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SAFETY, PERFORMANCE AND COMFORT ON EUROMOONMARS MDRS MISSION SIMULATION

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ABSTRACT

This paper presents the results of studies on living and working activities from the International Lunar Exploration Working Group (ILEWG) EuroMoonMars campaign 2013, carried out at the Mars Desert Research Station (MDRS) in Utah to test exploration procedures in Analogue Moon/Mars Base Infrastructure. Inside the station the feasibility and limitations of human and robotic planetary exploration were investigated by two teams of seven and six members (crew 124-125, respectively) for a period of two weeks each. This paper presents the analysis performed by the crews on safety, performance, and comfort during living and working activities. The living conditions were investigated with a debriefing workshop in order to increase the crew's well-being and performance in isolation and an observation of how food and sound impacted the crew. Among the working activities of the crew, this report is concerning the development of an Arduino-based Device for Monitoring Internal EVA Helmet Temperature During EVA, and the ergonomics and balance of transport and access to heavy hand tools on the simulation space suit. Crewmember Comfort and Safety were investigated by Perception of risk, realistic risk of injury, and knowledge of emergency procedures in a simulated Mars environment. Also investigated were design and development of geological field equipment for use in space suit, and ATV capability assessment at MDRS. The campaign was organized by ILEWG with the support of Mars Society, VU Amsterdam, George Washington University, and NASA Ames.

I. INTRODUCTION

Fig. 1: MDRS, 2010 © Irene Lia Schlacht

The Mars Desert Research Station (MDRS) is located in the Utah desert near Hanksville. Every year, a rotation of several crews up to 7 people at a time, go there to perform investigations of various kinds related to simulations of Moon/Mars exploration. In February-March of 2013, two ILEWG EuroMoonMars Mission crews (crew 124 and 125), went to MDRS to investigate techniques to explore Mars/Moon geology, and to experience the simulation of a Mars/Moon mission.

This paper presents some of the elements investigated and observed concerning the safety, performance and comfort at the rotation of these crews. The first part of the paper, section II presents the method and results of a habitability study, where common problems at MDRS experienced by several different crews were identified and solutions found. The next section presents observations from the impact that food had on comfort and mood at MDRS during crew 124. Section IV presents the development of an Arduino based device for monitoring internal EVA helmet temperature during EVA to assess crewmember comfort and safety. Section V describes the ergonomics and balance of transport and access to heavy hand tools on the simulation space suit used at MDRS. Section VI describes some of the challenges of using geologic field equipment while wearing a space suit and offers design and development solutions for such equipment. Section VII presents a study of ATV capability assessment at MDRS. The last section before the conclusions presents the perception of risk, realistic risk of injury, and knowledge of emergency procedures in a simulated Mars environment.

II. HUMAN FACTORS AND HABITABILITY

(Schlacht, Ono)

Since psychological and stress-related problems are serious issues on long-term missions, countermeasures are needed for future long-duration missions because astronauts may suffer from insomnia, depression, and stress. These negative effects may reduce crew performance [1]. To counter those relevant human factors effects [2], the Moon-Mars habitability project was conducted during the EuroMoonMars campaign from 2010 to 2013 on 5 crews: 91, 100A, 113, 124 and 125 [3, 4, 5, 6, 7, 8, 9, 10, 11]. The aim of this study was to discover the needs and potentials of the environment and to improve the habitability, well-being, and productivity of the astronauts for long duration missions. Through the study from 2010 to 2012, we hypothesized that the use of music and nature sounds could be a countermeasure to stress contributors such as noise.

Methods.

Ninety minute crew debriefings were conducted two days before the missions ended at MDRS. During the debriefing, the main mission problems and possible solutions were discussed from the perspective of performance, well-being, and safety. Key words that were used most frequently were analyzed by the crews. Human factors aspects were investigated, with a particular focus on problems and problem solving under stress conditions, and the role of music, nature sounds, and entertainment as a countermeasure.

Crew 125 was asked to bring their favorite music and personal belongings for entertainment. The duration of these activities were not pre-determined, but was decided by the commander. The analysis was performed using direct observations, interviews, and the same crew debriefing.

The results are presented with comparison analyses between the different crews from 2010 to 2013, particular focus is on the result of crew 124 and 125 from 2013.

