kit protocol calls for a 4C microcentrifuge, which was unavailable, and the samples were centrifuged at RT]. This supernatant was transferred to a new 1.5mL tube, and 0.7 volumes of isopropanol (91%) was added. The sample was then incubated at 0C for 1 hour [note: protocol calls for -20C]. Samples were then centrifuged at full speed for 10 minutes [note: protocol calls for 4C centrifuge]. Cells were then allowed to incubate on ice again for 1 hour to increase DNA concentration.
Plates were also removed from the incubator. Successful bacterial colony growth for samples for all samples except sample 1.

LB media was prepared using 500mL of dH2O, and 13g of LB media. Lid was loosely capped and placed in a pressure cooker with about 1in. of water in the bottom. The solution was heated in the pressure cooker for 45 minutes to ensure sterilization [note: the pressure cooker is missing the top; I'm not sure if that will affect sterilization technique or not].

When cooled, 1000uL of LB media was added to a 1.5mL centrifuge tube, and colonies were picked with sterile inoculation loops. Tubes were then placed in the incubator at 37C.

**Results:** As mentioned, successful growth was seen from all samples except sample 1. Sample 8, in particular, grew extremely well.

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**EVA 13 Report – Jon Kosh reporting**

1148-1255

EVA Crewmembers: Jon, Mitesh

Base Communications: Tommy

Mode of Transportation: Foot

**EVA Procedure:** High winds from the weekend (gusts of up to 48mph) have brought the repeater antenna down. The crew will depart the hab with a shovel and hacksaw to re-raise the repeater antenna.

**EVA Results:** Repeater antenna successfully raised. It was found that, as anticipated, the fiberglass mast holding the antenna had snapped near the base of the repeater setup, just above where the mast was buried. The EVA team sawed off the bottom portion of the mast and dug a deeper hole to hold the mast. The slightly shorter mast was inserted and raised to its full height.

**Lessons Learned:** Our pelican box holding our repeater equipment is sufficiently weighed down by the two 12V batteries inside, however, wind speeds in the mid 40mph range will bend our fully erect repeater to critical angles.

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**EVA 14 Report – Tommy Caillouet Reporting**

1353-1516

EVA Crewmembers: Tommy, Cody

Base Communications: Jon

Mode of Transportation: ATV

**EVA Procedure:** The purpose of this EVA is to prepare for the later EVA along the Radio Ridge trail. Tommy will lead Cody to show the beginning of this trail. The crew will then retrieve UTM coordinates of the trailhead.

**EVA Results:** Cody was successfully shown the beginning of the trail. UTM coordinates found were: 12N 517812 4254502. The crew was also surprised to learn that the new radio improvements now made two way communications from the road with the hab available for the length of Cow Dung Road to the trail separation.

**Lessons Learned:** None
EVA 15 Report – Cody Hall Reporting
1416 - 1608

EVA Crewmembers: Cody, Christine

Base Comms: Tommy

Mode of Transportation: ATV

EVA Procedure: EVA team would travel north along Cow Dung Road, stopping every few minutes to give GPS coordinates and gauge ham radio signal strength for newly raised repeater antenna. Once team reaches Brahe Highway, they would head west. Team would stop every few minutes to give GPS location, and base would gauge signal strength. Once team reached what appeared to be Copernicus Highway, team would turn south and repeat GPS and signal strength tests. After many check-ins, team would turn around and return to base.

EVA Results: Signal strength was confirmed to be improved due to readings on Cow Dung Road. There is no signal strength to transmit or receive on Brahe Highway, or Copernicus Highway until radios are nearly due west of the hab. Two GPS locations were taken, but only radios transmitting on high power could transmit to base. After these two readings, team noticed that clouds were getting dark overhead and decided to head back instead of risking getting caught in rain or snow.

Lessons Learned: The roads off of Cow Dung Highway are much rougher, and teams will want to drive much more carefully. Crews should probably check weather reports before planning long and far away EVAs.

