Mars Society Engineering Report
from the Mars Desert Research Station (MDRS)
Report By: Joseph Palaia
6/26/2017

This report documents my observations and actions taken while visiting the Mars Desert Research Station on 6/23/17 and 6/24/17.

The station appears to be generally in a good state of repair. Upon arrival in the late afternoon of 6/23/17, an initial exterior survey was taken of the station and associated infrastructure. An interior survey was completed the following morning. My initial comments are that the station and associated infrastructure appear structurally sound, clean, well-organized, and uncluttered. This is especially in contrast to my experience at FMARS, where I found that station to be jammed packed with supplies, materials and equipment. I want to take this opportunity to extend my admiration to Shannon Rupert for her hard work and dedication to this program, and the running of a fine facility.

Signs greet you upon your arrival at the property, including one describing in general terms the station, its purpose, and the purpose of the Mars Society. There is also a “No Entry Please” sign to dissuade visitors from tampering with the station or interrupting simulations in progress. I would recommend that a much larger, more permanent, very professional sign be placed near the entrance to provide those curious visitors additional information as well as a request for their support of the program through donations and sponsorships.


The facility structures include the hab itself, a greenhouse, a Science Dome, and the Musk Observatory. These four structures are connected together by covered walkways intended to simulate pressurized corridors that would connect structures like these if they were on Mars.




Also on site, and of particular interest to this engineer, is power systems infrastructure. This consists of a large solar array, a generator, and a fuel storage drum for the generator. More on this later.

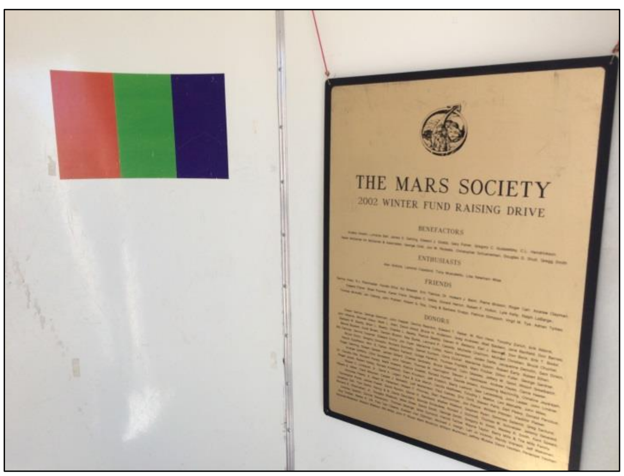
Mars Society Storage Unit in Hanksville

Prior to returning to the site on the 24th, I visited the Mars Society's storage locker. It seems fairly organized and appears to contain surplus and support materials. This included some older space suit parts as well as three small generators.

Return to the Hab

I returned to the site on the morning of the 24th. Two significant things strike me about the hab:

1) The exterior of the hab could use an aesthetic upgrade, to be performed by someone with an eye for detail. The surface is rough and uneven. It could use some sort of resurfacing and an exterior coat of paint or some other material to give it more of a high tech, refined look. Right now, it just looks old and low budget. An exterior upgrade would aid the illusion of this being a landed spacecraft, improving the psychological impact of the structure. It would also help The Mars Society to continue to attract high value donors and sponsors for whom aesthetics sometime are of significant importance. Question: What sponsor would want their logo on the side of a hab that looks old, beat up and low fidelity? On this subject, unlike FMARS, the hab is curiously devoid of names and logos, with the exception of the Musk Foundation. I would recommend an exterior upgrade first and placement of major donor and sponsor logos on the hab, using high quality decals, second. Also, I would recommend replacing the name decal at the top of the hab. Instead of “Mars Society Desert Research Station” which does not match the acronym “MDRS”, I would replace this with “Mars Desert Research Station (MDRS)” and beneath that put “A project of The Mars Society” perhaps also with the website.
2) At several places in and around the hab, there is significant use of wood. For example, the front porch and steps, around some of the portholes, railings and support structure inside the hab, and the main steps from the first floor of the hab to the second. While wood is a high utility, cheap, readily available material here on Earth, on Mars it will be a rare and exotic material. In my opinion, the use of wood significantly detracts from the aesthetic of the station and gives it more of a “club house” feel as opposed to a “spaceship”.