Fig. 2: Crew 125 performing music in MDRS March 2013 ©Ayako Ono

a) Results on Habitability and social factors

In four out of five investigated crews, "communication" has been mentioned as a main shared topic of discussion showing the necessity of improving communication of information/procedures, communication with the control center as well within the crew. Other shared topics of discussion from three out of five crew members were food, with particular redundancy of the words Nutella®, interior layout, and toilet. [Table 3].

In comparison in crew 124, a socio-cultural factor was mentioned as a problem: Missing personal time [Table 1 and Table 2].

Table 1: Habitability debriefing mission 201, crew 124

Field	Rel.	Problem Crew 124	Solution Crew 124
Op. (also Psy.), IVA	7/7	Lack of information (communication). What to expect, peoples responsibility, procedure	Get an up-to-date manual, more information given about peoples responsibilities, better protocols, need for structure
Phy.(Op.) EVA	7/7	Condition of Helmet: a. Scratches on helmet that destroys visibility b. Helmet not good fit. Head bumps, does not protect head	a. different type of plastic better procedure to clean/polish b. Get padded helmets. Eg. get cheap motorbike helmets, that fit your head.
Op. (Psy.) EVA IVA	6/7	Overall condition of equipment. Much of the gear is near failure and poorly maintained	- Scheduled maintenance checks - Spend money on fixing things up.
Ps. (En., IVA	3/7	Missing personal Space stay alone	Better room design (layout) with multiple functionality to sit on your bed to have a desk
Ps. (En., S-C), IVA	3/7	Missing personal Time	Schedule a time for personal and free activities.

Table 2: Habitability debriefing mission 201, crew 125

Field	Rel.	Problem Crew 125	Solution Crew 125
Op. (ps.) IVA	5/6	Mission Support information flow (communication)	1.Psychological Screening 2. Education on support
Op. (Phy.)	4/6	EVA Suits design	1. Use modified motorcycle helmet (safer). 2. More small suits
En., IVA,	4/6	State-room temperature	1. Individual thermal control 2. Isolate heating pipes
Op.(ps.) IVA	4/6	Outdoor Toilets (safety, psychological discomfort, wasting time)	1. Fix indoor toilet 2. Having real tunnel

Index table1&2: IVA= Intra Vehicular Activity; EVA Extra Vehicular Activity; Rel.= n. of crew members that find it relevant / tot. crew members; Op.= operational, Ps.=psychological, S-C= socio-cultural, Phy= physiological, En=environmental

Table 3: Habitability debriefing mission 2010-1-2-3

Field approached	Topics approached	Crew:	91	100a	113	124	125
All (Operational, psychological, socio-cultural, physiological, environmental)	Communication	4/5		x	x	x	x
	Food (Nutella®)	3/5	x	x	x		
	Interior layout	3/5	x		x	x	
	Toilet	3/5	x	x		x	
	Music	2/5	x	x			
	Gymnastics	2/5	x	x			
	Storage	2/5	x		x		

b) Study of music and sounds countermeasures

During crew 125 debriefing, noise was not mentioned as a problem. Also, socio-cultural factors were not addressed that may correspond with the increase of well-being given by sounds used and music activity performed. The majority of Crew 125 enjoyed playing music instead of watching a movie, and it was effective for group dynamics to use shorter time than a movie [12]. Therefore, the crew members could use their spare time to play musical instruments and music files, together with crew member's favorite music. Also, this crew played space science fiction movie soundtrack pieces as wake-up music. The movies and soundtracks then became a frequent topic of discussion during meal-time. Through the discussion, the crew members discovered their common interests and preferences in terms of these movies. One of the space science fiction became a theme of this crew. The crew's favorite soundtrack was frequently played, and especially helped encourage crew members prior to Extra Vehicular Activities.

It is here reported an example of human factors daily report of the life during the mission simulation of crew 125 in march 2013: "*The atmosphere of Crew 125 and social factors are good. Commander, M. who has a lot of experiences at MDRS was contributing to keep a good atmosphere with positive words and encouragements in an attitude of fairness. Crew members woke up with morning music. Music was always played except the specific time for experiments. When a crew member V. listened to a guitar sound from speakers at MDRS after dinner, he felt that he wanted to bring his guitar.*"

Furthermore, nature sounds of streaming water with occasional bird call were played in daytime. At night, streaming water with insect noises played. The commander requested to play the nature sounds as a wake-up call for one day, and it also became a topic of discussion during breakfast. These kinds of nature sounds could help to reduce stress from noise [13,14,15]. Therefore, our hypothesis that use of music and nature sounds as soundscape design or sound environment took on a very important role as a countermeasure to noise-induced stress in group dynamics.

