

Mars Desert Research Station

Initial End-of-Mission Summary

MDRS Crew 37

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<http://www.gtmars.org>

MDRS Crew 37

Hab Crew

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- Heidi M. Anderson: Public Affairs Officer, Logistician, Balloon Technician
- Kyle Brewer: Communications Engineer, Repeater Technician
- John A. Christian: Executive Officer, Navigator, Astronomer
- Rebecca Fink: IT Engineer, Biologist
- Douglas Martin: Mechanical Systems Engineer, Health and Safety Officer, Robot Climber Technician

Mission Support Team

- Emily Colvin: Mission Support Lead
- Prashanta Bagchi: Mission Support Specialist
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1. Overview

Crew 37 consisted of members of the *Mars Society @ Georgia Tech*, which is the Georgia Tech student chapter of the Mars Society, and the chapter's faculty advisor as mission commander. Six crewmembers were at MDRS, three more crewmembers ran Crew 37's own Mission Support Center at Georgia Tech in Atlanta.

The mission was proposed to the Mars Society in October 2004 and approved by MSHQ in November 2004. Detailed planning and initial training began in late 2004, and final crew selection took place in early February 2005. Crew 37 arrived at MDRS on 19 March 2005 and left on 03 April 2005.

The following science and engineering activities were performed:

- ? Development and testing of radio communication systems and techniques, including use of Automatic Position Reporting System (APRS) and a balloon-borne repeater
- ? Testing a tether-climbing robot for compatibility with EVA suits and general design evaluation
- ? Performing in-situ soil contamination analysis using an EVA suit-compatible measuring device
- ? Developing and applying navigation techniques and procedures, including GIS-based EVA planning, surveying of roads and waypoints, and overhead imagery analysis
- ? Performing numerous human factors experiments
- ? Installation of a water meter for improved water consumption logging
- ? Working on general MDRS engineering upgrades
- ? Providing ongoing GreenHab support

Along with this research, an outreach program covered Internet presence (at <http://www.gtmars.org>), interaction with local and national print and broadcast media, and auxiliary mission support activities by high schools and members of the Georgia Tech campus community.

The mission was made possible by the support of Crew 37's sponsors, which include: Vascent Internet services, Georgia Tech's Guggenheim School of Aerospace Engineering, the Liftport Group, the Georgia Tech amateur radio club, watermeters.com, and the Georgia Tech student government. However, all crew members also contributed substantially out of their own pockets to make this mission a success.

This end-of-mission summary briefly covers the key accomplishments and documents initial lessons learned and recommendations. A more detailed post-mission report will be compiled after Crew 37's return to Atlanta.

2. Research Program Summary

2.1. Radio Communication System and Techniques

2.1.1. APRS (Kyle)

The Automatic Position Reporting System is a protocol for sending location (GPS) data via radio between locations. Crew 37 successfully employed this system for real-time tracking of EVA missions. We learned a number of limitations of the system, but highly recommend it for future Mars crews, real or simulated. We tried the system in a few different APRS configurations during our mission. We used the following equipment for these tests: Two Kenwood TH-D7A handheld ham radios, a Kenwood TM-D700A mobile radio, a Garmin Legend GPS receiver, and the UI-View APRS mapping software.

Direct APRS is the simpler of the two methods: a beacon station (handheld radio + GPS) is carried by the EVA team and the radio signal travels directly to the Hab. This technique is extremely useful as it provides a map of direct radio access. We used this method as a baseline for "normal" communication availability. Obvious holes in communication were apparent in areas to the north along Lowell highway and to the west over radio ridge.

Moving up one step in complexity, a repeater station can be used to relay the APRS information over a hill, or from a hilltop near the Hab that is higher than placing antennas on the roof. The TM-D700A radio has a "digipeater" capability built in, so implementation was not difficult. A plastic container containing the radio, a lawn mower sized battery, and a mag-mount antenna was assembled which could be placed in the field during or before an EVA. When this device was placed on Radio Ridge, coverage to the east and west of the Hab were great. For coverage to the north, the repeater box was placed on the new-named "Mount Nutella." From this vantage point, Lowell highway has coverage until just before the "Family Crest" waypoint. What's significant about this coverage is that if an APRS signal can make its way back to the Hab for a location, a voice signal could as well. More on that topic below.

