Commander's Observations: NASA Spaceward Bound V / MDRS Crew 61

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ABSTRACT

Conducting simulated space missions in analog facilities on Earth has valuable lessons to teach engineers, managers, students, and potential crewmembers that will improve designs and operations of the actual missions. That is why the Mars Society built, maintains, and operates these types of facilities, including the Mars Desert Research Facility (MDRS) in Utah, and why NASA sponsors the "Spaceward Bound" education outreach program at the MDRS and other sites. The author served as Commander for NASA Spaceward Bound V / MDRS Mission 61 in April 2007, and has spent the past three years building lunar habitat mockups at the NASA Johnson Space Center. This paper shares lessons and observations from his two-week experience in the MDRS that he is incorporating into this work at NASA-JSC, and compare and contrast his findings with those reported by the FMARS 2003 crew and Zubrin's "Mars on Earth".

INTRODUCTION

Whether the destination is Mars, the Moon, or low-earth orbit (LEO), part of the preparation for a manned space mission is to conduct simulated missions in analog facilities on Earth. For the past three years, I have been working as part of a team of engineers, scientists, designers, and technicians building lunar habitat mockups at the NASA Johnson Space Center (JSC). To help me develop a "user/crewmember" perspective that I could apply to my work, I volunteered to live in the Mars Desert Research Station (MDRS), a planetary analog base located in the remote desert near Hanksville, Utah (Figure 1).

Figure 1. The Mars Desert Research Station.

I felt the MDRS would be a good place to obtain this education, because of its similarity to one of the

lunar habitat mockups our team had recently completed (the Vertical Axis Lunar Habitat Mockup, pictured in Figure 2), and because of its remote location and relatively extreme environment. I'm convinced the best lessons regarding lunar/Mars habitats are learned at just such a site *in the context of conducting exploration*. As Zubrin writes in "Mars on Earth", "Psychological studies of human factors issues, including isolation and habitat architecture, are nearly useless unless the crew being studied is attempting to do real work."[9]

Figure 2. The Vertical Axis Lunar Habitat Mockup at NASA-JSC.

In January, 2006, I and a couple of my JSC colleagues visited the MDRS 42 crew [2]. We learned a lot just from a single day with them, and I was convinced I needed to experience a full rotation firsthand. I was provided with that opportunity the next season, when I was invited to join the final crew of the season, a fifth NASA Spaceward Bound crew, and to serve as the crew's Commander.

MDRS CREW 61

Crew 61 (shown in Figure 3) was a diverse crew, selected from a pool of NASA Spaceward Bound applicants.

- Executive Officer Alex Diaz. Alex was a graduate student at UCLA, has roots in Peru, and is a full-time engineer at Boeing. Alex previously commanded MDRS Crew 27 in 2004, and would have been an excellent choice to command our mission, but instead chose to concentrate on his planned EVA program. I found him to be a kindred spirit and we worked extremely well together.
- Crew Engineer Marcus Medley. Marcus was a Junior at the University of North Carolina at Charlotte. He was a whiz at keeping our systems running and always looked cool doing it.
- Crew Geologist and Astronomer Elizabeth Wolfe. Elizabeth was born and raised in Colorado, attended the University of Colorado at Boulder, and personifies the bold explorer archetype. She volunteered to be our Journalist, and wrote lively chronicles.
- Crew Biologist Pieter Jan Asbroeck. "PJ" lives in Belgium, and was a very agreeable, helpful crewmember. He also had a paramedic background, so he was a natural choice to be our medical officer. The Belgium media covered his rotation like he was a rock star.

- Crew Physicist and Radiation Specialist Irene Schneider. Irene was earning her doctorate at Penn State University. She hails from Spain, and has a truly engaging personality.

Figure 3. MDRS Crew 61. Front: Medley, Wolfe.
Middle: Schneider. Back: Diaz, Jan Asbroeck, Shepherd.

MDRS Crew 61 accomplished a great deal. Among other things, we helped the University of North Dakota demonstrate their extra-mobile NDX-1 spacesuit, the State University of New York at Buffalo to try out their custom EVA tools, conducted an extensive EVA program ourselves, built an ATV-mounted EVA stretcher (Figure 4), and equipped the MDRS with simulated emergency air units. For more details about the accomplishments of Crew 61, the reader may refer to our summary report on the MDRS website [4].