Conclusion

From this study, communication emerged as a key element related to the habitability and performance level in space mission. Music and food also emerged as important aspects that need more attention and investigation. In conclusion in order to improve habitability, the needs of the crew must be investigated from operational, psychological, socio-cultural, physiological, and environmental perspectives [11]. The results show that all those fields emerged as problem areas in every year from 2010 until 2013 [11, table 1 and Table 2]. Moreover the Moon-Mars Habitability Project also increased the crew's awareness and knowledge regarding habitability factors and their relevance. Considering that habitability will become even more important in long duration missions, this research provided some baseline data and a methodology for further investigation in long duration missions.

III.IMPACT OF FOOD AT MDRS

(Svendsen)

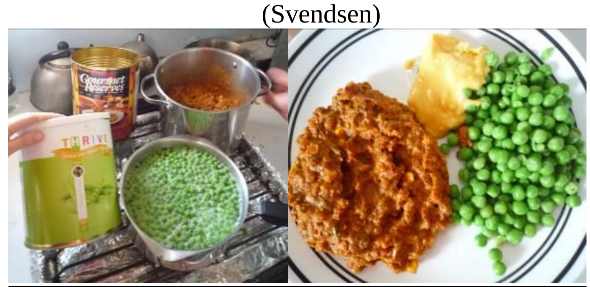

Fig. 3: Meal preparation at MDRS © Irene Lia Schlacht, 2010

One of the factors that has been mentioned often in the habitability debriefing is concerning food (See table 3). During the rotations at MDRS, the food provided represents the kind of food one would expect to have available on a mission on the Moon/Mars. This is food with a long storage capability, which is mainly dried and freeze-dried. In addition to this, the crews have access to a small greenhouse that can provide a little fresh greens a few times a week. Since food is consumed every day, it is a natural assumption that the kind of food consumed has a potential of influencing the crew in some way. During the rotation of crew 124, special care was taken to prepare food that would taste good, using the available ingredients. The main focus was then how this food affected the mood and comfort of the crew.

The key to making tasty food seemed to lie in the preparation. If the food was made from scratch, it usually resulted in a much tastier product than the readily processed foods that just needed to have water added. During the rotation, the crew succeeded in making tasty food most days with the exception of three days when the time and ingredients available would not allow for anything better than easily prepared instant food which did not have a pleasant taste.

Observation

There was a noticeable difference on the impact food had on the crew when it was tasty and when it was not. When tasty, the time to eat was a point in the day to look forward to, and also the overall mood among the crew would rise, meaning it would generally seem better than before the meal. When the food was not as tasty, the mood of the crew would stay relatively unchanged. Some examples of foods that resulted in tasty meals made from the available ingredients are; pancakes, freshly baked bread, pizza, brownies, hash browns, quinoa salad, and the greens from the green hab.

Conclusion

Based on the experience at MDRS, it is highly recommended that on long term missions, there should be an emphasis on providing ingredients and recipes to make food that is tasty, since this can increase the feeling of well-being and comfort of the crew.

IV. ARDUINO BASED DEVICE FOR MONITORING INTERNAL EVA HELMET TEMPERATURE DURING EVA (Crock)

Prior to our rotation the team's veteran crewmember, Kent Nebergall, stated that a long-standing issue with MDRS crewmembers on EVA is the potential for overheating due to exertion and simulation suits with little ventilation or cooling. Better understanding of helmet conditions during EVA would assist in developing technology to ameliorate heat stress on EVA crewmembers. Therefore, part of the work done at MDRS during the first EuroMoonMars rotation was to test a prototype system for logging temperature and light intensity inside and outside a simulation suit helmet to try to better understand the conditions that exist for EVA crewmembers.

