--- FINAL MISSION REPORT – CREW 135 ---

CREW 135:

Commander: Ondřej Doule, Ph.D.

Executive Officer, GreenHab Officer: Lucie Poulet, Ph.D. candidate

Health Officer, Crew Engineer: Filip Koubek, PhDr.

Crew Scientist: Elif Oguz, Ph.D. candidate

Crew Journalist: Tereza Pultarová, M.Sc.

Crew Engineer: Martin Kubíček, Ph.D. candidate

Crew Engineer: *Vratislav Šálený, Ph.D. candidate (remote support from LMO)*

Crew introduction: Crew 135 was composed of researchers and enthusiasts with a common interest in analog habitat research and experience. All of them are highly skilled individuals with great emotional intelligence, analytical and conceptual thinking, as well as intercultural experience, used to perform in stressful conditions. Although some of them had not met before the simulation commenced, they showed great team spirit, mutual respect, empathy and developed excellent interpersonal relationships within the team.

Despite the fact that one crew member decided to terminate the simulation half way through the mission due to excessive workload and confinement related stress, the rest of the team managed to cope well with the situation.

Mission Objectives: The RAR mission was focused on analyses and upgrades of the MDRS habitat systems and structures. The mission objectives were slightly modified based on MDRS requirements and research capacity in situ. All research experiments were successfully conducted and data processing for all of them will be performed over the next months.

EXTRA VEHICULAR ACTIVITIES (EVAS)

CREW 135 performed 10 sortie EVAs focusing on topography mapping and exploration, habitat geometry measurements, HUD displays usability research, and habitat systems mapping and monitoring. The success of all EVAs was very high considering our initial unfamiliarity with the base's analog systems and procedures.

MDRS HABITAT MAINTENANCE

Apart from regular cleaning and habitat system maintenance, Crew 135 fixed:

- The Engineering airlock port and latches. The port was impossible to close due to loose joints and a broken latch.
- Drainage system of the science lab sink that was not only clogged with mud but was also leaking due to instability of the sink. Sink was fixed, re-calked and the piping was re-assembled and sealed.
- Path to the Greenhouse was re-stabilized as the grid tiles were sinking in the mud.
- Two charging cables for the PLSS backpacks were re-constructed and soldered.
- Habitat SUV got a new (used) spare tire and got a double complete wash.

MDRS HABITAT SPONSORSHIP

An LED lamp was donated to the GreenHab by Crew 135 member Vratislav Šálený (Sobriety s.r.o. company)

EXP01 - RELIABILITY AND REDUNDANCY OF SPACE ANALOG HABITAT SYSTEMS – FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS OF PRELIMINARY DESIGN PHASE CONSIDERING HUMAN FACTORS

The experiment focused on modifications of the FMECA (Failure Modes, Effects and Criticality Analysis) method to study reliability of space habitats. FMECA is a methodology for identifying and solving critical problems in systems before they occur, while considering the role of a human element. Human factors often influence the reliability of systems as each modification of a system by a human operator creates the possibility of critical errors. These errors can be created during repairs or simple random interaction including an accidental trip over an improperly placed object. For this purpose, many critical systems were selected by the researchers as the first step of the study including the generator, water tank or the air-conditioning system. Since all subsystems require electricity, the generator was identified as the most important system at the habitat. During the identification of the systems and subsystems, the water system was selected as the most hazardous system in the habitat. The water tank, located at the third floor poses several risks including flooding and overflowing. The risks depend on improper installation of the tank and also weak pipe connections in the vicinity of electrical systems.

EXP02 - GREENHAB RESEARCH

Activities in the GreenHab included daily operations and maintenance, as well as a specific experiment. The routine tasks consisted of checking the environmental parameters, watering plants, and refilling the hydroponics tank. Five sprouts of sweet peppers were transplanted to the hydroponics tank; and carrots, snap peas, and radishes were germinated successfully. It appeared that germination is faster with a higher success rate when performed in a small greenhouse (transparent plastic lid taped to the plant tray) than when planting seeds directly in big pots. Crew time was recorded for all these operations and will be recorded for the entire season. This will help identify where automation in the GreenHab is desirable (watering, seeding, covering plants).