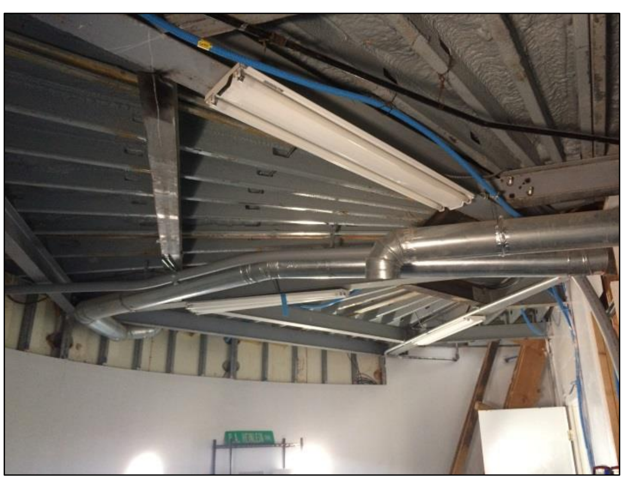


Proceeding inside, the first thing you encounter is the Red, Green, Blue flag of Mars, and a plaque listing sponsors and donors. This is a good thing, and I’m glad these two items are there. That’s the right place for them IMO, so they are the first things you see upon entering the hab. I recommend this be where the similar plaque be placed at FMARS (within the front airlock).

Entering into the hab proper, you are greeted by spacesuit backpacks and helmets. Everything is neat and organized. The helmets are a little bit on the tired side, with significant scratches in the transparent domes. I recommend The Mars Society task someone with finding an alternative dome material which will not scratch and scuff as easily as these polycarbonate ones. This could perhaps be an opportunity for collaboration with researchers, maybe at JSC. What better field testing could there be for new Mars space suit helmet materials than an MDRS field season? The other thing to consider is to have each crew member that visits the station have the option of buying their own replacement dome, or choosing instead to live with the scratched one. This approach would give crew members extra incentive to be careful with the helmets to prevent scratches.

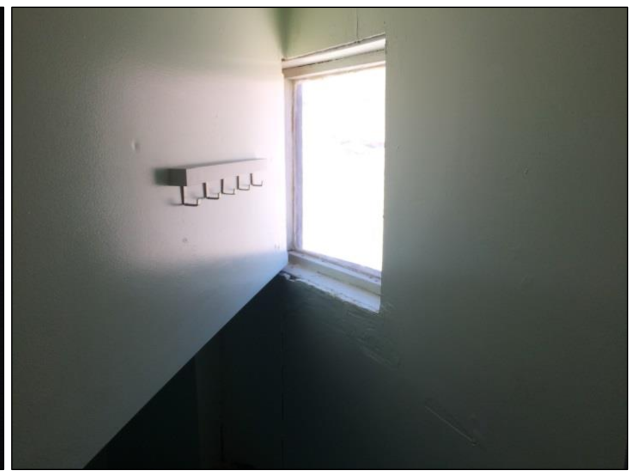

The lower deck of the hab is almost Spartan, most likely due to the fact that science lab equipment which (I believe) had been located within this area has been moved to the new Science Dome structure.

One of my biggest issues with the Mars Society's simulated habs has been nearly complete lack of emphasis on finishes, look and aesthetic. While this space is clearly of high utility, just because it needs to be utilitarian doesn't mean that it can't also look good! In the case of this space, I'm hit overhead with the thought "basement!" not "spaceship!" FMARS is not any better… this is not a complaint directed at MDRS solely. Let's just say, I can't wait to see what the team from IKEA proposes in terms of a complete refit of this floor of the hab.




