HUMAN FACTORS RESEARCH AS PART OF A MARS EXPLORATION ANALOGUE MISSION ON DEVON ISLAND

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ABSTRACT

Human factors research is a critical element of space exploration as it provides insight into a crew's performance, psychology and interpersonal relationships. Understanding the way humans work in space-exploration analogue environments permits the development and testing of countermeasures for and responses to potential hazardous situations, and can thus help improve mission efficiency and safety. Analogue missions, such as the one described here, have plausible mission constraints and operational scenarios, similar to those that a real Mars crew would experience. Long duration analogue studies, such as those being conducted at the Flashline Mars Arctic Research Station (FMARS) on Devon Island, Canada, offer an opportunity to study mission operations and human factors in a semi-realistic environment, and contribute to the design of missions to explore the Moon and Mars. The FMARS XI Long Duration Mission (F-XI LDM) was, at four months, the longest designed analogue Mars mission conducted to date, and thus provides a unique insight into human factors issues for long-duration space exploration.
Here, we describe the six human factors studies that took place during F-XI LDM, and give a summary of their results, where available. We also present a meta-study, which examined the impact of the human-factors research itself on crew schedule and workload. Based on this experience, we offer some

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lessons learned: some aspects (perceived risk and crew motivation, for example) of analogue missions must be realistic for study results to be valid; human factors studies are time-consuming, and should be fully integrated into crew schedules; and crew-ground communication and collaboration under long-term exploration conditions can present serious challenges.

KEYWORDS: human factors, analogue environments, human space exploration, Mars, extreme environments

1 INTRODUCTION

Human factors[†] (HF) research studies that target long-term spaceflight missions in relevant analogue environments are invaluable. HF experiments and the follow-up analyses allow an increased understanding of human performance on long-term missions, providing lessons learned that optimize mission efficiency and success. On the other hand, HF studies can be time-consuming, and may constitute an additional stress factor for crews. For this reason, it may be of strategic importance to integrate HF projects in the overall mission science program to enable full participation by the crew. This approach avoids the perception of an additional task being added to the tight mission timelines.

A 2007 four-month simulated Mars mission on Devon Island, Nunavut, offered realistic mission constraints and operational scenarios, similar to those that a real Mars crew would experience (Battler et al., 2008). This is the longest such study completed to date. A total of seven HF projects were completed during the mission, including a meta-study examining the effects of the HF research on crew schedules.

The seven HF studies, described in Section 4, were:

- FHFS-01: Countermeasures to stress and isolation
- FHFS-02: Analysis of group dynamics
- FHFS-03: Analysis of the station environment habitability, cognitive performance, and crewmember stress and coping
- FHFS-04: Sleep disruption under Mars exploration conditions
- FHFS-05: Food choice, preparation and satisfaction
- FHFS-06: Cognitive function and sleep disruption during the Arctic Martian sol

[†] We use "human factors" in a broad sense, including psychology, physiology, performance, and human-computer interaction.

- FHFS07: Human factors meta-study – the impact of human factors research on crew schedules and attitudes

In this paper, we provide an overview of these seven studies, and make a case for an ongoing program of HF research conducted during analogue missions.

2 HUMAN FACTORS RESEARCH ON ANALOGUE MISSIONS

An **analogue mission** has been defined as "a fully integrated set of activities in support of, and/or simulating future exploration missions on the Moon or Mars" (Williamson et al, 2007). Analogue missions are often conducted in **analogue environments**, that is, environments that share one or more salient feature (e.g. temperature, remoteness, topology, mineralogy, etc.) with the target environment. However, some analogue missions are conducted entirely **in simulation**, such as the upcoming MARS-500 study (MARS-500 website, 2009). In some cases, the analogue nature of the mission is **serendipitous**, in that the participants did not realize (or care) that their situation might be similar to that of Mars or Moon astronauts. Serendipitous analogues such as Antarctic exploration (Stuster, 1996; Hoffman, 2002) can offer valuable insights into the human response to risk, isolation and other such challenges. However, some analogue conditions (such as the 24.9 hour Martian Sol, or particular crew compositions) are unlikely to appear serendipitously. For this reason, we also need **designed** analogue missions, which deliberately mimic certain conditions of the target mission, usually a specific reference mission (e.g. Duke et al, 2003 or Drake, 2009).

In all cases, as specified in the definition above, it is important that the activities of the mission be **fully integrated**. Some of the most challenging risks (see Section 2.1 below) only arise in complex situations where heterogeneous groups and systems have to work together successfully over the long term. Integration is important both for discovering these issues, and for testing potential counter-measures.

Of course, one of the best analogues for planetary exploration is the International Space Station (ISS), and many valuable HF studies have been conducted there. However, ISS studies are expensive and infrequent, relative to Earth-based studies. They typically have a very small number of subjects, and there are often significant privacy concerns, since the astronauts are public figures. Moreover, the ISS is far from being a perfect analogue, in that all operations are in micro-gravity (as opposed to Moon or Mars gravity), and there are no surface-exploration or field-science equivalents.