One of our proposed uses of APRS was the idea that the unsuited crewmember could sit in the hab and essentially take notes for the EVA crew and correlate those notes to their position as reported by APRS. Based on our experience, this is not as functional as it might seem. The EVA crew can readily set GPS waypoints and take notes in the field, while the APRS signal only updates about once a minute, has two decimal degrees accuracy, and uses the wrong GPS datum and coordinate system. Also, for the Hab crew to take notes for the EVA team, a reliable voice link must be available, which was not often the case during our mission.

We proposed that APRS could be used to map terrain. Again, after a full mission of test runs, we decided that it is far more practical to use data stored in the GPS during the EVA to create map points. But, the technique could be used if absolutely necessary.

One of the "cool" features of APRS is that there is an infrastructure available to post APRS data to the internet. For our last two EVAs, we utilized this feature, allowing observers to track the EVA real-time from their home computers. While this

is cool for general tracking of stations driving around town, it becomes a key element for involving the public in a future Mars mission. We live in a time of high information demand; the public wants to know everything that is happening, right now. The publicity plan of a future Mars mission would be well served having "live" updates of mission status and EVA progress. Our suggestions would be: frequent updates, reliable internet connection, and custom software which includes preplanned routes, waypoints, and information pertinent to the EVA.

2.1.2. Repeater System (Kyle)

Crew 37 proposed the use of a balloon-based repeater system which would allow for the deployment of a radio system near the Hab to a height above average terrain. This is a far more practical from a weight standpoint than carrying a radio tower to Mars and more practical from a crew time usage standpoint than traveling to some nearby hill or mountain to set up a remote station.

The balloon we used is described in a separate section of this report. The radio used for the repeater is a crossband capable handheld: Icom IC-W32A. This radio can retransmit what it is hearing in real time. We were severely limited by windy weather. Each time we put the balloon up, attached the radio, and prepped the crew for EVA, enough time had passed for the winds to pick up and necessitate bringing the balloon to the ground and deflating it.

While we were not able to perform thorough field testing of the system on the balloon, we believe that the concept of a balloon system is still quite valid. From our experience with APRS, we believe that for full testing of the extended coverage capabilities, the balloon should carry an APRS digipeater, as discussed above, in addition to the voice relay radio. Equipment was not available for that particular function on this mission, but can be readily created from COTS (commercial off the shelf) equipment. (The mobile radio mentioned in the APRS section was far too large and heavy). Using a system with both voice and APRS is highly beneficial for both testing and operation. The APRS provides mapped coverage data and the voice link allows for EVA-Hab communications.

2.1.3. Balloon and Robotic Climber

The terrain of the most scientifically rewarding landing sites on Mars will likely be as rugged and varied as that around MDRS. Reports from previous crews and our own experience at MDRS suggests that communication using ground-based line-of-sight FRS radios is insufficient to allow the EVA team to maintain constant contact with the hab during extended EVAs. In the event of an emergency in such a hostile environment, continuous communication with hab crewmembers would be extremely important.

Before heading leaving for MDRS, the crew designed and built a balloon based repeater system. For more information about the repeater, see the radio section of this report. The balloon used was a 10 ft spherical helium balloon (manufactured by Arizona Balloon Company) and loaned to us by the LiftPort Group. During our two-week rotation at MDRS, we launched the balloon twice for a few hours at a time (longer duration flight times and an additional launch were prevented by high winds).

In addition to the balloon, the team also tested a robot capable of climbing a ribbon suspended from a balloon. This robot was designed and built by the LiftPort Group, who requested that our team test the device in the field. Before testing the climber on the balloon, the team put it through a set of tests inside the hab. The climber was tested in the field during the second balloon launch. Unfortunately, the test was cut short due to motor failures in the climber system. These failures were attributed to the ribbon binding and creating an excessive load on the motors.