Figure 4. "Injured" crewmember being transported on the ATV-mounted stretcher.

THE MDRS

Many papers have described the MDRS in depth. Osburg 2003 [6] includes a very good description. Briefly, the MDRS is a two-story structure with two airlocks, EVA suit and equipment area, labs, staging area, bathroom and shower downstairs, and six separate crew quarters, galley, eating area, office/work areas, communications upstairs (Figure 5). There is also a storage loft that has the interior water supply, hot water heater, emergency exit, and sometimes serves as a sleeping area for visitors and handover crew. Outside is a "GreenHab" that biologically filters gray water and grows a few edible plants, a fleet of ATV's, and an observatory.

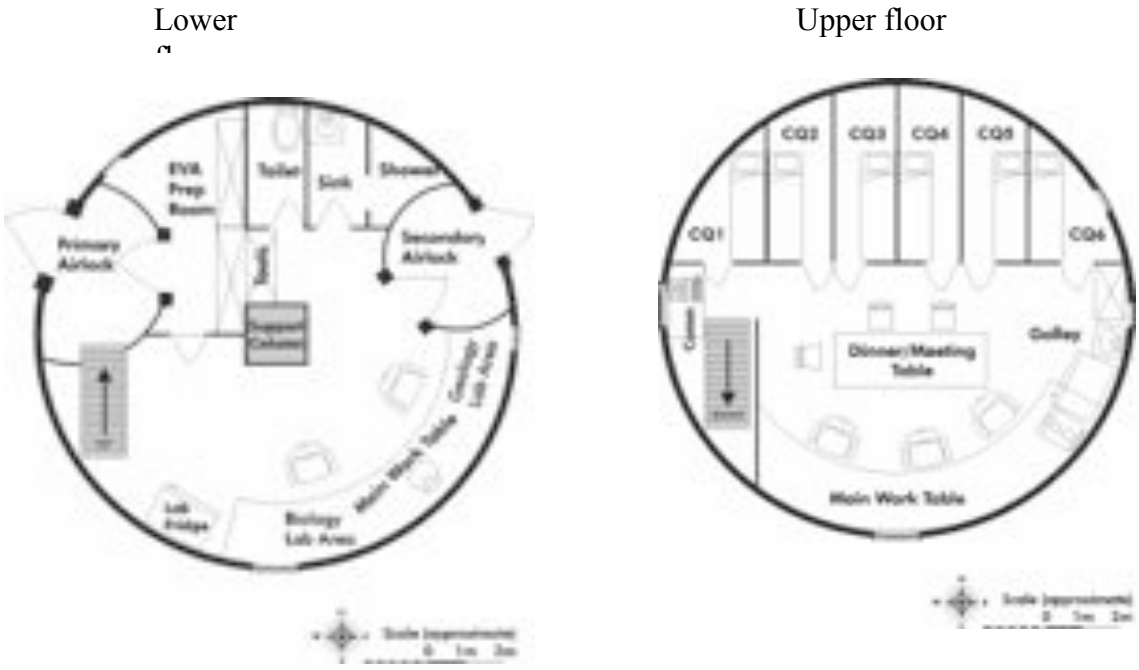

Figure 5. MDRS layout.

LESSONS LEARNED: COMPARISON WITH MDRS MISSION 5

I learned many valuable lessons that I have been incorporating into my work at NASA JSC. Osburg wrote about the lessons that MDRS Crew 5 learned at the MDRS and numerically listed their observations [6]. In this paper, I build upon their comments with my own, and the numbers I use below correspond to the ones used by Osburg. If I don't comment on one of their findings below, the reader may conclude that I am in general agreement with their statements.

I emphatically agree with Osburg's comments #2, 11, 14, 16, 18, 33, 35, 37, 42, 48, 49, 61, 62, and 64. I have further comments for the following of Osburg's observations:

9. "High ceiling on upper floor of hab gave feeling of spaciousness." I agree with this, and feel it contributes to long-term habitability of the module, but some of our lunar habitat mockups at JSC have featured high ceilings and this has been generally perceived by our evaluators as being a waste of limited volume. I anticipate that NASA-sponsored habitats will *not* have high ceilings.