FX-I LDM was a *designed analogue mission* in a strong Mars *analogue environment* (Section 3.1) with some *simulated constraints* (Section 3.4), which *integrated several operational elements* (Section 3.5) of a

Mars surface exploration mission. In this paper, we advocate for HF research on further missions with these traits.

2.1 Human Factors Risks And Questions Appropriate For Analogue Research

NASA's Bioastronautics Roadmap (Charles, 2005) and Human Research Integrated Research Plan (Grounds et al., 2009) identify a number of barriers to safe human spaceflight, and some strategies for overcoming them. Of these, some clearly are not appropriate for investigation in analogue environments, such as "Risk of Carcinogenesis from Space Radiation" (ibid., p16), and of the remainder, many require laboratory and/or spaceflight studies for thorough study. Nonetheless, many of these issues are amenable to analogue research. Moreover, analogue research is relatively safe and inexpensive (especially relative to spaceflight) and permits a holistic approach, wherein many of the conditions of space exploration (lengthy periods of isolation, communications latency, crowding, bulky life-support equipment, small heterogeneous crews, packed schedules, etc.) can be experienced in parallel by the participants. The downside of such complex scenarios is that it is difficult to conduct a traditional human factors (HF) study, with a control group and minimized confounding factors, that yields statistically significant results. However, we believe that HF analogue studies can provide vital insights into the risks of human spaceflight and the value of potential countermeasures. Some areas of particular promise include the following:

- Testing of EVA equipment, procedures and communications
- Crew selection
- Countermeasures for psychosocial problems
- Design and testing of information systems

These are described in more detail in the following sub-sections.

2.1.1 Testing of EVA equipment, procedures and communications

Although it is difficult (if not impossible) to mimic the gravity or atmospheric pressure of another planetary surface in an analogue environment here on Earth, many of the other factors that would affect an EVA can be simulated, such as suit bulk, in-suit conditions, field of view, geology, communications technology, science goals and safety considerations. Moreover, analogues allow us to work through full-cycle (planning, training, execution, debrief) EVA operations with all stakeholders (astronauts, scientists, and mission planners, amongst others) over and over again, increasing the opportunity for discovering potential problems and opportunities.

2.1.2 Crew selection

It is tempting to assume that homogenous crews (i.e. crews in which all crewmembers have the same 'ideal' social, cultural, professional, and psychological profile) will generally perform better than heterogeneous crews, in part because the latter are less studied and harder to predict. However, some studies (such as FHFS-03, described in Section 5.3) suggest that crews with at least some heterogeneity might be more stable than homogenous crews. Moreover, it seems politically unlikely that NASA will return to the days of crews of all-male, all-American, mostly-military astronauts. One of the best ways of testing heterogeneous crew compositions, both in general (e.g. "Can men and women work well together?") and in specifics ("Does this particular crew work well together?"), is to put the crew in a realistic simulation in an analogue environment.

2.1.3 Countermeasures for psychosocial problems

Even the best crew will have issues if working under stressful conditions for a long time. Many of these potential problems have already been identified in analogue and laboratory studies (see (Stuster, 1996) for some excellent examples). Now the key question is: What countermeasures are practical and effective under realistic conditions? This is where the integrative nature of analogue research becomes particularly valuable. An individual set of countermeasures that prove effective in population studies may not be as effective when applied to astronauts during spaceflight, or may be infeasible under spaceflight constraints. Conversely, everyday strategies (such as preparing a special meal for a stressed crewmember) might be more effective than expected.

2.1.4 Design and testing of information systems

It is a truism of software development that the best design is done in the context of intended use, with the intended users. Although it would be impractical to send software designers to space, we can send them to analogue environments relatively easily, where they will have the opportunity to interact with various stakeholders in the context of a mission. Moreover, the design-implement-test software cycle can be run through repeatedly, increasing the chances that the software eventually used in spaceflight will be bug-free and enhance (rather than impede) the workflow of the users.

3 THE FMARS XI LONG-DURATION MISSION (FXI-LDM)

3.1 The Flashline Mars Arctic Research Station (FMARS)

FMARS (Figure 1) is one of two Mars analogue stations used by the Mars Society, a privately-funded grass-roots advocacy organization, to investigate how to live and work under Mars mission constraints. The other station is the Mars Desert Research Station (MDRS) located in Utah, USA. FMARS sits on the rim of 39 million year old Haughton Impact Crater on Devon Island, the largest uninhabited island in the world. The closest town is an hour away by small plane, and weather conditions vary rapidly and may delay any rescue by weeks. Devon Island is a polar desert, so visible life is rare. With temperatures reaching as low as negative forty degrees (Celsius or Fahrenheit) at the start of the summer season, the harsh conditions simulate some of the hardships that a crew would experience during a real Mars mission.