The Prototype Device

A custom-built Arduino-based temperature and light intensity logger was developed to monitor helmet conditions. This small, low-power unit shown in Fig. 3 includes a 6 AA battery pack, an Arduino microcontroller, a logging system to write data to an SD card, a light intensity sensor and a temperature sensor

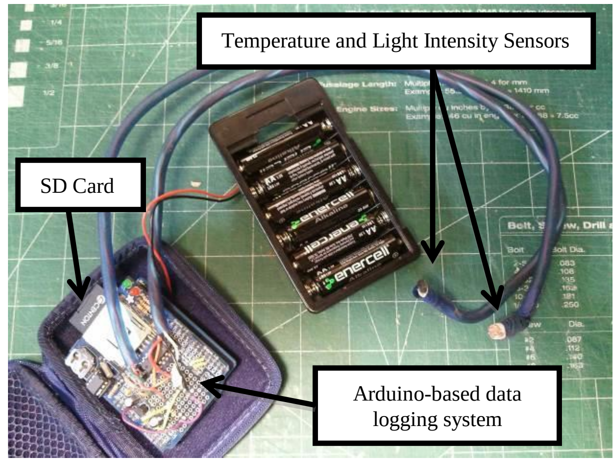

Fig. 4: Arduino-based Temperature and Light Intensity Logging Device

The temperature sensor is a TMP36, which outputs analog voltage linearly proportional to ambient temperature. Temperature data were calibrated using two standard laboratory thermometers. The light sensor is a CdS photocell, which has resistance proportional to incident light on the cell. Light intensity data were not calibrated for this project and thus represent relative light intensity only. A program written to the microcontroller is used to collect sensor data every 5 seconds and write the data to the SD card. The power supply and Arduino system is secured to the top of the simulation suit backpack and the blue sensor wires fed through the back of the helmet to sit just above the ear of the crewmember. This system was used to collect helmet interior temperature and light intensity data on 4 different EVAs and has been incorporated into data collected earlier in the season. A single set of 6 AA batteries was sufficient for all four EVAs. A sample data set is shown in Fig. 4.

Test Results and Future Plans

The goal of this project was to test the prototype itself; therefore, the data collected during EuroMoonMars will be used to assess and improve the system. The testing showed that while the system did experience anomalous data (see data just after 13:48 in Figure 4 for a typical example) which needs to be addressed it is otherwise ready to be used in collecting data on MDRS crewmembers. A project is being planned for the 2014 season of MDRS which will use several of these systems to collect data on helmet conditions, both exterior and interior, on crewmembers during EVA. These data will be used to assess actual conditions inside MDRS simulation suit helmets and will give future researchers a baseline to use when incorporating new techniques or equipment to ameliorate the conditions that can lead to overheating.

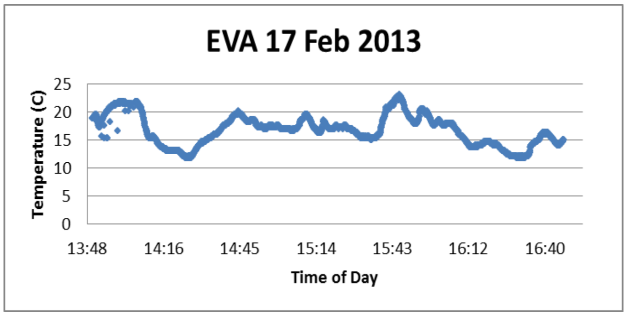

Fig. 5: Representative EVA Temperature Data

Additional Opportunity for the Logging System

The same system used to collect data during EVA also collected data in the MDRS GreenHab for 24 hours Feb 12 -13 and also from Feb 21 through the end of our rotation. To date GreenHab environmental data are collected manually four times per day. An Arduino-based system like the one developed for this project would allow for continuous monitoring of GreenHab conditions and thereby give a much more accurate measure of hourly, daily and seasonal variations that plants in the GreenHab are exposed to. To this end a second project is planned for the 2014 season of MDRS to build two or more Arduino-based systems similar to the ones already developed, but with an AC power supply. These systems will supplement the manually collected environmental data that the GreenHab coordinator uses to plan the growing season and assess the GreenHab system.

V. SPACESUIT GEAR LOADING

(Nebergall)

Since the spacesuit integrates a life support backpack, the user's options for carrying field gear are very limited. This project examined gear loading options with the current suit configuration, and proposes low cost, incremental improvements to advance both field science and analog engineering at MDRS and other analog and eventually real exploration environments.