14. “Useful galley equipment: breadmaker (availability of fresh-baked bread boosted crew morale and improved diet while requiring only minimal effort), crock-pot-style slow cooker (low crew time and power requirements).” We never used a crock pot, but I could certainly see the benefit. However, we used our breadmaker, coffeemaker, and microwave oven daily. I believe NASA's “100% ready-made” Shuttle/ISS food system is acceptable for short/medium lunar missions, but not for Mars missions. NASA should start development of these common kitchen appliances and use them in the Lunar base so they will be well tried and true by the time we send the next-generation flight units to Mars.

20. “Crew quarters doors should have ventilation slats and 'windows'.” At a place that has little enough privacy, I think adding these features to the doors would take away even more. In addition, from time to time, crewmembers need to be able to conduct a private conversation. When Alex and I needed to discuss something privately, we would simply shut the door to one of our crew cabins and turn on a CD or DVD player. As long as we kept our voices low, we couldn't be overheard. Cutting more holes in the door will sabotage this function, and I didn't find the ventilation to be that bad.

21. “All crew quarters should feature outside windows.” Before I went to the MDRS, I would have automatically agreed with this statement. Now, I'm not so sure. Windows weaken your outer structure and increase your overall leakage rate, therefore a habitat's structural engineers fight for fewer and smaller widows while human factors engineers and crewmembers, based on all flight experience to date, fight for bigger and more windows, especially in the crew quarters. I agree that some windows are necessary, but since my MDRS mission, I see the driving requirement on quantity and location as operations, not habitability. I explain more about that further in the paper.

28. “A fail-safe backup toilet system is crucial to crew health and morale.” I couldn't agree more. Every time our toilet failed, it immediately became first on my list to attend. I got it working again every time, but I don't like to contemplate what would have happened if I hadn't. And yet, our JSC mockups that had two toilets were deemed wasteful, and our current layouts feature a single unit.

31. “Lots of filing cabinets and shelves are needed in work areas.” Storage space is always appreciated and we are planning to fill every nook and cranny we can, as we've seen in submarines. But it actually surprised me how extremely little paper we used during the Crew 61 rotation. I've also noted that our baseline Crew Exploration Vehicle (CEV, or Orion) does not plan to send a printer or hardly any paper at all. We're going to have an electronic-based base, and filing cabinets, in my opinion, will probably not be a high demand.

45. “Not having a mattress on bunks in crew quarters improves hygiene, while crewmembers' personal self-inflating mattresses provide sufficient padding.” Our crew was told that no one has to bring mattresses to the MDRS anymore, because so many others have already brought foam padding and donated it to the Hab (not wanting to take it back with them on their return flights). There are plenty of individual pads to create your own mattress however deep you want (Figure 6). And there will be an abundant amount of foam padding sent to Mars on logistics shipments to protect portable hardware, which could be cut to size and unwrapped at the final destination and used in the bunk areas. I think we can design our lunar/mars bunks without any mattresses and let the crew use their own sleeping bag and foam sheets from logistics flights to customize their own crew quarters.