5.12 March 23 – Day 10 in Sim

Commander’s Report - Tommy Caillouet Reporting

Today was a bit of a turning point in the mission. During EVA 16, one of the ATVs encountered trouble, so we are now down to one consistently working ATV. This puts us in a bit of a bind because our remaining planned EVAs were all very long range - exploratory and radio range testing. Without two working ATVs, our work here is effectively over. None of us were terribly heart broken at the thought of there being no point in continuing sim, though. We'll continue what science we can in the hab, but that's looking to be all for the EVAs.

It was my turn to cook, so I decided to try my hand at red beans and rice. The hab's cooking equipment is surpassed even by my lowly apartment's set up (the general lack of a 'seriously, just barely higher than warm' setting on the stove is a pain), but it was sufficient to whip up a decent meal from various dehydrated meats and vegetables. Our batch of french bread went even better than last time, if only because we got four loaves instead of just two (it still only took one meal to finish off, though). I've certainly made better, but I end the day pretty satisfied.

Journalist’s Report - Christine Redmond reporting

This morning Mitesh and Cody took the same trail Cody and I took yesterday, hoping to gather more data past the point we had to turn back due to weather. Unfortunately, no such luck. The EVA team had to turn back before the spot due to the shifter breaking on Spirit.
Tommy made an awesome dinner! He made beans and sausage over rice and bread this afternoon. Crew 101 enjoyed an afternoon hike to mount Olympus (Raj’s favorite spot on Mars). Crew 101 also enjoyed the Martian sunset and is looking forward to the long anticipated movie Serenity tonight!

**Biology Science Report - Christina Graves reporting**

**Objectives:**
Science objectives for the day is to complete DNA isolation from soil samples collected thus far (8 in all) using the E.Z.N.A. Soil DNA kit (Omega).

**Materials and Equipment:**
1. water bath set to 70°C
2. centrifuge
3. 1.5 mL centrifuge tubes
4. 95% ethanol for sterilization
5. ice bath
6. dIH2O

**Preparation and Procedure:**
The water bath was set to 70°C, and elution buffer was preheated. Prepare an ice bath using a styrofoam bucket and ice.

DNA was allowed to sit on ice (0°C) overnight to maximize DNA precipitation. They were then centrifuged again at full speed (13000rpm) for 10 minutes [note: protocol calls for 4C centrifuge]. The supernatant was then discarded. To the pelleted DNA, 200uL of elution buffer was added to the tube, and shaken thoroughly. The samples were then incubated at 70°C for 20 minutes to dissolve the DNA pellet. 100uL of HTR reagent was then added, and mixed thoroughly by shaking for 20 seconds. The samples were incubated at room temperature for 2 minutes, and centrifuged at full speed (13000rpm) for 2 minutes. The supernatant was the transferred to a new 1.5mL eppendorf tube, and an equal volume (400uL) of XP1 buffer was added and thoroughly mixed. The samples where then applied to a HiBind DNA column in a provided 2mL collection tube, and were centrifuged at 10000 rpm for 1 minute. The flow-through was discarded, and 300uL XP1 buffer was again added to the column. The samples were again centrifuged at 10000rpm for 1 minute, and collection tubes and flow-through were discarded. The columns were then placed into a new 2mL collection tube (provided) and was with 700uL of SPW Wash Buffer diluted with ethanol, and centrifuged at 10000rpm for 1min. The flow-through was discarded, and samples were rewashed with 700uL of SPW Wash Buffer diluted with ethanol, centrifuged at 10000rpm for 1min. Flow through was again discarded, and the samples were centrifuged at 13000rpm for 2min. at room temperature to ensure removal of trace ethanol from the samples. The HiBind DNA columns were then placed into sterile 1.5mL centrifuge tubes, and 30uL of preheated Elution Buffer was added directly to the center of the matrix. The samples were incubated at 70°C for 15 minutes, and then centrifuged at full speed (13000rpm) for 1min. to elute DNA. The elution step was then repeated with an additional 30uL of Elution Buffer.
Tomorrow, we will perform chromatography and PCR experiments on the DNA collected, as well as the bacterial staining and colony PCR experiments.