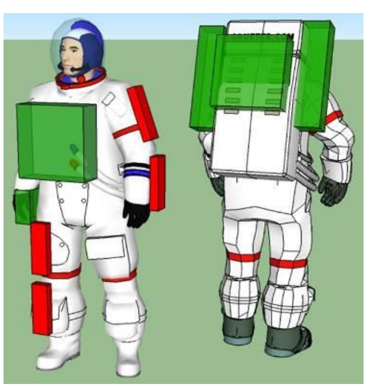

Fig. 6: Spacesuit Gear Options

Equipment Location and Mass Guidelines

See Figure 5 for gear locations – core locations are shown in green, and limb options in red.

Due to inertia, any gear carried on the forearm or shin requires more exertion while working or hiking, respectively. Due to this weight consideration, the forearms are best for lightweight gear such as ATV mirrors, GPS, or other displays and control pads that can be operated with the opposite hand

Since the backpack area is used for "life support", a chest pack can be used for heavier, bulkier gear. A hydration pack with additional backpack space, looped through the chest-straps of the backpack, is an ideal location for carrying gear and sample containers. It offsets the backpack by moving the center of gravity (CG) forward on the body. This makes hiking less stressful and climbing safer. It also allows two-handed access to gear, tools, and sample containers.

The ideal place to carry heavier hand tools, such as a hammer drill, is on a belt holster. This moves the center of gravity slightly downward for added stability, and places weight on the hips where it is most easily transferred to the ground via the legs without stressing the back. Holsters or side bags should be placed to avoid restricting leg movement.

Lightweight, bulky gear can be strapped to the backpack externally if it does not interfere with the fans or overly shift the CG backwards or upwards.

Due to the helmet visibility and glove tactile limitations of the suit, the user should memorize and practice using any gear holsters, pockets, and pouches prior to putting on gloves.

Proposed Suit Improvements

MOLLE (MOdular Lightweight Load-carrying Equipment) is a gear-carrying system currently available for military and first responder gear, but migrating into conventional camping gear. This replaces built-in pockets and pouches on packs and vests with a series of parallel webbed straps that are sown in at regular intervals. If a MOLLE vest and/or belt were kept at MDRS, researchers would be able to select pouches for their equipment prior to departure. Future crews could size pouches to their gear and bring the pouches with them. They could then be attached to these straps for field work and removed after the rotation.

While most analog suits are modeled after Apollo, more recent suit designs are backpack entry designs. Work should be done to at least make experimental single versions of an affordable analog.

Technology Integration with Future MDRS Missions

A USB charging accessory should be added to the backpack. This would allow recharging for small camera drones in the field while hiking between sites, and offer back-up power for electronics. Light drones typically allow 5 minutes of flight between 45 minute recharging sessions, making them ideal for occasional use in inaccessible terrain or for navigation siting. Currently, one can purchase 20 by 20 cm quad-copters with low-end HD video cameras, or larger drones that can stream video to smart phones. Future MDRS suits should allow for technologies such as smart watches, heads-up displays, micro-drones, and other off-the-shelf technologies.

A wi-fi point-to-point communications system could eventually replace or supplant FRS radios, and be used with headsets to simplify communication. Wi-fi would also allow real-time recording and streaming of GPS coordinates, sensor readings, images, and speech recognition recording of field notes.

In 2005, NASA used MDRS for experiments with advanced digital networks, suits with voice recognition, and large robot rovers that would follow the crews around and respond to voice commands, all while relaying data live back to headquarters via satellite. These projects involved three moving trucks of equipment costing millions of dollars. Eight years later, we can do most of the same engineering studies with a smart phone and wi-fi network near the hab. The only thing missing is a rover and extended wi-fi network.

To fill that role, University Rover Challenge (URC) past participants can be reconfigured to follow crews and relay data. A bridge program between URC and MDRS Science would allow ongoing university research to pick up where NASA left off, and coordinate with NASA and other organizations to expand this field.

VI. DESIGN AND DEVELOPMENT OF GEOLOGIC FIELD EQUIPMENT FOR USE IN A SPACESUIT

(Davis)

Fig. 7: Kent Nebergall drilling into a small gypsum vein at MDRS in Hanksville, Utah

This project started off with the intent to develop more efficient and reliable geological survey and analysis equipment that would be appropriate for use in small, enclosed, low-gravity environments. We planned to develop equipment that would maximize the available space of a small habitat such as MDRS and living quarters off-world, while easing the difficulties of geologists working in a Mars field environment. However, we found that the difficulties geologists will face when considering hands-on research while wearing a space suit to be worthy of its own project.