The ceiling is unfinished with the “bones” of the structure showing. This is not necessarily a bad thing, and might in fact be more or less how an actual Mars transfer craft / habitat might be (to save weight). Although, I tend to think that these ceiling volumes would most likely be used on an actual spacecraft for storage, and a change here could help improve the aesthetic.

The ladder used to get from the first floor of the hab to the second is of a design similar to one I saw implemented in a lunar habitat prototype in Hanger X at Johnson Space Center many years ago. It’s a good design, but this one is made out of wood. I would recommend replacing this with a similar model made out of metal, again to significantly improve the aesthetic and make this feel like a spaceship instead of like a club house.



I am somewhat concerned about emergency egress routes from the second story of the hab. The first story has two exits, the primary airlock and the back secondary airlock. They are at opposite ends of the hab, which is good because if there is a fire on one side of the structure, then one of these two exits should be unobstructed. However, the ladder appears to be the only way in or out of the second floor of the hab. There is a porthole that looks to have four quick release handles (guarded by a mechanical cat) that could be used to remove the porthole quickly in an emergency. However, there is no emergency ladder in sight which could be thrown out and used to climb down. Also, this porthole is in close proximity to the main ladder, which means that if the main ladder was an unsafe path, this likely would be an unsafe path as well. This engineer recommends that a modification be made to the window (not a porthole?) that is located in what I assume to be the commander’s cabin (the last cabin, located nearest to the kitchen), to allow this to be used as an emergency exit in case of a fire. This cabin is located at the far extreme opposite side of the upper floor of the hab, so it would address that concern. A similar pull tab arrangement could be implemented and an emergency egress rope ladder could be stored on the floor just under this window. This engineer recommends that this be a priority item for upgrade / improvement as it is a major safety concern in my opinion.

The 2nd floor of the hab is clean, organized, uncluttered and clearly functional. The aesthetic here is better than it is on the 1st floor, but undoubtedly it could be improved so as to give it more of a spaceship feel. We will see what IKEA proposes for this floor.

There are five gasoline powered ATVs parked between the hab and the greenhouse. This engineer did not inspect them for functionality, but did note that some of them could use replacement seats (which should not be prohibitively expensive).

The previously mentioned covered walkways have been constructed through use of metal mesh to form a structural arch, and tarps secured over the top of them. This serves as a fairly effective, while low fidelity and inexpensive way to simulate pressured connectors. There were significant portions of the walkways which were missing tarp coverings. Where there were tarps, these tarps were clearly of the very inexpensive variety, and were in most cases tattered and torn. I recommend replacing all of these tarps with thick, high-quality tarp material which can be securely fastened to the metal supports. This will significantly improve the aesthetic and psychological aspects for only a small investment.

The greenhouse looks to be a solid structure of good, new construction.

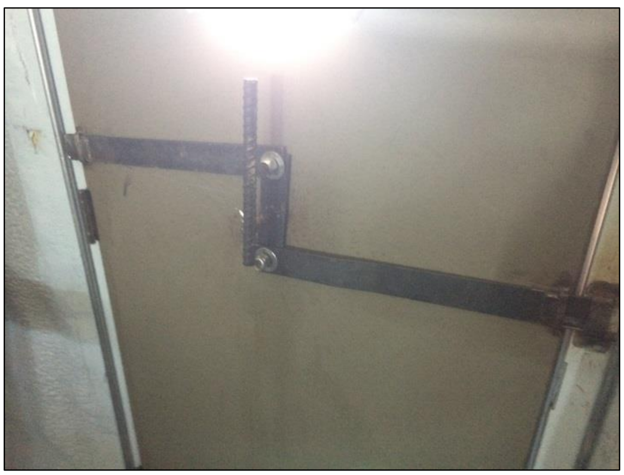
There is equipment in place for air circulation and water storage. Some thought should be given to how this greenhouse is laid out internally to provide maximum growing area. An immediate thought would be to relocate the water storage tank to the exterior of the structure.

The Musk Observatory is at the end of one of the connector linkages. The exterior of the structure looks to be in good condition, however it is recommended that a high quality replacement decal be obtained to replace the faded and weathered Mars Society logo.