2.2. Navigation Techniques

2.2.1. GIS-based EVA planning and mapping

We made extensive use of GPS-based EVA navigation and surveying. Field data from our WAAS-enabled GPS receivers was generated during each EVA, uploaded onto our laptops using free software (GPS TrackMaker, www.gpstm.com), and processed using GPS TrackMaker and an Excel database. Prior to the mission, a large topo map was created by combining digital raster graphics of the USGS Skyline Rim 1:24000 map with the eight adjacent maps. Processing included:

- Creating new waypoints from field survey data
- Reducing GPS tracklog information for dirt road mapping
- Plotting waypoints and roads onto the digital map
- Planning EVAs by creating routes on the screen, then uploading them to our GPS units, and by printing customized maps on the hab printer

The combination of standard and free software worked out exceedingly well for us, since everyone involved could install their own copy without additional cost. All mapping files and up-to-date waypoint and road survey data was put on a CD-ROM and left at the hab for subsequent crews.

2.2.2. Use of Overhead Imagery by Off-Site Support Personnel

Using overhead images and topographical maps of the MDRS surroundings, our Mission Support Center Atlanta planned a pedestrian EVA route that successfully identified a navigable path through otherwise rugged terrain. This demonstrated the value of an integrated GIS setup for EVA planning and post-processing that was shared between the hab and mission support.

2.3. Environmental Impact Assessment

The presence of MDRS crews undoubtedly affects the local desert environment. One of the research objectives of Crew 37 was to establish a baseline for the environmental impact of MDRS operations on the local environment. Such an assessment was accomplished by in-situ analyzing of surface soil samples from various locations around the Hab. A Photo Ionization Detector (PID) was used to detect volatile organic compounds as indicators of anthropogenic contamination. Our handheld PID sucked in air from around a sampling site which was then passed through an ultra violet light. There, the organic compounds were ionized and the ions then collected on electrodes. The resulting voltage was converted into a Parts per Million (PPM) readout on the screen. The PID, which was rented from Pine

Environmental in Atlanta, was crucial in this research and worked flawlessly. The data collected from this research is currently being analyzed and will be submitted to the Mars Society.

2.4. Human Factors

Due to the unique importance of Human Factors to long-duration manned space exploration missions, and given the unique environment that MDRS provides, several Human Factors research projects were performed during Crew 37's rotation. Their evaluation will be completed after the end of our mission and formally published in the appropriate forums. Copies of any resulting papers will be forwarded to the Mars Society.

The Human Factors research program included the following experiments:

- Mars Analog Station Cognitive Testing (MASCOT): This experiment provided insight into the quantitative development of test participants' cognitive performance over time, while a variety of external and internal stressors caused by simulated exploration mission activities, station systems operation and group interaction affects the crew. It is based on the Spaceflight Cognitive Assessment Tool for Windows (WinSCAT®). WinSCAT is a participant-administered, self-contained computer-based battery of four neuro-cognitive assessment tests that allow participants to objectively evaluate brain functions. WinSCAT was developed for NASA's ISS program at Wyle Laboratories in Houston, TX, and its program manager will be involved in the proposed research.
- PHADES Habitability Survey: This long-term experiment collects feedback from space and analog-environment crews regarding the design of their habitats. PHADES is based on the use of a standard survey form.
- Crew Mood Observations: Crew members recorded their subjective impressions of crew mood and other intangible crew performance parameters, in order to provide context for other Human Factors experiments and for post-mission evaluation.

2.5. Astronomy

The GT team originally planned to collect data of a variable eclipsing binary star system in support of an ongoing project led by Dr. Robert Zavala of the U.S. Naval Observatory in Flagstaff, AZ. There were two eclipses of the eclipsing binary *RS Canum Venaticorum* during the expedition. Unfortunately, the Musk Observatory was not operational during our entire rotation due to a missing motor control board. Because of this, we were unable to complete any of our astronomy science objectives.