Methods

MDRS is an immersive Mars research simulation; participants are required to wear a simulated space suit when outside of the habitat building. During the crew 120 and 124 rotations, crew members shared responsibilities while on extra-vehicular activities (EVA) that ranged from carrying equipment to collecting uncontaminated samples.

Fig. 8: Clay sample collected to return to habitat for spectral analysis

Results

We found that determining the type and composition of minerals and soil was extremely difficult while wearing a helmet. The hand lens was nearly useless and using our senses, as geologists are taught to do in the field, was We had to take numerous samples to the lab, and in more than one case had to drill for a sample a second time because it was not what we had intended to collect (e.g. siltstone instead of sandstone).

Backpacking numerous samples or carrying large amounts of equipment is inefficient and impractical. The weight of the suits paired with the equipment and samples slowed down the entire team and made for tenuous conditions when navigating terrain. These are small inconveniences during a simulation, but could amount to loss of productivity and, at worst, life during an actual Mars mission.

Future Plans

We are currently considering a modification of the hand lens to a light-weight optical head-mounted display (OHMD) that could connect wirelessly to a small high definition camera. The camera will be small enough to wear in the top of user's glove and will be hardened against the effects of radiation that will be encountered while on the surface of Mars. It will have software compatibility for use with a tablet, as backup, should an issue arise with the OHMD integration. A sample device, using store-bought hardware, will be carried to MDRS to test this field season, 2013-2014. If the results show that geologic field activities are more easily carried out and/or moral of the crew increases due to ease of use of the equipment then we will create an independent design. We intend to continue our research to explore improvements of other geologic field equipment. We will make our data and designs available online open source, and hope that our results will be expanded and improved upon by a community with the shared goal of exploring Mars.

Fig. 9: MDRS Crew 124 members navigating through a canyon while returning from EVA

VII. ATV STUDY

(Bruneau)

This study aimed to understand the difficulties encountered in the field for the crossing of different obstacles, and to have a user-centered approach, to evaluate the ATV in usability terms.

Protocol

The data was collected by Audrey Bruneau with the participation of all the EuroMoonMars A crewmembers, who filled out a questionnaire. Each of them had driven the ATVs during at least four EVAs. Off-roading was strictly forbidden, this is why the users have evaluated the ATV's capacities by staying on the road and walking on the different kind of terrain.

Questionnaire

A list of questions has been validated. This list was split into four categories in order to adapt the questions to the type of terrain (sandy terrain and dunes, terrain scattered with rocks, terrain covered of rocks, slopes).


Fig. 10: Crew 124 on the quads (*Photo: D.Oltheten*)

Results

- Ergonomics

The vehicle is very easy to learn, especially for people having a driver license (all subjects of the experiment). A few minutes are sufficient to learn to use the quad. However, crossing rocky terrain or driving the quad at moderate speed (over 50km / h) is more difficult to learn.

- Safety

Users have a good understanding of the risks on flat terrain, sandy terrain and small hills. Ascending steep terrain is the most difficult type of terrain to assess risk from because it is difficult to see where you are going and to assess your weight balance.

The bigger danger for the driver is to injury and damage on the suit. A safety cage, a speed controller and an indicator for the balance can help the driver to feel safer.

- Space suits

The space suits of MDRS are not suitable for driving an ATV. The spacesuit makes driving the vehicle difficult. The user has a very limited peripheral vision and no way to protect his head if he falls. The suit is cumbersome and makes avoiding injury (in event of fall) difficult. The collar tends to bang in to you on bumps. The pack create instability on rough terrain, especially when it is loose.

- Capacity to manoeuver

Most quads have a great turning radius and making a three point (or more) turn is usually possible even in difficult sandy and rocky terrain allow turning around. The terrain types that strongly restrict turning are those with many large rocks, steep slopes, or narrow passages.

- Two people on the quad

It seems to be difficult to have two astronauts on the same vehicle, because the EVA suits take up space. It also reduces the exploration speed and balance when crossing hills. However, this would provide a greater viewing angle. The passenger can watch on the sides while the driver maneuvers.

[VII readings, 18,19, 20]

VIII. RISKS AND SAFETY AT MDRS

(Holotnak)

The perception of risk, realistic risk of injury, and knowledge of emergency procedures in a simulated Mars Environment

Habitat

The habitat at MDRS consists of two levels connected by a steep ladder. The lower level contains laboratory facilities, toilet and shower facilities, as well as two hatches for entry and exit. The upper level is made up of private sleeping areas for the crew, kitchen facilities, and general work space. There is also an external greenhouse and a small astronomy observatory.