**EVA 16 Report - Cody Hall Reporting**
1247-1358
EVA Crewmembers: Cody, Mitesh
Base Communications: Jon

EVA Procedure: EVA team would travel north along Cow Dung Road, stopping every few minutes to give GPS coordinates and gauge ham radio signal strength for newly raised repeater antenna. Once team reaches Brahe Highway, they would head west. Team would stop every few minutes to give GPS location, and base would gauge signal strength. Once team reached what appeared to be Copernicus Highway, team would turn south and repeat GPS and signal strength tests. After many check-ins, team would turn around and return to base.

EVA Results: Multiple GPS readings were obtained along Brahe Highway, but the gear shift lever on Spirit, the ATV Mitesh was driving, broke at the weld during shifting. This made shifting gears very difficult, so we turned around and headed back to the hab.

Lessons Learned: Be wary of ATV troubles.

5.13 March 24

Figure 5.13: During an out of sim field trip, the crew hiked to the top of 'Olympus Mons,' a large hill about a mile north of the hab.

**Commander’s Report - Tommy Caillouet Reporting**
It has been another day of science for Crew 101. Most of the crew spent the day in the lab prepping samples and completing various analyses (I'm not exactly sure what it all entails, I am but a mere
engineer). Cody and I spent some time attempting to get the ATVs to cooperate, but when our repair methodology is attempting to jump thenon-working units, we run out of strategies fairly quickly. The remainder of the day has been spent wrapping up our work here. Writing reports (though full science results won't be ready until tomorrow), cleaning, if we can't gather any more samples, we'll at least have am extremely smooth transition ready for the next crew's arrival. Tomorrow, we will officially break sim to bring down the radio repeater - no need to endanger more equipment.

**Journalist's Report - Christine Redmond Reporting**

Happy Thursday earthlings! Crew 101 has only two more days on Mars. Although we are all going to miss the red planet, we are all excited for burgers in our near future. Last night Crew 101 enjoyed a nice clear night to stargaze. That was definitely a night sky you can only see on Mars! We will all hold on to that memory for a long time.

Crew 101 had a busy and rewarding day starting to wrap up our work here on Mars. Christina, Mitesh and I had a productive morning in the lab. I ran some tests for our contamination study and Mitesh and Christina were busy running some biology tests. Cody and Tommy worked this afternoon to try to get the ATVs back up and running. Unfortunately they were not able to get the running. Today is our last day on the food study. Tonight we celebrate our last “pre prepared day” with chili!

**5.14 March 25**

![Figure 5.14](image)

Figure 5.14: Part of the crew hiked to the 'Birthday Cake,' a rock tower several miles south of the hab.

**Commander's Report - Tommy Caillouet reporting**

It's our last full day on 'Mars.' We've been scrambling to get last minute science completed, but also taking time to enjoy our remaining time in this awesome area of the planet (err... awesome area of another 'planet'?). We enjoyed breaking sim right with a ride into town for breakfast at Blondie's. Nothing could quite prepare us for the rush of having fresh food for the first time in two weeks. After returning to the hab, part of the crew continued work on analyzing biology and contamination
experiment samples, while the rest went on a hike along radio ridge and retrieved the radio repeater. Apparently, it sustained additional wind damage during the night, but this time there would be no repair EVA. We grabbed a block of cheese and other ingredients in town to make some proper (only semi-shelf stable) pizza tonight. There will be some tasty perks transitioning back into our daily lives, but hopefully lessons from our time at the hab won't be washed away like the taste of instant meals.

**Journalist’s Report - Christine Redmond reporting**
This morning crew 101 had a celebration breakfast at Blondie’s. After a hearty breakfast crew 101 was ready to tackle a challenging hike to the top of birthday cake in celebration of Raj’s birthday! At times I felt like I was in an Indiana Jones movie climbing between the desert rocks. Crew 101 also climbed to the top of radio ridge to take down our radio equipment. Christina had a busy afternoon packing up the science equipment to be shipped back to earth and preparing the lab for the next crew. Tommy had a busy afternoon working on our final report. Cody, Tommy and Christina had a busy afternoon preparing our last dinner on Mars, homemade pizza! The entire crew is looking forward to celebrating this last night on the red planet! We are all anxious to meet and greet crew 102 tomorrow afternoon! We look forward to sharing with them our experience as well as the many lessons we have learned during simulation.