The layout of the habitat (Figure 2) offers some visual privacy in the very small crew quarters, but the walls are not soundproof. Although there are many possible designs for a Mars exploration habitat, the particular design chosen for FMARS is not unrealistic, and is based on a design proposed by Zubrin (1996). The 24-hour daylight is analogous to that of a polar Moon or Mars mission, where the crew's schedule would be conducted in the absence of visual cues for the time of day; moreover, it allows FMARS crews to work on alternate schedules, such as the Martian sol (see Section 4.4). These conditions make FMARS an ideal location for hosting human factors research and an excellent analogue for human exploration of other planetary surfaces.

3.2 The F-XI LDM Crew

The F-XI LDM crew was composed of seven researchers, all either university graduate students or faculty, selected by the FMARS Science Advisory Group from a pool of about 40 applicants. See Table 1 for a summary of their crew responsibilities, ages, genders and backgrounds.

The crew's objectives were to:

1. Adapt to the harsh conditions and psychological challenges of the analogue mission, and operate safely for the duration of the mission,
2. Prepare for eventual human missions to other planetary surfaces, by living and working in a strong Mars-analogue environment, and participating in human factors research,
3. Focus on scientific exploration, by
    a. Developing field exploration techniques relevant to the scientific exploration of Mars
    b. Pursuing a suite of relevant science goals in a Mars analogue environment
    c. Conducting scientific exploration under many of the constraints that Mars astronauts will one day face, and
4. Generate and support public interest in space exploration.

3.3 Pre-Mission Training

Before the four-month Arctic expedition, there was a two-week crew training rotation at MDRS in Utah. The training program included a handover of project information from the remote science team to the crew leads for the various projects. The projects were reviewed and the approximate schedule was designed. Early issues were identified, such as difficulty of obtaining a VO2max value on a treadmill with limited monitoring equipment, and procedures were adjusted accordingly. Also during these two weeks, the crew planned the field science operations in collaboration with the remote science team, and received safety training (ATV operation, wilderness first aid, firearm handing and emergency procedures).

The crew found this training stage to be invaluable. It allowed the crewmembers to get to know each other in a relatively low-stress environment, and to approach the upcoming mission and its challenges as a team. Later, astronaut Clay Anderson reinforced the need for crew training by saying that it is: “important… to become as close as you can on the ground and that you do as much of your training as possible together” (Anderson, 2007).

3.4 Simulation Constraints

In addition to the analogue conditions imposed by the FMARS environment, the fidelity of the analogue mission was strengthened by simulation protocols, including the following:

- Crewmembers could only exit the habitat in a simulated spacesuit as part of an organized traverse, after having spent five minutes in the ‘airlock’. Two crew members (the Safety Officer and the

Medical Officer) were not bound by this constraint when doing essential engineering tasks (e.g. filling the generator) or acting as polar bear monitor during a sortie.

- To simulate Mars-Earth communications latency, (almost) all communications with the outside world were subject to a twenty minute delay. The infrequent, brief exceptions were either safety-related or unavoidable practicalities, such as the daily safety check-ins with the Polar Shelf Project monitors, real-time components of the stress countermeasure study and end-of-mission flight confirmations. Private real-time communications were very rare and episodic.
- All food was shelf-stable without refrigeration (see Section 4.5).
- Water use was tightly restricted and monitored (Bamsey et al, 2009). For example, crewmembers showered only once per week, and used as little water as possible when doing so.

3.5 Operations

Operations followed a weekly cycle, with Monday-Friday as work days, Saturday as a half-day, and Sunday off. An outline of a typical working day is given in Table 2.

An important analogue feature of FX-I LDM operations was that the bulk of crew work was not simulated, and was instead motivated by real needs and interests. In particular, all of the field science projects were genuine attempts to learn more about Haughton Crater geology and biology. We strongly believe that it is impossible for participants in HF studies to maintain motivation in make-work over the long-term, and that this is a potential confounding factor in fully-simulated analogue missions.

Following is a list of the field science (some with a laboratory component) research projects carried out during the mission:

- Biological properties of the active layer above the permafrost
- Microbial community comparison within the active layer above the permafrost
- Diversification of microbial activity in different snow types on Devon Island
- Seasonal variation of Chironomidae in the ponds of Devon Island as a paleoclimatic indicator
- Seasonal variation of the ponds on Devon Island
- The role of geologic parameters in predicting bioload above the permafrost, while varying depth, location, and soil type, through the spring thaw transition

- Transient hydrothermal systems of the Haughton impact structure: Implications for the development of biological habitats
- Tracing the relative contribution of basement and carbonate lithologies in the Haughton crater impactites
- Permafrost landform development over the winter-to-summer transition: Characterization of evolving physical conditions of a polygon field
- Observing the “Weeping Cliffs” phenomenon near Haughton Crater as an analogue for Mars
- Regolith landform mapping of Haughton Crater as an analogue for Mars
- Mars Radiation Environment Modeling (MarsREM)

4 FMARS HUMAN FACTORS STUDIES (FHFS) OVERVIEW

The seven FMARS human factors studies (FHFS) are described in this section, including a ‘meta-study’ (FHFS-07) on the effects of human-factors research itself on crew schedules and attitudes. The data for FHFS-01 (Lapierre & al., 2007) and FHFS-02 are being integrated into the data from other analogue missions, so no results are presented here. The results of FHFS-03, FHFS-04 and FHFS-06 have been published elsewhere (Bishop et al, to appear; OGriofa & O’Keeffe, 2008; OGriofa et al, to appear), so are only summarized. This is the first published description of FHFS-05 and FHFS-07, so their rationales, methods and results are given in considerably more detail.