Risks in this environment mirror those of these facilities outside of simulation such as common kitchen injuries (cuts and burns) or chemical exposure in the laboratory. However, they are exacerbated by the confined nature of MDRS and long working hours. In addition, the high turnover rate for crews can contribute to unfamiliarity. Poor labelling or the use of inappropriate equipment left by previous crews in the laboratory facility could also lead to higher risk of injury.

Extra Vehicular Activity

EVAs at MDRS are carried out in a desert environment by walking or a combination of walking and ATV travel. Normal risks in this environment such as heat exhaustion are greatly exacerbated by the simulated space suits worn by crew members due to minimal ventilation and poor support for hydration. In addition, the risks of potential trauma from ATV collisions or falls are enhanced compared with normal use. Space suit helmets are not rated for crash protection and some of their design features (helmet material and latches) may contribute to injuries in a collision or fall from the ATV. The potential for harm from becoming lost, injured, or confronted by animals is likely lower than outside of simulation due to the buddy system and communication with the habitat.

Isolation and Confined Space

The confined space and design of the habitat makes the evacuation of personnel in the event of a serious injury or fire more difficult. In addition, the 24 hour occupation of this space by the crew enhances the potential for the spread of communicable illness. Finally, the isolated location of MDRS along with the lack of direct real-time communication with external mission control would lead to an extended evacuation time in the event of serious injury.

Realistic risk of Injury and Illness

Injury and illness at MDRS during crew 124's rotation was limited to short bouts of an influenza-like illness, minor respiratory complaints, and minor cuts and scrapes. This is in line with the typical experience of MDRS crews where serious injury and the need for evacuation is rare.

Knowledge of emergency procedures and risk perception

Crew 124 arrived at MDRS with differing levels of experience on expeditions and in remote environments, first aid knowledge, ATV skill level, and perceptions of risk deriving from MDRS activities. All crew members were required to participate in a mandatory briefing prior to arrival which discussed basic MDRS procedures and safety protocols.

While the risk of injury at MDRS is enhanced compared with similar activities outside of simulation it still remains relatively small. Instead, most of the additional risk posed by MDRS participation pertains to inherent difficulties posed by managing a serious injury or need for evacuation in this environment.

This risk could be greatly mitigated through practical measures. These measures may include the introduction of 24 hour monitored communications with mission control, improved suit to habitat communications, or the availability of a satellite phone.

Consistency among crew perceptions and procedures is essential. Currently safety briefings and their emphasis vary on a crew by crew basis. The introduction of daily safety briefings and pre-EVA safety briefings with mandatory elements introduced by the external MDRS management and support teams would be of benefit. This would lead to greater clarity in a true emergency situation and for the evaluation of crew performance afterwards.

IX. CONCLUSIONS

A human factors methodology for investigating efficiency and habitability on long term missions has been tested, and proven to give results. Communication came out to be the most relevant key factor within more years of investigation in 5 crews at MDRS. Also music and tasty food has shown to have a positive impact on comfort. Our hypothesis that the use of music and nature sounds can function as a countermeasure to stress in group dynamics was supported. As a conclusion of the human factors study it can be very useful to implement this methodology on other long term missions to investigate and make astronauts aware of problems that can be solved to improve their comfort and productivity on a mission.

Focuses investigations have been also performed on suits and geological equipment for EVA including ATV. To learn more about external and internal EVA suit conditions astronauts are exposed to during EVA, a custom built Arduino device is ready for implementation to gather data on temperature and light intensity inside and outside EVA helmets; these data can be used to investigate how to improve astronaut comfort. EVA gear loading should restrict heavy loads to chest packs and belts, with the encouragement of modular pouches for mission-specific items. We have also investigated at enhancing human operations and science performances for geological exploration using instruments, and sample acquisition following previous EuroMoonMars campaigns [16, 17]. A system to replace the use of a normal geological hand lens is under development, which will make it easier to see the same features but while wearing an EVA helmet. ATVs can be useful when investigating a new terrain on a different celestial body. To better the safety and knowledge of what to do in case of emergency at MDRS, safety briefings at MDRS could be useful. An improvement of current communication could also make the safety risks smaller at MDRS in case of the occurrence of dangerous situations.

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