Early in our rotation, high winds caused the shutter on the observatory to come open, risking damage to the dome and telescope. We employed the following strategy to secure the dome for the rest of our rotation:

- One ratcheting tie-down was used to secure the bottom panel. A piece of cloth was placed between the ratchet and the dome to prevent scratching. This tie-down is hooked onto bolt ends which extend through the sides of

the dome. These bolts were placed through pre-existing holes and have large washers on both head and nut for sufficient strain relief.

- One ratcheting tie-down was used to secure the top panel. This tie-down uses a different set of bolts, but is otherwise just like the one just described.
- The orange and black rope previously used to keep the top panel on (it was attached to the wood screw that was ripped out) was run from a tie-down point within the dome (the cleat originally meant for the blue cord use to move the top panel), through the hole in the top, and attached to the tie-down securing the bottom panel. This rope serves a double purpose: it keeps the lower tie-down from slipping off the lower panel and provides extra securing force to the upper panel.
- The hole in the top was covered with plastic from a heavy duty freezer bag; it is being held down by duct tape from underneath. For redundancy, duct tape was also used to seal off the inside of the dome hole. This assembly is shaped such that any water that comes through flows along the black/red rope down to the side of the dome and clear of the telescope equipment.
- The tarp covering the telescope was secured such that if panels were to open again, the tarp would not fly off leaving the telescope unprotected.

2.6. Water Consumption Logging

Water consumption is also important in terms of a crew on Mars. While we have as much water as we need here on Earth, a Mars crew will have a limited water supply. Watermeters.com donated one of their DLJ contact head water meters. This unit outputs a pulse for every gallon that passes through it. Therefore, it can be easily hooked up to a data logger for real time water consumption data. The meter also has a traditional accumulating counter that shows how many gallons have passed through it since its installation. This meter was hooked up the first day at MDRS and has been invaluable in keeping an accurate measure of our water usage, and it will continue to do so for many crews in the future.

2.7. MDRS Engineering Upgrades

The Georgia Tech team has coordinated with the MDRS engineering task force to perform necessary upgrades to the Hab. The team has a strong and diverse engineering background that has proved very useful in performing MDRS maintenance and upgrades. In our two weeks here we have used much of our free time to continue to upgrade and improve MDRS. Not only through our planned research upgrades such as the water meter, but also continuing work set out by the engineering task force. The following is a list of some of the many things we were able to implement.

- Adjusted and refit all internal swinging doors.
- Added a lock bolt to the inside door of the secondary airlock

- Connected external weather station to the second hab laptop, installed Boxcar software and started logging weather data. We also ran a quick CFD analysis to assess the location of the weather station's anemometer.
- Moved contents of "secondary pile" to main "Antarctic pile".
- Moved old barrels of diesel fuel to main engineering.
- Fastened internal water tank feeder line.
- Bolted down ladder to attic.
- Secured LP alarm.
- Rebuilt internal aft air-lock door.
- Replaced 500 watt halogen light fixtures with fluorescent light fixtures.
- Installed new 12-Volt internal water pressure pump.
- Installed water meter.
- Installed various receptacle cover plates.
- Removed old internal water tank fill line.
- Filled in hole around grey-water tank.
- Removed old unused electrical outlets.
- Calked south facing window to reduce draft.
- Helped install Casper the friendly generator.
- Cleaned and oiled brass bearing in the Shopvac motor assembly.

2.8. GreenHab Support

During this rotation, Crew 37 performed GreenHab maintenance and upgrades as needed or instructed. We made several improvements that have allowed a consistent, cleaner (and less smelly) toilet flush water supply. At the beginning of the rotation, the gray water holding tank outside the hab appeared flooded and there were frequent problems providing enough flush water to the toilet. The levels in the aquatic tanks were somewhat below the nominal level and only appeared to get worse despite the large amounts of grey water fed to the system each day. After analyzing the system and updating the posted plumbing diagram to reflect the as-built status, the following actions were taken to return the GreenHab to working condition:

- Replaced filters between Tank 5 and TST
- Removed some dead floating material from aquatic tank surfaces
- Installed fuse for pump from TST to toilet
- Reset float switch to allow more water in the TST
- Reset breaker switch for holding tank pump after every power loss (Note that this is no longer necessary as a regular maintenance item, as the generator no longer needs to be turned off for fueling.)