Our goal in this section is to provide examples of the kinds of HF studies that can only be carried out as part of long-term designed analogue missions with integrated operations, and illustrate the value of such studies.

4.1 <u>Study FHFS-01: Countermeasures to stress and isolation</u>

4.1.1 Goals and hypotheses

The goal of this study was to investigate counter-measures to stress and isolation related to long duration work in extreme environments. We hypothesized that the interventions (described below) would ameliorate the symptoms of stress and effects of isolation.

4.1.2 Methods and measures

We measured and evaluated the effects of various support interventions based on distance communication technologies and of physical training, using measures of relevance, feasibility and perceived efficacy.

The support interventions included Telecommunication & Support Sessions (TCSS), a personalized exercise program, personal history surveys and critical incident logs. The TCSS consists of a set of questions delivered using various types of electronic communications media, including emails and real-time video chat. Six sessions were conducted with a different medium every other week. The questions and answers provide insight into daily routines and communication patterns. Traditional and systematic approaches were used to help with relationship strategies. The design of this study was based on data collected previously by the principal investigator (PI) on the "Terre Adélie" mission in Antarctica, and during a 110-day confinement mission simulation in Russia. After each session the crew would fill in a technology evaluation survey and submit it to the PI.

The personalized exercise program included the use of a stationary bike, free weights, an exercise ball, and elastics for resistance training. The bike was positioned for a scenic view of Haughton Impact Crater out the larger downstairs window. The three goals of the exercise protocol were to increase the volume of oxygen transported by the cardio respiratory system (VO2max, a standard measure of fitness), to improve aerobic endurance, and to improve muscular endurance and flexibility (see Figure 3 top left and Figure 4).

The critical incident log was filled out at the end of each third of the mission. The log had no specific structure, but asked the crew to write down any events, positive or negative, that they felt influenced their personal feelings during the mission.

4.1.3 Results

A paper presenting the results of this study is in preparation (Lapierre et al, 2010).

4.2 Study FHFS-02: Analysis of group dynamics

4.2.1 Goals and Hypotheses

This study dealt with the impact of crew diversity (social characteristics, personality traits, and interpersonal needs) on the wellbeing and adaptation of the crewmembers (perception of group functioning and attitudes during the mission), within an international mission in a space analogue environment. It also explored the hypothesized relationship between the individual's identification with the group and their self-reported stress and way of coping with it.

4.2.2 Methods and measures

This study included several online surveys to be completed during various parts of the mission using SurveyMonkey.com. The surveys included: the Personal History Questionnaire (PHQ) which had to be completed before the start of the mission; the Flashline Mars Arctic Research Station Opinion Survey (FMARS-OS) completed at the beginning and end; as well as the Profile of Mood States (POMS) and the Group Environment Scales (GES) which were taken at monthly intervals during the mission.

These measurements had multiple purposes. On the one hand, this study examined the effect of leadership on group cohesion, within a crew living and working in such an isolated, confined, and hostile environment. At the same time, it explored the possible effects of the crewmembers' personal characteristics (social characteristics, but also personality traits and interpersonal needs) on their individual mood states and perceptions of attitudes, group environment, and group functioning. Finally, it studied the possible relationship between the individual's identification with the group and perceived stress and explored the speed of adaptation in this new environment.

4.2.3 Results

It is a particular strength of this study to have been able to accommodate several human factors study teams with multiple interests within this Mars mission simulation, which has also rendered it possible to share the data and gain new knowledge from such a multi-interest approach. However, the number of participants to this simulation being small, it is necessary to combine this data with that from other analogue missions in order to get results which can be generalized, with the goal of helping to develop optimal psychological selection criteria and appropriate training and countermeasures for individuals and teams working and living in multicultural extreme environments such as the polar regions, the International Space Station and the surfaces of the Moon and Mars (Lasslop & LaPierre, 2007).

4.3 <u>Study FHFS-03: Analysis of the station environment habitability, cognitive performance, and crewmember stress and coping</u>

4.3.1 Goals and Hypotheses

The goals of this study were to assess the station environmental habitability at mission end through the Planetary Habitat Analog Design Efficiency Survey (PHADES); to evaluate monthly cognitive performance utilizing a software cognitive assessment tool (WinSCAT: Spaceflight Cognitive Assessment Tool for Windows); and to investigate the interaction of personality, stress and coping styles upon group dynamics using a composite battery of assessments through an online survey site (SurveyMonkey.com). Due to the exploratory nature of this research, there were no formal *a priori* hypotheses.