All good things, as the saying goes, must come to an end. I am convinced that time on Mars passes 10 times as fast as on Earth! It is hard to believe that today is our last full day on Mars and that crew 101 will be returning to earth tomorrow afternoon. Crew 101 has had one memorable experience on the red planet! From this experience we take away strengthened friendships, great stories, unexpected lessons learned, scientific and engineering knowledge, quotes only understood by crew 101, strengthened teamwork and communication skills, cooking skills (a new found skill for many of our male crew members), resourcefulness, courage, inspiration, a greater understanding of the technology and skills required to survive on Mars, breathtaking views and most importantly a sense of Mars being within reach and a burning desire to be a part of this historic goal! Crew 101 is sad to leave Mars but we are overjoyed to return to share our experience with planet Earth!

**Geology Science Report - Tommy Caillouet reporting**
Crew 101 ran a geology experiment attempting to aid EVA planning by gathering quantitative and qualitative data of several sites around MDRS to gauge movement difficulty for crew members and rovers along several soil types and compare the data against satellite imagery of the area.

At each target site, crew members marked off a 1.8m x 1.8m area for sampling. UTM coordinates, a small soil sample, soil depth, and the number of 'significant' rocks at each site was collected. Rocks were considered 'significant' when they were large enough to force consideration for movement. For consistency, it was decided that rocks with a 15 cm characteristic length would qualify for this label. Once samples were returned to the hab, top soil was characterized by measuring the percent mass of each sample that was fine dust (under .3mm diameter), medium dust (0.3mm to 1mm diameter), and large dust (over 1mm diameter). The purpose of this is to give an idea at the type of dust contamination likely to be picked up in an area. Data for the ten samples can be found in Table 5.2.

Table 5.2: Geology sample site data. UTM Coordinates for Sector 12N.
<table>
<thead>
<tr>
<th>Easterly</th>
<th>Northerly</th>
<th>Significant Rocks</th>
<th>Est. Soil Depth (cm)</th>
<th>Total Mass (g)</th>
<th>Small Dust (%)</th>
<th>Medium Dust (%)</th>
<th>Large Dust (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>518290</td>
<td>4250809</td>
<td>3</td>
<td>5</td>
<td>102.21</td>
<td>6.47</td>
<td>28.96</td>
<td>64.57</td>
</tr>
<tr>
<td>518342</td>
<td>4250833</td>
<td>13</td>
<td>1</td>
<td>202.51</td>
<td>5.99</td>
<td>13.46</td>
<td>80.55</td>
</tr>
<tr>
<td>518345</td>
<td>4250950</td>
<td>0</td>
<td>10</td>
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<td>27.37</td>
<td>26.92</td>
<td>45.71</td>
</tr>
<tr>
<td>519191</td>
<td>4250809</td>
<td>9</td>
<td>1</td>
<td>315.72</td>
<td>23.75</td>
<td>42.01</td>
<td>34.25</td>
</tr>
<tr>
<td>518280</td>
<td>4255774</td>
<td>3</td>
<td>10</td>
<td>201.01</td>
<td>2.06</td>
<td>7.11</td>
<td>90.83</td>
</tr>
<tr>
<td>518175</td>
<td>4253614</td>
<td>3</td>
<td>1</td>
<td>137.77</td>
<td>16.19</td>
<td>21.72</td>
<td>62.09</td>
</tr>
<tr>
<td>517686</td>
<td>4254622</td>
<td>0</td>
<td>15</td>
<td>48.74</td>
<td>7.73</td>
<td>52.83</td>
<td>39.43</td>
</tr>
<tr>
<td>510979</td>
<td>4251416</td>
<td>0</td>
<td>2.5</td>
<td>136.8</td>
<td>19.61</td>
<td>14.26</td>
<td>66.13</td>
</tr>
</tbody>
</table>

There appears to be no major patterns in the results or when compared to satellite imagery. More sites must be analyzed before conclusive results can be reached, but it appears that each EVA crew must be fully prepared for a wide range of environmental contaminates and movement impediments.