In addition to the above actions, Crew 37 watered the plants in the aft portion of the GreenHab daily. The new water hyacinths and duckweed brought by Dave Blersch at the beginning of the rotation appear to be developing nicely, but the potted plants were in bad shape originally, and do not appear to have made any significant improvements.

In summary, the GreenHab has been running stable for over one week and we always had enough flush water. The incoming Crew 38 was given a thorough briefing on peculiarities and procedures related to the GreenHab.

3. Outreach Summary

The purpose of our outreach was to inform and connect with people interested in space exploration. The target group ranged from elementary school students to people in industry. To accomplish our goals, we intended to make our research accessible and pertinent to our target groups. We wanted to make the information that is being exchanged with the target groups to be both beneficial to the simulation program as well as to the offsite participants.

3.1. Internet

We created an interactive website (<http://www.gtmars.org>) supported by our sponsor Vascent Internet services in Atlanta, and run by members of the Mars Society @ Georgia Tech mission support team. The site includes an updated section with daily reports, pictures, and videos as well as a forum to stimulate MDRS-related discussions. This website has been close to real-time information on mission progress.

3.2. Broadcast and Print

Although we were mildly successful with projecting our mission to the Georgia Tech campus, we were very successful reaching out to the greater community. MDRS Crew 37 was repeatedly interviewed by WXIA Channel 11 news in Atlanta. The Channel 11 cameraman filmed the crew both before and during the rotation. Also during our rotation we had a reporter from the The Daily Mail in London, England interview us. We were featured as the center page spread and have heard nothing but positive remarks from the reporter about the readers' responses. Additionally, The History Channel sent out a crew to film us as part of a Modern Marvels episode. The History Channel team interviewed Jan, the crew commander, and filmed crewmembers doing various in-sim activities such as suiting up and going on a long-range EVA. In the future we hope to continue sharing our stories and promoting MDRS through Georgia Tech's student newspaper, the Technique, and other local media.

3.3. Educational Outreach

Our main educational outreach was linked to running our own dedicated mission support center. This effort involved members of the Georgia Tech Mars Society, and students from Marietta High School and the Indian School Al Ghubrah in Muscat,

Oman. During our preparation time before our rotation we presented our research goals and Mars Society background to students at Marietta High School. The Georgia Tech mission support center has been more than helpful by sending us daily news information, keeping our website up-to-date, and even doing a Computational Fluid Dynamics (CFD) model of the Hab in windy conditions to assess the anemometer location of the GreenHab weather station. The Marietta High School students also prepared a pedestrian EVA route that we successfully followed in the field.

After our return, we plan to make presentations to K-12 school students to elevate interest in engineering and space exploration. We also hope to present to college-age audiences and above to increase awareness of MDRS and the Mars Society.

4. Lessons Learned

This section documents some initial lessons learned and recommendations from Crew 37 to the Mars Society MDRS team and to subsequent crews. The final report will likely contain more detail and additional recommendations.

4.1. Contributors to Mission Success

- Thorough crew selection process and intense crew training and familiarization activities that started months before the crew's departure to MDRS. Specific training activities included:
 - Medical training (two-day "Wilderness First Aid" class offered by Wilderness Medical Associates)
 - Two-night winter hike in the North Georgia mountains, with hands-on training in GPS, radio communications, navigation and general backcountry skills (this activity also provided observational data for crew selection)
 - Weekly in-person meetings for mission planning and briefings
- Crew selection focus on achieving a balanced set of skills and experience, with emphasis on practical abilities, high work ethic, general professional skills, and interpersonal compatibility
- Can-do spirit and hands-on engineering skills of every single crewmember - after all, everyone was "Ramblin' Wreck from Georgia Tech and a hell of an engineer" :-)
- Every crewmember has their own laptop and all productivity software the need for their areas of responsibility
- Use of commonly available or free software for key applications (such as GIS) so more people can get involved