4.3.2 Methods and Measures

PHADES is an end-of-mission survey that allowed the crew to give feedback on a relative scale about the layout and design of the habitat. It asked about space use within the structure and other aspects of habitat design. WinSCAT is a computer-based battery of neuro-cognitive assessment tests designed by researchers at NASA Johnson Space Center and Wyle Laboratories (Flynn and Sypes, 1998) (see Figure 3 top right). It has been validated in various clinical settings and on the International Space Station. Its purpose is to objectively evaluate crew cognitive performance. Data from WinSCAT was incorporated into the data on stress and coping, as a physiological indicator of fatigue and impaired performance. Measures of personality included the NEOPI-FFA (Costa & McCrae, 1978-1991; global five factor personality dimensions) and the AstroPCI (Chidester, Helmreich, Gregorich & Geis, 1991: achievement motivation, personal orientation, type A) both of which have been used extensively in previous space analog research as well as on general populations (Rose, Helmreich, Fogg & McFadden, 1994; Helmreich & Foushee, 1993; Helmreich & Merritt, 1998; Helmreich, 2001; Manzy & Lorenz, 1997). Assessment of perceived stress was conducted by using the Cohen's Perceived Stress Inventory (Cohen, Karmarck & Mermelstein, 1983), while coping styles were measured using the brief COPE (Endler & Parker, 1994).

4.3.3 Results

Results reported in *Acta Astronautica* (Bishop et al, to appear) indicated that stress was clearly evident across the mission for both males and females. Sources of crew stress were primarily structural team factors that have been shown to contribute to team fission, e.g., the inclusion of a single member whose mother tongue was not English or the relegation of some team members to purely support roles. The lack of meaningful inclusion to the discovery part of exploration has persistently been found to contribute to lack of ownership of mission goals by team members. Other sources included differential goals and priorities between in-simulation and out of simulation groups, majority versus minority decisions taken by the group and poor matches between personality and mission parameters of isolation, confinement and roles for several individuals. Research from various extreme environments clearly indicates that not all personalities are good fits for confined and isolated environments (Bishop, 2004).

Positive adaptation to many of these challenges was exemplified by the emergence of several individuals who were uniformly lauded by group members as being key sources of leadership and support. The emergence of these boundary role persons has been repeatedly shown to be critical to effective team functioning. They serve to bridge the various interests of subgroups and individuals and provide the social ties that hold groups together. Finally, the team reported stress from pressures to be inclusive of all members in all activities. Taking private time away from the group was difficult to accomplish and often frustrated by the lack of auditory privacy. The use of email contact with family provided substantial resources for venting and emotional relief for all team members.

Coping was found to follow different patterns generally distributed along gender lines with males utilizing more avoidant coping and females with more active coping. This reflects similar results found in other studies (Ben-Zur & Zeidner, 1996; Rosario, Shinn, March and Huckabee, 1988; Brems & Johnson, 1989; Matud, 2004) that suggest that males are more reluctant to address interpersonal conflict openly and withdraw rather than seek immediate resolution. This may be one explanation for other findings (Aries, 1976; Anderson & Blanchard, 1982; Baird, 1976; Wall, 1977; Wood, 1987; Sandal, 1995; Rothblum, Weinstock, & Morris, 1998) that suggest that mixed gendered teams outperform mono-gendered teams because the presence of women 'normalizes' male functioning and, perhaps, promotes more active coping behavior and earlier conflict resolution. These relationships need further verification in future studies.

4.4 Studies FHFS-04 and FHFS-06: Sleep disruption under Mars exploration conditions and cognitive function and sleep disruption during the Arctic Martian sol

Originally posed as two separate studies, this study examines the effects of analogue/simulation conditions on sleep disruption and cognitive function.

4.4.1 Goals and Hypotheses

Sleep research is crucial for the success of manned spaceflight. The results of previous studies on short and long duration spaceflight missions, suggests that approximately 25% of crew-members experience dramatic impairment in the quantity and/or quality of sleep. Astronauts only average 6 hours of sleep and can also suffer severe disentrainment of their circadian rhythm after ~100 days in space. We hypothesized that similar effects would be observed during the analogue mission, including sleep disruption and a negative effect on cognitive function. Astronaut fatigue, alertness deficits and performance failure have all been identified as critical risk factors during both extended spaceflight and Antarctic missions (Dinges at al., 1999). Extended expeditions to polar regions have also provided intense challenges to the circadian system due to the extreme fluctuation and seasonal variation in light/dark cycles combined with the varying degrees of social isolation that accompany an expedition of this nature. The absence of the 24 hour Terran light pattern experienced by astronauts in orbit around the Earth and the absence of a day/light alteration on interplanetary flight can be directly compared to the condition of continuous polar sunlight (Scheer at al., 2007) During this mission, crew-members collected both objective and subjective physiological data, including cardiopulmonary coupling and changes in cardiac autonomic activity, in order to monitor sleep stability and disruption. They also underwent cognitive function testing, including decision speed and reaction time testing, to evaluate any decline during the mission.