*Contamination Science Report - Christine Redmond Reporting*

**Objectives:**

Science objective for today is to weigh contaminants brought in after each EVA, classifying the contaminants by conducting Nitrate, Ammonia and Carbonate tests on the sample from each site.

**Materials and Equipment:**

- 24 sterilized 15 mL tubes
- Nitrate aquarium test kit
- Ammonia aquarium test kit
- Carbonate aquarium test kit
- Bagged samples of contaminants collected after each EVA
- Dust pan
- 95% ethanol for sterilization
- dIH2O
- Weighing paper
- Balance
- Small brush
- Pipette

**Preparation and Procedure:**

Each bagged contaminant sample was emptied onto weighing paper and weighed individually on balance. Each sample was placed in individual test tubes and 10 mL of dIH2O was added to each sample test tube. Test tube was capped and shook several times.

Nitrate test: 1 mL of test solution was taken from each sample test tube and placed in separate test tubes. Pipette was sterilized with ethanol between each extraction. One drop of Nitrate indicator was
placed in each test tube. Test tubes were capped and shook. After five minutes color of each sample was observed to determine concentration of Nitrate.

Ammonia test: 1.25 mL of test solution was taken from each sample test tube and placed in spate test tubes for each sample. Pipette was sterilized with ethanol between each extraction. Two drops of Ammonia indicator was added to each test tub. Test tubes were capped and shook. Color of solution was observed immediately to determine concentration of Ammonia.

Carbonate test: 5 mL of test solution was taken from each sample test tube and placed in separate test tubes for each sample. Pipette was sterilized with ethanol between each extraction. One drop of Carbonate indicator was placed in each test tube. Tubes were capped and shook. Solution turned blue or yellow. If the solution turned yellow an insignificant amount of carbonate was present. If the solution turned blue one drop of indicator was added, test tube was capped and test tube was shook. This process was repeated until the solution turned from blue to yellowish noting how many drops of indicator were added.

Results:
Carbonate was the only test that showed any results from any of the given samples. Carbonate was found in two samples both collected from EVAs on radio ridge. After six EVAs a total of 4.23 grams of dust contaminant was collected.

**EVA Stress Study Science Report - Mitesh Agrawal Reporting**
A Study of the Activity Levels of MDRS Operations

**Purpose:**
Oftentimes we forget how specific our evolutionary path is and how adaptive it is to the terrestrial environment. Man must recreate appropriate atmospheric pressures and oxygen levels in order to survive outside of our natural habitat. Currently, design of the environmental control system utilizes standards of oxygen based on metabolic activity and body type/size. The crew is interested in quantifying life support parameters for the duration of the mission using measured heart rate. This data can be used to describe the intensity of various activities at the MDRS and serve as the basis for future environmental control experiments.

**Materials:**
A Heart Rate Monitor which attaches to the wrist

**Methods/Procedure:**
1. Testing subjects are the MDRS 101 crew (3 members).
2. Have subjects fill out a consent form.
3. Have subjects complete a questionnaire to determine participant eligibility and record age and gender.
4. Have subjects have their weight and height measured.
5. Have subjects wear a heart rate monitor for periods while they carry out their normal activities and operations at the Mars Desert Research Station and while they go out on EVA's.
Data Collection and Interpretation:
After gathering all the data from the procedure including the changes in heart rate, we determined how the rate of oxygen consumption was affected while carrying out different activities, especially the EVAIs. The oxygen consumption was roughly estimated by using the data of heart rate and the weight of the subject. All of this data was implemented in determining the estimated average amount of life support parameters needed for the duration and simulated conditions at the Mars Desert Research Station. This data can serve as a basic estimation of the life support parameters that should be available for future similar environmental control projects. The oxygen consumption was calculated by \((\text{Average Heart Rate}) \times \text{constant}/(\text{Maximum Heart Rate})\) in liters per minute. The constant ranges from 2.5-3.5 ranging for people with different height/weight ratio.