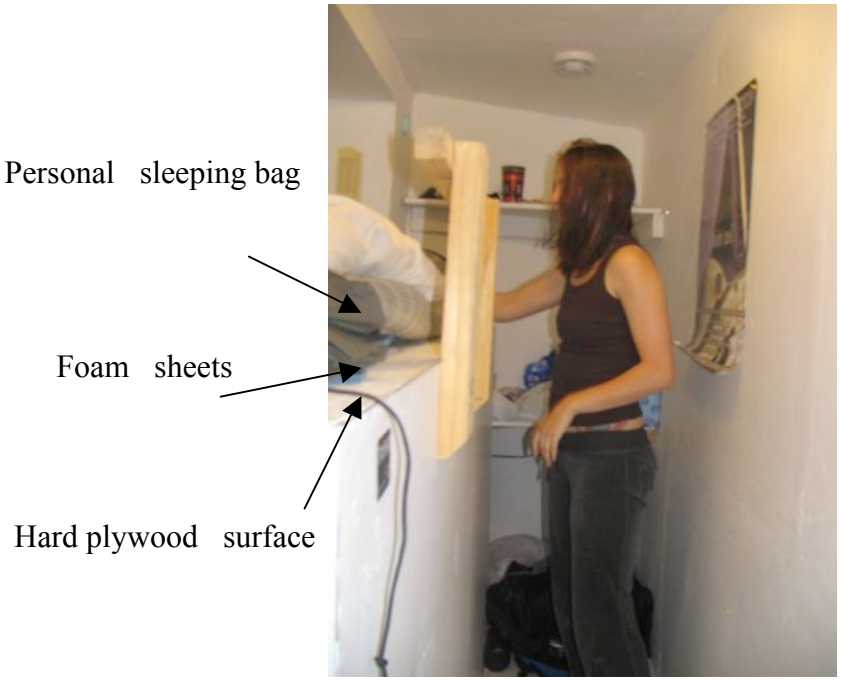

Figure 6. MDRS crew customize bunks with foam sheets.

46. "In the early phase of a simulation facility's life, on-site technical support is needed to fix mechanical and electronic problems quickly that are frequent during set-up and initial simulations." This support is also needed more towards the end of a season, when your facility has accumulated a lot of use, and as it gets older. During Crew 61, we were the final crew of the season and the MDRS had a number of such breakdowns (a faucet handle that came off in our hands, only one functional ATV, Greenhab parts that needed to be replaced, etc.).

I have other observations to add, and do so by continuing Osburg's numerical system:

65. After the handover is complete, and the former MDRS crew has left, a new MDRS crew should spend at least a couple of hours cleaning the Hab, before they settle into it. Yes, the Hab has just been cleaned, but by a crew that is about to leave it, not by a crew about to live in it. There's a big difference. By doing this, the new crew can enjoy the results of their labor for the next 14 days, and their final clean-up at the end of the rotation will be that much easier to accomplish.

66. After this cleanup and settling in has been done, a new crew might want to take a group hike. Doesn't matter where, almost any direction from the Hab offers spectacular scenery. It's a good way to bond as a crew, get oriented, and get the crew talking informally to one another. This was suggested to me by a former Commander, and I think it worked great for our crew.

67. In an unnumbered comment, Osburg states that "the crew had brought DVDs to run on personal laptops, as well as a computer projector and a screen." Crew 61 also enjoyed the use of a computer projector for watching DVD's, selecting *as a group* which daily photos to post, and receiving presentations from visitors. It's a versatile machine, able to be re-located at will, and it's much more comfortable to conduct these activities with this device than huddled at the table

around a single laptop. I also note that this equipment weighs much less than having several flat screens mounted about the Hab, so we are designing our mockups this way. Keep the big flat screens at home, and send a portable LCD projector and screen to Mars to work with the crew's laptops.

68. In another unnumbered comment, Osburg says "the basic design of MDRS...seems appropriate for the support of human operations on a planetary surface." I agree, and it helped me to answer a debate we've often had at JSC: If you have two stories, do you put the crew habitation areas on the top or bottom floor? Each has their pluses and minuses, in radiation protection (bottom floor is better protected, so sleep there), habitability, operations, etc. But the MDRS, for me, demonstrated the key driver: put the work areas near to where the work is, and the habitable areas after that. For a lunar or Mars base, the work is outside, on the surface. So you put the airlock, rover and suit maintenance, and labs nearest to the surface; i.e., downstairs. Otherwise, you're dragging the work (the rocks, the dust, the tools, etc.) through the habitation areas, which makes the work harder and habitation areas much less habitable.

69. When I discuss the mission, the most common question I get is "What was the toughest part?" We certainly faced our share of difficulties, but my answer comes quickly and for me nothing else comes close --- it was being away from my wife and school-age daughters. It's not a new finding, but is worth repeating: separation from loved ones is tough, and getting by on a series of one-way communications is not fully satisfying, but due to communications delay that's what Mars crews will face.

70. A lunar base does not have the same communications delay that a Mars base will have. Thus, our lunar habitats have requirements to support private medical conferences and real-time communications with family, press, and mission control that are not possible on a Mars base.

71. I was impressed with the thick plastic "barrier" that divides the recycling side of the Greenhab from the greenhouse side. It even keeps the smells isolated. I am incorporating this observation, together with a low step-over barrier, as a possible means of dust mitigation in our lunar habitat mockup. Perhaps the MDRS should consider doing the same in their EVA preparation area to mitigate dust?