The experiment consisted of two different light treatments, one using a supplemental LED lamp (Figure 1) and a control using only natural light. Light measurements revealed that light intensity on the experiment shelf almost never goes above 200 µmol/m2/s, which is too low for mature lettuces. The LED lamp located 64 cm from the growing surface, provided between 75 and 165 µmol/m2/s (in the center) of supplemental light. One-month old lettuce plants and one-week old lettuce seedlings (Ithaca and Crisp Mint) were grown during the rotation under these two treatments. Plants under the treatment sun + LED showed healthier shapes and seemed to suffer less from the lack of light than those receiving only natural light. MDRS architectural greenhouse upgrade and expansion concepts were created and will be presented in a separated paper at IAC 2014.

Figure 1: MDRS GreenHab and corridor illuminated by experimental LED system.

EXP03 – STRUCTURAL PROPERTIES OF THE MDRS

A loading test of the exterior structure (Figure 2) was performed using simple testing hardware gentle to the exterior structure. The experiment was recorded optically and confirmed that the combination of modern digital photography and Digital Image Correlation using software Mercury (http://www.mercuryprogram.eu/) enables exact identification of surface deformations of the habitat structure. Surface imperfections of the habitat surface were helpful to this experiment and no additional pattern on the structure surface was necessary. An exact model of the MDRS habitat was created, which was further used for this experiment and for structural analyses using the Finite Element Method in simulation code MSC. NASTRAN (Figure 3).

Figure 2: Crew 135 crewmember during structural experiment preparation for the exterior wall of habitat loading.

The deformation behaviour in the digital model was set according to optical measurements on the MDRS structure exterior surface. According to the original simulation scenario, additional simulations will be performed regarding residual stability of the MDRS habitat and a structural enforcement of the base will be suggested to prepare the MDRS for the Great Mars Storm.

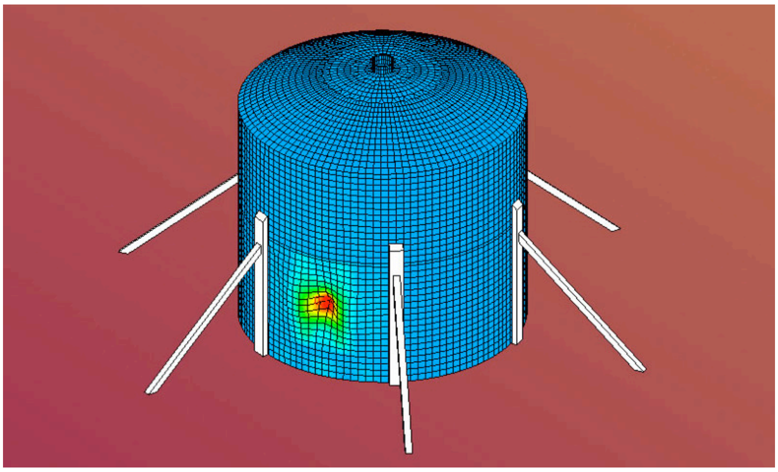

Figure 3: MDRS habitat structural behaviour analyses - local loading on the structure simulated in NASTRAN.

EXP04 - IMPROVEMENT OF INTERNAL ACOUSTIC ENVIRONMENT INSIDE SPACE ANALOG HABITAT BASED ON ACOUSTIC MEASUREMENTS AND MITIGATION TECHNIQUES

Several acoustic measurements were performed during the RAR mission providing a good source for computer simulations of the MDRS interior acoustic behavior. The crew measured reverberation time on the station's upper deck bursting small inflatable balloons (Figure 4). Procedures for precise control of acoustic energy were verified during the mission. For the further analyses of the MDRS interior, crew 135 recorded the most intense source of noise in the upper deck of the base – the water pump. This research is intended for AIAA publication.