Results:
Because of this protocol being under the supervision of IRBwise (Institutional Review Board) of Georgia institute of Technology, all the data is kept anonymous except for the Investigator. So, all the results posted here are under anonymous subject names. The data from 3 subjects was collected for this study. The number of data is low because of the late approval of the project from IRBwise and limited number of EVAs on the MDRS mission.

Table 5.3: Oxygen consumption of test subjects during normal, in-hab, activity and during EVA.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Oxygen Consumption - Normal Activity (L/min)</th>
<th>Oxygen Consumption - On EVA (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 A</td>
<td>1.00</td>
<td>1.75</td>
</tr>
<tr>
<td>101 B</td>
<td>1.08</td>
<td>1.85</td>
</tr>
<tr>
<td>101 C</td>
<td>2.14</td>
<td>1.98</td>
</tr>
</tbody>
</table>

So, as expected, in case of subjects 101A and 101B, the oxygen consumption was more during EVA activity than normal activity. The abnormality in data in case of subject 101C might be explained by calm nature while on EVA or increased anxiety or fear while normal activity which might occur due to watching movie.

Conclusion/ Discussion:
So, by extrapolation and considering the normal oxygen consumption while sleeping is 300ml/min and that an average person sleeps for 8hours and lives in the hab for the 16hours doing normal activities, the oxygen consumption for the day was found in the range of 1100-2100 lit/min which matches with the normal average oxygen consumption on Earth. The average oxygen consumption per person per day was found out to be 1500 lit/min. So, in conclusion, the hab must be equipped with life support parameters related to oxygen so as to support an average person for the entire duration of the mission multiplied by the members of the crew. Also, while going out on EVAs, it is essential to quantify the time and the intensity of the EVA activity to find the oxygen needed for the operation. So, from this study, we
tried to quantify and characterize the oxygen consumption by the crew thus helping in determining the extent to which the life support parameters should be equipped.

*Biology Science Report - Mitesh Agrawal reporting*

**Objectives:**
Science objectives for the day was to use liquid samples made on 03/22/11 for gram staining and to determine whether the bacterial growth detected was acid fast or nonacid fast bacteria

**Materials and Equipment:**
1. 4 Liquid samples of bacteria
2. Acid Fast Stain kit (includes Carbol Fuchsin Stain, Acid Alcohol Decolorizer and Methylene Blue Counterstain)
3. Slides
4. Heat plate (to fix the bacteria)
5. Sterilized H2O

**Preparation and Procedure:**
1. Four liquid samples were spread on a glass slide in a thin smear. They were dried and heat fixed.
2. The slides with fixed bacterial samples were flooded with carbol fuchsin stain for 2 minutes and then rinsed with water.
3. A gentle stream of acid alcohol decolorizer was directed at the slide till the decolorizing stopped.
4. The slide was rinsed with water again.
5. Methylene blue was used as a counterstain and the slide was flooded with it for 2 minutes.
6. The slide was rinsed and allowed to dry for 20 minutes.

**Results:**
Sample 1: No stained bacterial bodies were observed. This might have been due to the low concentration of bacteria in liquid sample 1.
Sample 2: Blue stained bacteria were observed on the slide indicating the presence of non acid fast bacteria.
Sample 3: Same results as Sample 2.
Sample 4: This was our negative control for the experiment in which a non bacterial LB solution was stained to check for its sterility.

So, from the results, it can be derived that the bacterial presence in the soil samples collected are non-acid fast. This means that there are no bacteria of the mycobacterium family in the soil sample collected as the general acid fast bacteria are from the mycobacteria family. The indication of nonacid fast bacteria points to the general strains of E. Coli or Staphylococcus bacteria but further DNA analysis is essential to actually determine the type of bacteria present in the soil samples which we hope to achieve by PCR analysis.

*Biology Science Report - Christina Graves and Raj Patel Reporting*

**Objectives:**
Science objectives for the day were to perform chromatography experiments on soil samples, bacterial cultures, and isolated DNA, as well as to perform colony PCR and PCR using extracted DNA from soil samples as template.