4.4.2 Methods and Measures

CASPER (Cardiac Adapted Sleep Parameter Electrocardiogram Recorder) is an ergonomic method of monitoring sleep stability, which was implemented as part of the 2006 Astrolab ISS Mission. In 2007 it was employed during F-XI LDM, during the Arctic summer. The seven-person crew (4 males, 3 females) also lived a Martian sol (24.65 hours) for 37 days. The Martian sol was implemented by the adjustment of habitat clocks to a central "Martian" clock, which was designed to provide an accurate daily cycle of 24 hours and 39 minutes. This was aided by the absence of the terran light pattern during the Arctic summer.

It has become increasingly accepted that there is a need in both research and clinical practice to document and quantify sleep and waking behaviors in a comprehensive manner, which is achieved through the use of both objective and subjective data. As part of this mission each crewmember completed both subjective and objective testing including a computer-based decision speed test (DST) and reaction time test (RTT). Both of these measurements were completed twice daily (pre- and post-sleep) before, during and after the Martian sol period of 37 days. The reaction test involved timed reaction to visual stimuli, while the decision test involved timed identification and recognition. The hypothesis was that the implementation of the Martian Sol protocol would have a negative effect on decision speed and reaction time. A one-way analysis of variance (ANOVA) was performed on both individual and averaged group scores.

4.4.3 Results

Cardiopulmonary data indicated that stable sleep (non cyclic alternating pattern) decreased over the duration of the Martian sol period and then returned to its baseline levels in the post-Mars period, while the opposite was observed for unstable (cyclic alternating pattern) sleep during the same time period. Since there is an absence of sleep pathology noted, it is reasonable to assume that disrupted sleep patterns could have resulted from the experimental variables experienced during the Martian sol protocol and resolution following cessation of the Martian sol.

There was a significant change in the decision speed time score from the pre-Mars to the Mars time (P <0.05) while the crew maintained their percentage correct. There was no significant change in the reaction time or delta change in reaction time between pre- and post-sleep of the crew across the Martian sol protocol (P 0.46). While cardiopulmonary data indicated an increase of unstable sleep during the Martian sol, there was no significant evidence of impact on cognitive ability. We were able to demonstrate that cognitive function testing is a valuable and effective adjunct to monitoring sleep stability and performance for a long duration space analogue mission. Even though sleep was disrupted for the crew-members, they were able to maintain their cognitive function.

4.5 Study FHFS-05: Food choice, preparation and satisfaction

4.5.1 Goals and hypotheses

This study was concerned with the advantages and disadvantages of allowing the crew to prepare at least some meals from scratch[3]. So far in the history of space exploration, astronaut food has been almost entirely pre-prepared (Perchonok and Bourland, 2002). In microgravity, it is impractical to attempt anything resembling 'cooking', and crews are so tightly scheduled that meals must be quick and easy to prepare. However, the Martian surface offers 0.38G, enough to keep ingredients in a bowl and food on the table, and a Mars mission would take at least 2.5 years (Hoffman and Kaplan, 1997), so there could be time for cooking.

We hypothesize that there are significant psychological and nutritional advantages to allowing a long-term space exploration team at least some opportunities to prepare food from scratch. Cooking allows ingredients to be combined in novel ways, relieving menu fatigue. Special meals can be prepared for special occasions, such as birthdays and holidays. If the nutritional needs of the crew change, the meals can adapt to meet those needs. Foods with too short a shelf-life to bring all the way from Earth can be prepared as needed. Ingredients can be stored in bulk, reducing the weight of packaging individual meals. Finally, cooking can be

[3] A summary of the results of this study was presented as a poster at the International Astronautical Congress (Binsted et al., 2008).

a satisfying creative outlet for crewmembers. On the other hand, cooking takes time and skill, and requires additional equipment.

4.5.2 Methods and Measures

In order to provide some insight into these trade-offs, the FXI-LDM crew tried both pre-prepared meals and cooked meals over the four months of the mission. Overall food consumption was tracked, and crewmembers reported on their satisfaction with the food and the effort required to prepare it.

In order to realistically simulate a Mars exploration mission, FXI-LDM food was highly constrained. All food items had an unrefrigerated shelf life of at least one year and, to conserve weight, dried foods (if available) were preferred to canned. Food was prepared using as little water as possible, and water was reused (e.g. pasta water could be used in a soup) if feasible. The only fresh vegetables available to the crew were the lettuce from two small Aerogrow (Aerogrow 2008) hydroponic gardens and sprouts grown in jars.

The crew had a small but functional kitchen (see Table 4 for a list of equipment and Figure 3 bottom left). The Yogotherm and cheese-making kit were important because the only dairy products which met the food constraints were powdered milk, cheese powder, grated Parmesan cheese and powdered egg.