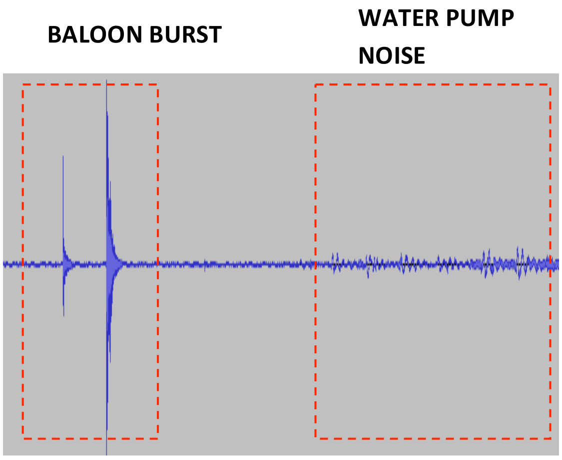

Figure 4: One successful channel record on the upper deck of MDRS

EXP05 - ERGONOMY OF HEAD MOUNTED HEAD UP DISPLAYS INSIDE ANALOG SPACE SUIT DURING MARS ANALOG EXTRAVEHICULAR ACTIVITIES

Evaluation of sight peripheral information head-mounted Head Up Displays (HUD) from user viewpoint during Extra Vehicular Activity exploratory tasks was successfully performed. The experiment focused on safety enhancement, usability regarding visual and voice aid, affordance, usefulness, mission reliability enhancement and risks. During the experiment we used two types (fixed information and head tracking) of commercially available HUDs providing time, navigation, video streaming and heart rate information.

Figure 5: Crew 135 crewmember during navigation and surveying using Glass, GPS navigation, and regular compass.

The HUDs were worn during 7 EVAs primarily focused on other tasks (Figure 5).

Following functions were tested during these experiments using Google Glass and 4iiii HUDs:

- Individual navigation and surveying

- Head motion relative to helmet motion - video recording
- Helmet to helmet video streaming for team situational awareness
- Helmet to Hab video streaming for EVA navigation and situational awareness

EXP06 - MDRS OUTPOST GROWTH

A large portion of the time was dedicated to analyzing internal habitat functions, layout, operational procedures and habitat utilization based on procedures provided and mental maps created by occupants (Figure 6).