The Science Dome is the final structure on site. It appears to be very well constructed.

The Science Dome appears to be equipped with a variety of scientific instruments and supplies, and is spacious enough to accommodate additional equipment which may be added over time. It is also where the battery charge controllers and batteries are located.

<u>Science Dome Latching Mechanism – Repair</u>



Upon arrival at the Science Dome, it was discovered that the latching mechanism was non-functional. This presented an issue, because without the mechanism working, there was no way to secure and close the door. This engineer troubleshot the problem and identified that the issue was that there was no physical stop which prevented someone from turning the hatch release too far, and when it was turned too far, the metal cross members slid out of the supports at the edge of the door. This engineer realigned the cross members in their supports and installed a physical stop (a metal screw through the end of one of the metal cross members) and this has solved the problem.

Solar Array Power System, Charge Controllers, Battery Bank Energy Storage

One of the primary purposes of my visit was to document the current state of the solar power and energy storage system at MDRS and to assess its functionality. I began by creating this record, identifying and documenting, to the best of my ability, the hardware currently installed.

Solar Array

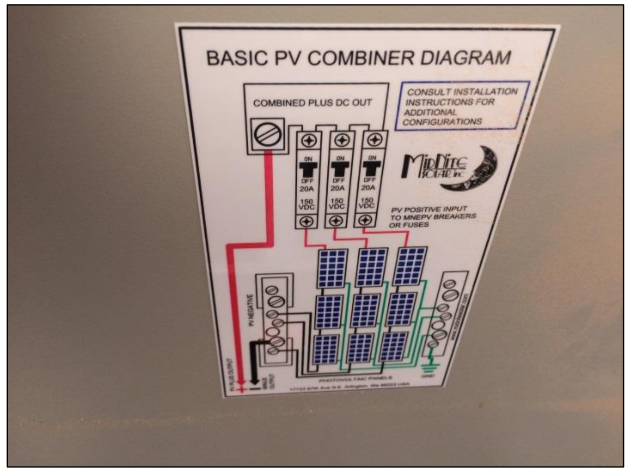








MidNite
SOLAR, Inc

This is a sizeable solar array! There are a total of 45 individual panels. The solar cells on each panel measure ~37.5" x 75", or 3.125 ' x 6.25' = ~19.5 sq ft ea. The total area of solar cells is therefore ~878 sq ft. I captured a picture of the label on the underside of one of the panels. It indicates a maximum power production per panel of 335W. With 45 panels, this is a max power output from this array of 15,075 W (15kW).


The installation of this array appears to have been professionally done. There are three PV combiner boxes which are then all connected together by conduit. A single conduit then heads underground and comes back above ground and goes into the Science Dome. There is also conduit leading from the generator into the Science Dome, and then conduit that leaves the Science Dome and goes towards the hab.


Inside the Science Dome, a good section of the wall on one side is taken up by electrical conditioning equipment and batteries which are stored in three large boxes on the floor.

There are three white boxes labeled “MagnaSine Magnum Energy”. The first is labeled “Master Inverter”. The others are labeled “Slave 1 Inverter” and “Slave 2 Inverter”. I am not sure of the precise configuration or why there is a Master, Slave 1 and Slave 2, but these are clearly the invertors that take DC put out by the solar panels and stored in the batteries and convert it to AC.

There is a Magnum Energy master controller with LCD display. Without having the manual in hand, I did not make any changes to it. The display did show that there is a fault, and the red fault indicator light is on. Note this picture was taken during the day when the solar panels were exposed to full sunlight. The SOC (State of Charge) of the batteries is indicated at 100%. Clearly, any small electrical demand in the facility was at that moment being met by the energy production of the panels, with sufficient excess available to keep the batteries fully charged.

There were breakers that indicated they would be used for Inverter AC Bypass, Invertor AC Output, Inverter AC Input, Inverter DC Disconnect, C.C. #1 PV Array Input and C.C. #1 PV MPPT Output.