72. At the MDRS, showers are not an everyday occurrence. In fact, they are dependent on a number of resources to all be working (water outside, water inside, storage capacity in the holding tank, water heater, gas supply, electricity, pumps functioning, etc.). I had to cancel them more than once because one or more necessary sub-systems was running low or malfunctioning. Since showers do not occur all that frequently, I am no longer in favor of allocating dedicated volume to the performance of this activity. Instead, I advocate combining this function into the bathroom (as done in RV's, boats, and Amtrak train cars) and turning the dedicated shower stall into a second combination bathroom/shower in our mockups, which then provides a backup toilet.

73. We don't have a clothes washer/dryer at MDRS and we didn't need one during the Crew 61 rotation. But if we had (for instance, if I had spilled my lasagna all over my shirt), I would have used our handy multi-purpose bucket with a little dish soap. I think taking this approach for lunar/Mars bases would be much simpler and save many millions of dollars over a NASA-developed laundry facility. As Stuster points out in "Bold Endeavors"[8], polar expeditions travel with a minimum of clothes; in one example, it was two shirts to last four months (one

side of a shirt for each month). He states that "human tolerance concerning this issue (clothing) is extremely elastic." This is one area where I believe the camping metaphor is applicable.

74. We used the MDRS dishwasher machine at first, but it sprang a leak at the faucet connection a few days into the mission, and I, for one, just couldn't trust it after that. It didn't hold a whole lot anyway and the rest of the crew agreed the benefit wasn't worth the counter space so we put it away and hand-washed for the remainder of the rotation. Over the course of a whole mission, I think it's dubious whether an automatic dishwasher saves enough crew time to be worth its cost, weight, volume, resources, impacts to other sub-systems, and maintenance to send one to Mars. There's probably a lot more valuable supplies and contingency items we could send instead.

75. I donated ten surplus Russian gas mask kits to serve as volumetric simulated emergency air kits in the MDRS (Figure 7). After all, a real Mars base would have such kits taking up room inside. After consulting with the crew, we decided to place one inside each crew quarters and the other four in key locations (top and bottom of stairs, bathroom, EVA preparation area). This is interesting to me, because on ISS, the emergency air kits are distributed two per module, and none kept in the crew quarters. In submarines, they are much more numerous, and prevalent throughout the ship. In our lunar habitat mockups, we have been placing them in the crew quarters plus other key locations, and so far our evaluators have agreed with this placement.

Figure 7. MDRS 61 crewmember wearing simulated emergency air mask.

76. Our simulated emergency air kits looked a little too good, and MDRS Director Tony Muscatello had us mark them so they would not mistakenly be used during an emergency. Because of this, we have adopted a requirement for our mockups at JSC: "Outfitting items (especially simulated emergency response items) shall be of obvious low fidelity, or clearly marked 'Simulation Only'."

77. Different analog habitats have different lessons to teach. Some are better analogs than others for specific aspects of a lunar or mars base. For example, the MDRS is probably not the place

to find our answers about emergency air. The MDRS is a good analog when it comes to utilities like power and water, because it is similarly limited and isolated as a real lunar/Mars base. However, it is not similarly limited when it comes to atmosphere. We had all the air we wanted, and even during an emergency (real or simulated) we all knew we could just step outside at any point and breathe all we wanted, so lessons regarding air pressure, partial pressure, off-gassing, hull leaks, and emergency air supplies and operations probably cannot be evaluated with the proper perspective. On the other hand, I believe the MDRS is a superior analog for developing habitation requirements on other topics; for example, windows.

At JSC, we have always been taught that our NASA astronauts spend a significant percentage of their off-duty time during a mission gazing out the window, and the NASA man-system requirements document calls for us to put windows in the crew quarters and wardroom areas [5]. But toward the end of my MDRS rotation, I found I had spent almost no time gazing out my window, even though, as Commander, I had the only one in a crew quarter. I asked myself, "Why am I not behaving like a typical NASA crewmember?" I also recalled my previous experience on a cruise ship, where we gladly paid the extra money to upgrade from an interior (windowless) cabin to one with a window, and had spent a fair amount of time gazing out it. Even the analog experience of NEEMO crews have reported spending a lot of time looking out their windows. So, why does an MDRS crew behave differently?