A method for performing on-site PCR at the MDRS Hab in Hanksville, Utah, without a thermocycler is included. Verification of PCR products will be performed when back at our home university with appropriate equipment.

SET UP TIME: 11:00 AM
PCR BEGIN TIME: 11:55AM
PCR END TIME (35 cycles total): 3:30PM
TOTAL: 4HRS 30MIN

Background (PCR):
Polymerase chain reaction (PCR) is a common wet lab technique used to amplify a segment of DNA. Until this year, PCR has never been performed as part of an MDRS Georgia Tech rotation; and so, a feasible, on site PCR (while in sim) was developed.

A 16S rDNA PCR assay was chosen due to the conserved, universal sequences, and for ease in verifying these trial PCR methods.

Materials and Equipment (PCR):
- water bath set to 70C
- incubator set to 50C [Note: annealing temp. for GoTaq enzyme should be a few degrees lower than the lowest primer Tm]
- hot plate with beaker, for boiling water (95C)
- paraffin or mineral oil
- ice bath
- timer / stop watch
- 1.5mL centrifuge tubes
- 10mM dNTPs
- 10X Taq Buffer
- GoTaq Polymerase
- forward universal bacterial primer (from 16S rDNA) 5'-AGA GTT TGA TCC TGG CTC AG-3'
- reverse universal bacterial primer (from 16S rDNA)5'-GGT TAC CTT GTT ACG ACT T-3'
- template DNA
- p200 and p20 pipettes with appropriate tips
- thermocouple (water baths)
- glass thermometer (incubator)
- deionized water (dIH2O)
- aluminum foil
- lots of great music to keep you entertained: "We all live in a yellow submarine!"

Preparation and Procedure (PCR):
The water bath was set to 70C, the incubator to 55C, and a beaker with boiling water over a hot plate was also prepared 1 hour prior to beginning PCR. The water bath, and hot bath were rearranged to be in close proximity to the incubator, in order to minimize the amount of time the samples were exposed to room temperature. An ice bath was prepared using a styrofoam bucket and ice. [Note: it is important to set the incubator about 5-10C higher than the temperature at which you want to perform the annealing step; opening and closing the incubator door repeatedly throughout the process causes a significant amount of incubator heat loss. Additionally, be mindful to keep the incubator door closed during each cycle, opening it only to put in/take out a sample.] A piece of aluminum foil large enough to cover the top of the beaker with boiling water and capable of holding 10 samples (as shown in attached picture) was cut. Small holes were poked in the aluminum foil, equidistant from one another.

A PCR "master mix" was prepared on ice using 10mM dNTP’s (17uL), universal (16S rDNA)bacterial primers (forward and reverse, 17uL each), 10X Taq Buffer (136uL), dH2O (646uL), and Taq Polymerase (17uL). If not preparing a master mix, each reaction should be as follows:

38uL dH2O  
8uL 10X PCR buffer  
1uL 10mM dNTPs  
1uL 10uM Forward primer  
1uL 10uM Reverse primer  
1uL Taq polymerase

10 prechilled, 1.5mL eppendorf tubes were labeled, and 50uL of the master mix was added to each tube. To 5 (labeled 1-5) of the tubes, 1uL of template DNA (from soil samples 6, 7, 8, 2, 3 on 3/22-3/23) was added to the master mix (locations are noted below). To the remaining 5 tubes (labelled 6-10), the 50uL of master mix was inoculated with colonies picked from plates 6, 5, 3, 2, 8. To the top, 20uL of paraffin oil was added. Eppendorf tubes were capped and arranged in the aluminum foil. [Note: Do not attempt to perform the PCR reactions in the PCR tubes currently at the hab, using this methodology - they will explode; for this method, large eppendorf tubes and oil "caps" were found to be necessary].

The tubes were incubated for 5min. at 95C [initial denaturation], followed by (1) 1min. at 95C [denaturation]; (2) 1min.30sec. at 50C [annealing]; and (3) 1min at 72C [extension]. Steps 1-3 were repeated for a total of 35 cycles, followed by 5min at 72C [final extension]. The samples were then stored at 0C.