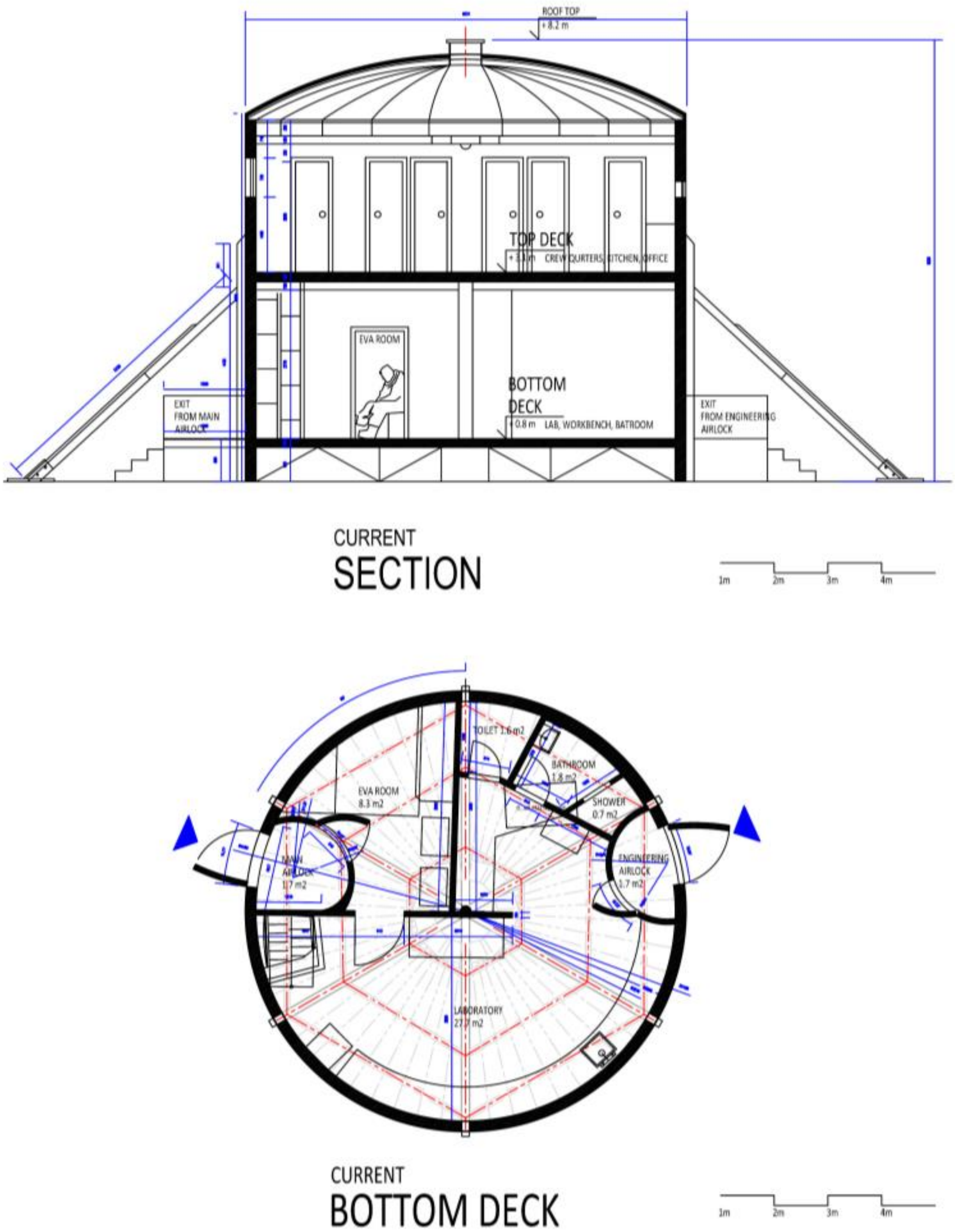

Figure 6: Current state of the MDRS based on Crew 135 measurements.

The internal geometry was converted into CAD drawings that served as a starting point for the MDRS upgrade proposal starting by the modest and most necessary Upgrade 01 (Figure 7) and continuing with a larger Upgrade 02 (Figure 8) and a very ambitious Upgrade 03, which introduces the next stage of living on Mars using In-Situ Resource Utilization.

The upgrades and evolution of the station were based on following priorities and design drivers:

1. Re-configuration (Figure 7) and enlargement of private spaces
2. Paving of frequently used surrounding areas to eliminate direct entrance to Mars surface / maintenance of Hab, safety operations
3. Upgrade of the base subsystem to provide higher level of integration
4. Enlargement of the GreenHab
5. Habitat shield
6. Simulation zone border
7. Emergency escape vehicle
8. Landing / Launching pad - Spaceport
9. Separating dirt lab from clean lab – geology and samples research including ATV access

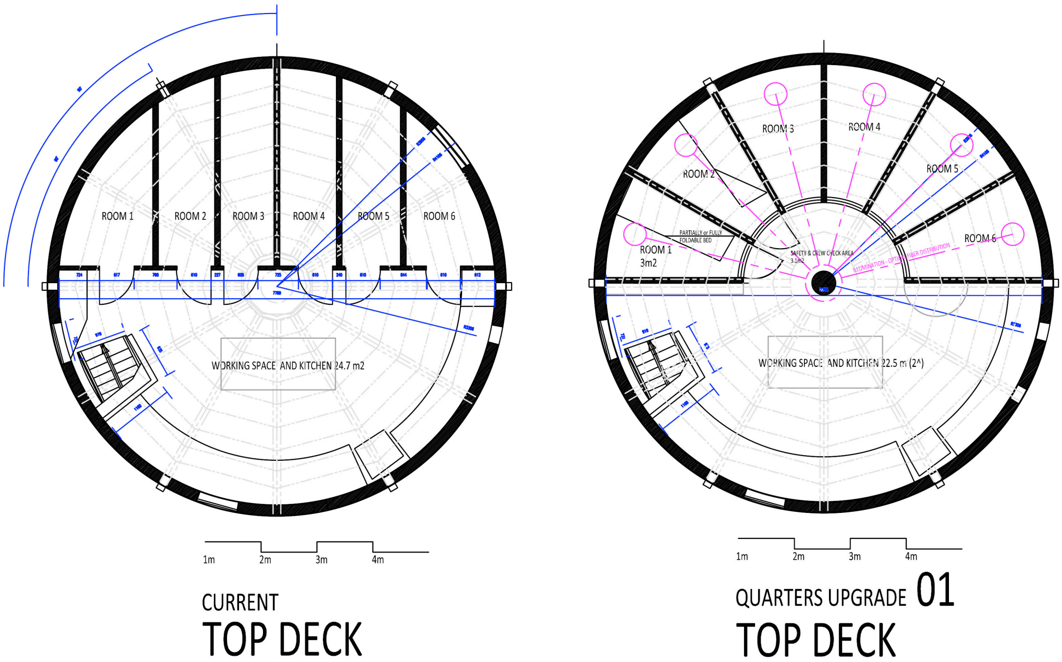

Figure 7: MDRS top deck upgrade proposal - the first stage proposal and minimum upgrade for the MDRS outpost growth.