On a typical day, each crewmember would prepare his or her own breakfast. Crewmembers would take turns being responsible for the preparation of lunch and dinner, and could choose to either use a pre-prepared meal, or prepare one from scratch. Cooked meals included dishes like pumpkin and coconut curry on couscous, sweet and sour TVP (textured vegetable protein) balls with stir-fried noodles and bean sprouts, or chili with "ground beef" TVP on rice.

At the end of the expedition, all crewmembers (except the crewmember who conducted the study) filled out a questionnaire, tracking:

- Satisfaction with the taste, nutritional quality, texture, variety, appearance, and quantity of the food, both relative to the crewmember's normal diet and to his or her expectations for the mission.
- Effort put into food preparation, and satisfaction with this effort.
- Kitchen equipment usage.
- How the crewmember felt about meals as social occasions.
- Which food items were particularly liked or disliked, and which were most missed.

4.5.3 Results

Overall, crew satisfaction with both the food and the effort put into preparation was surprisingly high (see Table 3), given the strict constraints required by the simulation. The high variation in the "effort" scores is probably due in part to the availability of easy-to-prepare or pre-prepared food, but also to the fact that crewmembers would often swap chores, allowing those that did not enjoy cooking to avoid it on many occasions. There was a range of cooking experience amongst the crewmembers: two cited cooking amongst their hobbies, while two others claimed to do little or no cooking as part of their regular routine, and the rest fell somewhere in between.

The frequency of use for each piece of kitchen equipment is shown in Table 4. The high standard deviation for several items indicates a degree of specialization – particular crewmembers became responsible for tending the Aerogrow gardens and the sprouts, and making the morning coffee.

All crewmembers missed fresh fruits, vegetables and meat, and highly valued the sprouts and Aerogrow lettuce. Missed food items that would *not* have violated the simulation rules were more idiosyncratic, including banana chips, spring rolls, and edamame. Food items that crewmembers had too much of included TVP (three crewmembers), crackers, dehydrated vegetables and powdered drink mix. Again, the list of foods the crew had too little of varied considerably, from mayonnaise to dried fruit.

The pre-prepared meals were generally unpopular, despite their convenience. The only pre-prepared meal that was appreciated was the canned chili, which two crewmembers liked. Of the meals prepared at FMARS, the 'high effort' meals garnered the most praise: sweet-and-sour TVP balls (three crewmembers), poutine (two crewmembers), curries (three crewmembers), tofu chocolate pudding (two crewmembers) and pizza (two crewmembers).

TVP was not a very satisfying meat substitute, and the entire crew was tired of it by the end of the expedition. Nonetheless, several TVP dishes were amongst those cited as being "favorites" by the crew. One problem with TVP is that some of its gastrointestinal side-effects can be difficult to tolerate, especially in the very close quarters of the FMARS habitat. Also, most shelf-stable protein sources are very low in fat content, so adding fat (typically lard or vegetable oil, although a tub of duck fat was particularly treasured) improved the taste of dishes considerably.

The psycho-social aspects of meal preparation and consumption were very clear. All crewmembers valued meal times as opportunities for social interaction, and particularly enjoyed the special occasion meals.

This is consistent with studies of teams in other analog environments (Stuster, 1996): meals eaten *en famille* provided the social glue that held the crew together. Meal times were an opportunity to discuss the challenges of the day, plan next steps, air complaints, share news, and so on. The crew would make detailed plans for special meals, and relished the challenge of trying to prepare dishes with the limited ingredients available. Special meals were used to break up the monotony of the long mission, and to mark the passage of time. One weekly ritual that was very highly valued was Sunday brunch, which invariably had a relaxed, festive atmosphere.

There are many questions still to answer. First, because the crewmembers were responsible for selecting and preparing the food, and are among the authors of this paper, there is necessarily a certain lack of objectivity in this data. Moreover, the small number of participants undermines the statistical significance of the study, even though the value of allowing at least some meals to be prepared from scratch is strongly suggested. A more formal, controlled study would be useful to determine whether or not this result is generalizable.

Second, all of these crewmembers had highly overlapping ‘food cultures’. A more culturally diverse crew might face greater challenges in devising meals that the whole group would find satisfactory, which might increase the value of individually-selected pre-prepared meals. On the other hand, the social glue of shared meals might be even more important for a more culturally diverse crew.

Third, although crewmembers were very satisfied with the perceived nutritional quality of the meals on the F-XI LDM expedition, this study did not compare the *actual* nutritional quality of pre-prepared and cooked meals.

4.6 FHFS-07: Human factors meta-study- the impact of human factors research on crew schedules and attitudes

4.6.1 Goals and Hypotheses

The purpose of this study was to track crew participation in and reactions to the human factors program[4]. Crew time is a valuable commodity on a space exploration mission. Even on a long duration mission, it is important to have projects planned out and a time slot dedicated to completing that task. This study had no *a priori* hypotheses as such – the goal instead was to gain a better understanding of the impact of HF research on crew schedules, so that future analogue missions can plan realistically.