Background (chromatography):
While macrobiotic life is unlikely to exist on Mars, it is certainly a suitable arena for prebiotic chemical analysis; which may not only provide insights to evolutionary mechanisms on Mars, but also those that may have taken place on the early Earth. Of particular interest are the bases familiar to us: adenine, cytosine, and thymine [Note: we do not use guanine in these experiments because it is highly insoluble in water]. Finding areas or samples wherein these bases accumulate would be of great interest for evolutionary studies.
**Materials and equipment (chromatography):**

TLC plates (fluorescent)
large (500mL) beaker
dIH2O
filter paper (coffee filter will suffice)
UV lamp (short wave; 254nm)
straight ruler
pencil
saturated base solutions (adenine, thymine, cytosine)

**Preparation and Procedure:**

A 500mL beaker was set up, with 1.27cm of dIH2O. A coffee filter (wetted with water) was formed around the inside of the beaker (covering about half the circumference). A TLC plate was prepared by drawing a line lightly in pencil 3cm from the bottom of the plate. 9 hash marks were drawn on the line, equidistant from one another and at least 2cm from each side. Using capillary tubes, standards and samples were applied to the TLC at the indicated hash marks. The hash marks of indicated samples were as follows:

1) A (adenine)
2) T (thymine)
3) C (cytosine)
4) DNA from colony 8.2
5) DNA from colony 6
6) DNA from colony 2
7) DNA from colony 5
8) DNA from colony 4
9) DNA from colony 3.1

For the three bases (ATC), 1uL of each sample was applied. For the DNA samples, 1uL was applied and allowed to dry, 3 times sequentially to increase concentration and allow for visibility on the plate.

The TLC plate was placed in the chamber, making sure that the water began below the initial line. Aluminum foil was placed atop the beaker. After about 30min, when the water line was 3cm from the top of the plate, the plate was taken out of the chamber, the line solvent front was marked, and the plate was laid on a flat surface to dry. After drying, a short wave (254nm) UV lamp was used to visualize spots on the plate; and Rf's (retention factors) corresponding to the dark spots on the plate were calculated for all lanes.

**RFs:**

1) A (adenine) - 3.0/6.8cm = .44
2) T (thymine) - 4.9/6.8cm = .72
3) C (cytosine) - 4.2/6.8cm = .62
4) DNA from colony 8.2 - 3/6.8 = 0.44; 5.0/6.8 = .74; 6/6.8cm = .88
5) DNA from colony 6 - 3/6.8 = 0.44; 5.0/6.8 = .74; 6/6.8cm = .88
6) DNA from colony 2 - 3/6.8 = 0.44; 5.0/6.8 = .74; 6/6.8cm = .88
7) DNA from colony 5 - 3/6.8 = 0.44; 5.0/6.8 = .74; 6/6.8cm = .88
8) DNA from colony 4 - 3/6.8 = 0.44; 4.1/6.8 = .60; 5.0/6.8 = .74;
9) DNA from colony 3.1 - 3/6.8 = 0.44; 5.0/6.8 = .74;

DNA from all lanes exhibited a RF equal to that found for the base standards thymine and adenine. DNA from lanes 4-7 showed additional dark spots at Rf of .88 which did not correspond to any standard used. DNA from lanes 8 showed an additional spot at Rf .60, which may correspond to the cytosine standard used.

**Results:**
From these experiments, a standard protocol was developed for on-site PCR at the MDRS hab in Utah, for potential use by future crews. Chromatography results also show that this may be a viable method for "screening" samples for bases common to life as we know it on Earth.
6. Sponsors
Crew 101 received funding and support from several sources which we would like to thank:

Georgia Space Grant Consortium

Georgia Tech Student Government Association

The Honors Program at Georgia Tech

The College of Science at Georgia Tech

The School of Biology at Georgia Tech

The David Guggenheim School of Aerospace Engineering at Georgia Tech
7. References