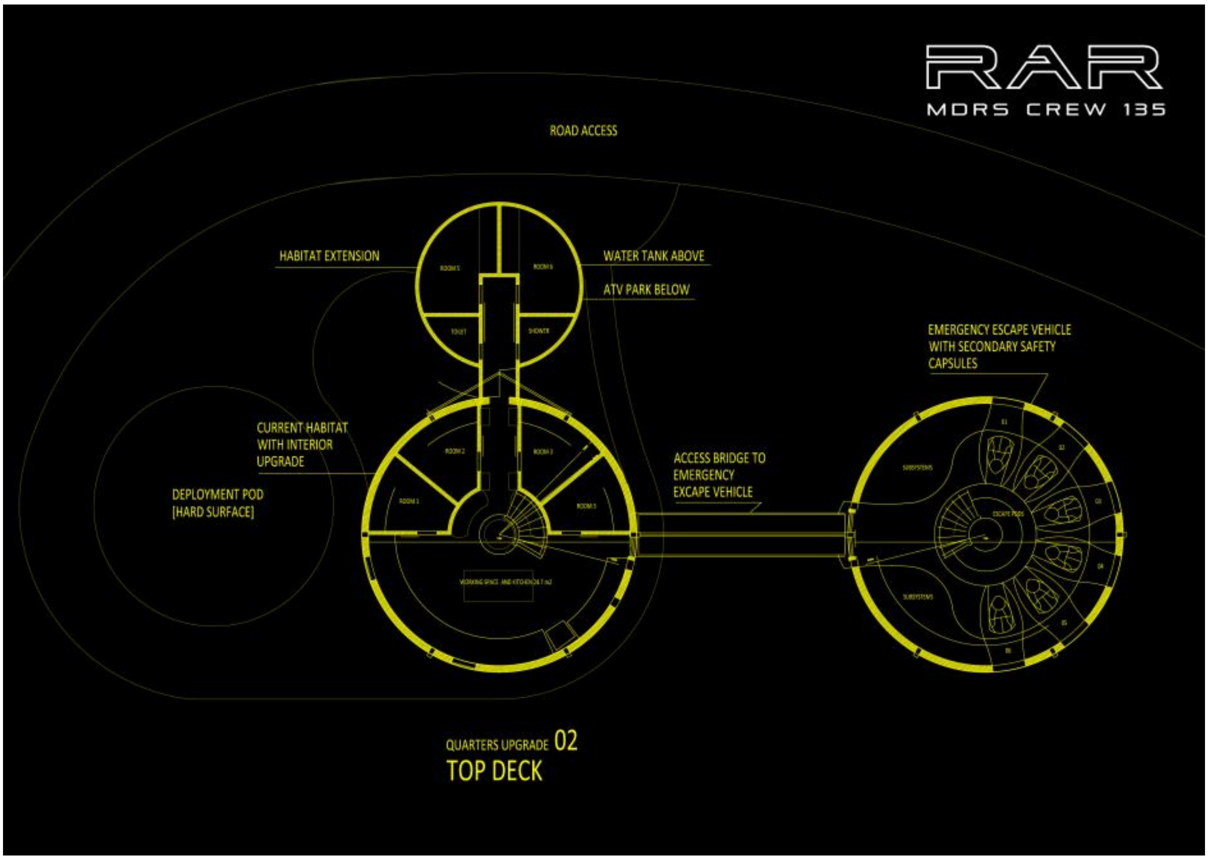

Figure 8: MDRS outpost expansion of habitable parts of the base including emergency escape vehicle.

EXP07 - FEEDING BEHAVIOUR AND SATIETY EXPERIMENT

The crew took part in an experiment assessing feeding behavior in extreme environments. It is a known fact that astronauts consume less food than they should, given the demands of their work and situation. Every day, the crew members were measuring their body weight and filling out short questionnaires about their subjective feeling of hunger and satiety. Every three days, they were required to record everything they ate including quantity and the preparation method.

The data will be co-evaluated by our nutrition expert, coordinator and advisor Dr. Audrey Bergouignan.

PR AND OUTREACH SUMMARY

The Crew 135 media team has been managing the rar2mars website, providing daily updates including photographs and videos, managing other media request and shooting a video documentary.

The mission was promoted in the media in the UK, the Czech Republic and Australia with the greatest level of coverage achieved in the Czech Republic were four of the crew members come from.

The team plans to produce a documentary movie to be aired at science and documentary film festivals and offered to TV channels.