I've come to the conclusion that those crews all looked out the windows a lot because the view was constantly changing (earth rotating; ocean undulating; fish swimming by, in the case of NEEMO), or they were still adapting to the novelty.

On MDRS, and on a real lunar/mars base, the view doesn't basically change very much (Figure 8). And the novelty wears off quickly. This is why we should base our real lunar/mars base requirements in this area on MDRS experience rather than past space missions or NEEMO. I predict our lunar/mars crews will not be spending much time in recreational viewing (every time you look, it's the same, old crater, the same old boulders); certainly not enough to warrant a window in their crew quarters.

Figure 8. Unlike ISS or Shuttle, the view out an MDRS window doesn't often change.

When outside operations were in progress, however, the inside crew would look outside often.

We need to keep tabs on external activities, and I, for one, would not have been satisfied being dependent on technology (i.e., having to watch via cameras, monitors, etc.); I'd rather be able to watch our EVA crew directly through a window. Hence I am in favor of placing windows primarily to allow the crew to see 100% around the habitat, and strongly urge these views be redundant so if one window is blocked the same location may viewed from at least one other. If this window location coincides with a crew quarters, fine. A natural light source is always nice to have, but then be sure to include a means of blocking the light so the crew can sleep.

To summarize this point, MDRS experience uniquely teaches us that the number and locations of lunar/mars base windows should be driven by (in priority order): 1. Operations – support 360-degree view around the habitat, with redundancy; 2. Structures and resource conservation (fewer, smaller windows makes a stronger habitat); 3. Habitability and crew comfort – providing natural light and a view with depth.

MARS ON EARTH

Zubrin and I appear to agree on most everything. Here are the comments and comparisons I wish to add:

1. Zubrin [9] notes, "By far the most common form of individual recreation observed in our stations is reading. Most crew members seem to prefer to do such reading in public areas, such as the wardroom, where they can snack and talk casually with others while they read. A substantial minority (about one-third) appear to prefer to read privately in their bunks." For Crew 61, our crew mostly preferred to surf the internet. They did so at the office areas near the wardroom. Two of us preferred to read or watch DVD's in our personal crew quarters.

2. It was almost a week before we got the opportunity to watch a movie together. Based on Zubrin's comments about how, "The overwhelming favorite type of movie among crewmembers are screwball comedies...After a long day's work, people want to get together and laugh. There seems to be little patience for anything serious", Crew 61 donated about a dozen classic comedies to the MDRS library, including "Spaceballs", "Airplane!" and "Mr. Bean – The Series". To my surprise, our crew did not seem to follow the patterns Zubrin expressed, favoring action-adventure (like "Red Planet") over the comedies.

3. The usual priorities on MDRS and FMARS missions are: 1) Safety; 2) Simulation; 3) Science; and 4) Comfort. For MDRS 61, being one of the initial NASA Spaceward Bound missions, I interpreted that the most important goal was to have these college students leave the MDRS healthy and jazzed about the space program. So being safe, of course, was paramount. Facing difficulties and challenges was to be part of the program, yes, but suffering unnecessarily in the name of maintaining "simulation" seemed counterproductive to our central purpose. And what was scientifically accomplished during the rotation seemed to be of secondary importance to our sponsors. So, our priorities were: 1) Safety; 2) Enjoyable, meaningful experiences; 3) the work itself. This I reinforced to the crew through our motto: "Be Safe! Have Fun! Get It Done! --- CREW 61!"

ACKNOWLEDGEMENTS

The author expresses his sincere appreciation to the fellow members of MDRS Crew 61, a fantastic

diverse group that pulled off a fun and memorable rotation.

Special thanks go to Tony Muscatello, Paul Graham, and Don Foutz. They have been the backbone of the Mars Society MDRS Program. We also thank the MDRS Mission Support, Engineering Team, and Remote Science Team for their support during our rotation.

I thank Lon Miller and Dr. Joy Kelly of Jacobs Engineering for their sponsorship, NASA Spaceward Bound for sponsoring the rest of the crew, and the Mars Society for building and maintaining that wonderful MDRS.

Above all, my deepest gratitude goes to my wife Helen, and daughters Samantha and Katie, for keeping things going at home and enabling their husband and Daddy to go off on an adventure to Mars for two weeks in the Spring of 2007.

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