4.2. Obstacles to Mission Success

Not much went wrong during our rotation that we could not overcome, but a few obstacles that could have been addressed before the mission are:

- Our astronomy research objectives were not accomplished because the Musk Observatory was inop throughout our mission, and the spare part required to fix it was not provided. The observatory should allow for manual operation if the complex control system is down.
- Battery life of most handheld devices is too short for a full day of operations.
- Wind at the hab can be strong for days – be sure to plan for that if you have any wind-dependent projects (e.g. balloons...)
- The FRS-based hab radio system is too weak for long-range EVAs. Plan to bring your own comms (or convince the powers that be to put some amplifiers in the RF line that leads to the remote antenna on Radio Ridge – even though the antenna is in a great location, the existing setup is not powerful enough for a 500m antenna wire)

4.3. Logistics

- Find out what is available ahead of time – bug the previous crew if necessary
- Make detailed shopping lists
- Buy more food than you think you need
- Make check lists of duties
- Rotate the Hab chores
- Keep a close count of trashbags, toilet paper, and paper towels
- Remember that everything takes twice as long as you think it will
- Know that things will not always go according to plan, so be creative

4.4. GreenHab

- Take time to understand the system at the beginning of the rotation.
- Check filters weekly and change when necessary. Request filter resupply well in advance.
- Monitor the health of the aquatic tanks daily and try to keep them as free of dead material as possible.
- Check the pump to the holding tank frequently to prevent flooding.
- Perform a thorough hand-over to following crews.

4.5. Balloon

Here are a few observations for future crews who may be interested in launching a helium balloon at MDRS:

- Don't drive stakes in EVA suits. It can be done, but it's very hard work, wastes crew time, and can lead to damaged stakes.
- Bring extra stakes.
- Filling the balloon requires 6 out-of-sim people:
 - Balloon holder (takes primary weight of filling balloon)

- Balloon filler (keeps fill tube in right place)
- Tank monitor (responsible for the tank valve)
- 2-3 spotters (don't let the balloon bounce around and hit anything.)
- 1 documenter/extra set of hands
- Servicing the balloon requires 3-4 people (radio changeout, switching tethers)
 - Balloon holder
 - 1-2 spotters
 - 1 servicer
- Bringing the balloon down requires 3 people
 - Balloon holder
 - 2 spotters/deflators
- Everyone should wear quality leather gloves
- Using a tripod tether system is a good idea in high winds. The extra lines serve as back-ups, should the main line (or its anchor stake) fail.
- Fill the balloon slowly. This prevents the helium from getting too cold.
- Measure the lift of the balloon using weights.
- Layout all lines ahead of time, with the attachment point downwind from your stakes.

4.6. Running a Mission Support Center

From running our own Mission Support Center on Georgia Tech campus in Atlanta, we learned several lessons about what mission support needs to do, how it works, etc. Even though most crews will not have their own mission support center, this is what we learned from running ours:

- Make sure the email address you are using has posting access to the hab mailing list.
- Have a few people working at a time – you end up with some downtime, but it's a lot more fun to be with other people.
- Communicate a lot. Make sure everyone knows what they're doing and what's been done. We didn't really have a list of things that the team for each night was supposed to be doing, and we really should have.
- Start late, end later. The crew isn't even going to eat dinner until at least 1800 or 1900, MST, so if you're there before that, you're not going to have anything to do.
- Make sure you can use the software you'll have to use beforehand – even if it should be self-explanatory. You may be surprised.
- Have fun – bring food, games, whatever. Get to know the other people you're working with. Everybody brings something different to the team.
- Spread people out more – even meeting twice during the week is a lot for any one person.
- Have someone check for last minute reports in the morning if you're operating in an eastern time zone – if they send something right before they go to bed, chances are the mission support team is already gone.

4.7. Miscellaneous

- We all had a blast and are proud of our accomplishments. There will definitely be a Mars Society @ Georgia Tech proposal for a 2006 mission to MDRS.