There were three white Magnum energy boxes labeled “Power Track Performance” and “MPPT Charge Controller”. MPPT stands for “Maximum Power Point Tracker”. These are DC to DC converters that match the output voltage of the PV array to the optimal voltage needed to charge the batteries.

There was an additional breaker box labeled C.C #1 PV Array Input and PV MPPT Output, and C.C.#2 PV Array Input and PV MPPT Output.

There was a traditional electrical distribution box with breakers labeled “Main” and “Dome Outlets”. There was also a box labeled “Auto Generator Start, Network Version” and another box with an RF antenna labeled “MagWeb”. The first box I believe is intended to start and stop the generator as needed depending upon the available power from the array and the state of charge of the batteries. The second box I believe communicates with a similar MagWeb box which is located in the hab and which is connected to the main wifi router, allowing you to interface with the system through a web-based application.



Finally there are the three battery storage boxes. Each box contains 8 batteries, for 24 batteries total. The batteries are labeled "Sealed Deep Cycle, Maintenance Free, AGM Battery". They are Crown 1 model number 6CRV390, 6 volts, 390 (20HR) A.H. Rating.


The master controller was observed several hours after sunset and a picture taken of the display. We can compare this photo (on the left) with the photo taken of the display during the day (on the right). As we can see, the state of charge has decreased from 100% to 96%. This was due to this engineer running some lights and other loads for several hours, drawing from the batteries. We can also observe that the current indicated has changed from +1.6 ADC during the day to -7.6 ADC at night. One can surmise that this shows that the batteries were being trickle charged using 1.6A during the day and that they were being discharged at night at a rate of 7.6A (with only a minimal number of loads running).

Battery Calculations

Each of the batteries is rated at 390AH. With 24 batteries, this is a total of 9,360 AH. Multiplying by 6V, we obtain 56,160 WH.

I know that we operated FMARS on a power budget (from the generator) of ~5kW continuously. If we were to divide the 56,160 WH by 5,000 W, we arrive at 11.2 hrs. This would seem to imply that this battery bank could provide the same energy as a 5kW generator running all night.

The problem is that we cannot completely discharge these batteries. In fact, the manufacturer recommends we only drain the batteries to a depth of discharge of 75% maximum (meaning 25% of the energy stored in the batteries is still in the batteries and we have only discharged 75% of the stored energy). So only 75% of the 56,160 WH is really available to us. This is 42,120 WH.

If we assume ~10 hours of darkness each night, this means that we can draw a maximum of 4,212 W continuously during this timeframe.

Conclusions

As far as this engineer is able to ascertain, the system seems for the most part to be operating as intended. The solar arrays maintain the batteries at a full state of charge during the day with copious extra energy available for running loads in the facility, and at night the batteries begin to discharge to meet the facility's electrical needs.

A complete assessment of the various electrical loads in use at MDRS should be performed, with a specific eye to those loads that need to be run at night. Most likely the largest load would be air conditioning (when needed). This assessment will identify the typical discharge rate of the batteries and determine if the current capacity is sufficient, or if it would be prudent to add additional batteries.

Another thing to consider would be relative timing of loads (such as hot water heating, for instance) to have these loads run during the day (when there is an energy surplus) as opposed to at night (when there is a scarcity).

There is also use of the generator to consider. It may be possible to run the generator from sundown until the crew goes to bed (when significant energy use is anticipated), conserving the energy in the batteries for use overnight (and preventing the generator from running and creating noise during hours when the crew is sleeping).

In addition to increasing the size of the battery energy storage bank, a future upgrade to consider would be a sophisticated energy consumption monitoring system. The idea would be to monitor every electrical load in the facility in real time in order to optimize energy consumption patterns. It may also present an interesting line of scientific inquiry with regards to studying how an early Mars exploration base makes use of electrical energy.

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This engineer enjoyed the opportunity to visit MDRS and see the systems and infrastructure first hand. I hope that this report will serve as useful. I look forward to watching the MDRS program continue to mature and will seek future opportunities to contribute to furthering the station's mission and that of The Mars Society.