[4] The results of this study were presented in a talk at the International Astronautical Congress (Kubrick et al., 2008).

4.6.2 Methods and Measures

Each HF project (except FHFS-06 and FHFS-07, which were proposed during the mission) provided an estimate of the crew member time commitment required, as part of the project proposal. During the mission, crewmembers recorded time spent on HF research, and the crew coordinator for HF research tracked communications between the crew and the HF science team. At the end of the mission, crewmembers filled out a questionnaire on their HF research participation, and the HF science team was asked to estimate actual time spent on each project.

4.6.3 Results

Table 6 summarizes the average time spent by the crew on each study, while Table 7 shows a summary of time requirements from the original four projects. Only six subjects were used for the exercise data, as one withdrew from that study (FHFS-01) early in the summer. Four crewmembers participated in the CASPER sleep study (FHFS-04) by rotating the two sets of equipment over 53 nights in total (equipment shown in Figure 3 bottom right). The Mars Time study (FHFS-06) was averaged over the 37 days that the experiment was conducted. Additionally, the tasks carried out by the crew post-mission were not tracked but include debriefing sessions (approximately 45 minutes per crewmember). For the averages, 100 days was used as the total in-simulation mission time.

The two most significant blocks of required crew time were for the Mars Time study and the exercise program. The Mars Time tasks included morning and night cognitive and reaction time tests, totaling 20 minutes per day. The exercise frequency for the crewmembers was between two and four times a week, averaging one hour per workout. Figure 4 shows the accumulated minutes of exercise by the six participating individuals. It should be noted that the crew continued to exercise as much as possible, even when the frequency of their EVAs increased significantly in the middle of the mission, to collect data during the permafrost transition phase. As laboratory work intensified mid-June, exercise sessions for some crewmembers became less frequent.

Another significant schedule load was the amount of time spent on the planning and management of the program. The HF lead and the Science Advisory Group (SAG) spent approximately eight hours in meetings for the initial human factors program selection. The SAG teleconferences were weekly for the four months leading up to the mission, with good attendance. During the mission, the teleconferences were poorly attended and all collaboration with the crew was conducted via emails and Prometheus, a discussion-based online collaborative workspace system (Suthers et al., 2008).

The HF lead and the HF crew coordinator worked together before and during the mission to manage the human factors program, including approximately 3 hours during the training phase and 9 hours on pre-mission planning. Approximately 80 emails were sent between the two during March and April. An estimated 20 hours were spent during the mission coordinating the program. Over 400 messages relating to the human factors program were sent during the four-month mission using email and Prometheus. From June 22 until August 18th, the crew coordinator spent an average of 1.7 hours per day facilitating the human factors program and preparing status reports for the SAG. This interaction was critical for maintaining the human factors program.

Prometheus was also used to communicate with the SAG for all studies, including field science and operations research. However, most of the HF project leads preferred to communicate by email. The only significant use of Prometheus in HF-related communication was for the CASPER sleep study: daily updates of issues encountered by the sleep subjects, and suggested solutions from the project lead, were posted there.

Table 5 shows workload estimates provided by the leads for each study. It is difficult to compare the workload across projects. Some projects required little front-end time because they have been in progress with other crews for many years, while others were new and required significant development time. All HF project leads expressed intent to publish their results, and gave similar estimates as to the time required to prepare papers.

The results of the crew’s end-of-mission questionnaire are tabulated in Table 8 with mean values and standard deviations for each HF study. Looking at the overall program, the crew rated the Mars Time study (FHFS-06) as most relevant, effective, and insightful, but it took significant time in their daily routine (20 mins out of the ‘extra’ 39). This is a good example of high crew time investment paying off in a high impact study. Conversely, the crew has expressed frustration with studies that have not yet produced results, whether or not they required a large time investment.

Based on the questionnaire responses, the crew agreed that all of the HF studies were relevant for human space exploration and that the FMARS environment was an appropriate location for conducting them. This suggests that the selection of projects was appropriate and was recognized as such by the participants.

5 LESSONS LEARNED

Here we describe some of the aspects of F-XI LDM which directly impacted mission success. Our emphasis is on lessons which either a) are relevant to future HF research or b) could be applied directly to Moon or Mars exploration missions, rather than those which were specific to the time and place of the mission.

5.1 Crew Motivation

No crew can fake motivation or play-act over the long-term. The work must be real, and genuinely important to the crew members. As found in FHFS-03 (Section 4.3), crewmembers who played primarily support roles did not feel as much ownership of the science/exploration aspects of the mission. This can in turn affect both crew cohesion and the fidelity of HF studies, since astronauts are typically highly motivated by their work. The fact that the field/lab activities during F-XI LDM were trying to answer real scientific questions about the Haughton Crater environment increased crew motivation and cohesion.

Despite a natural human resentment of being "treated like guinea pigs", the meta-study (FHFS-05, Section 4.6) showed that crews appreciate the value of HF research, and are willing to put in significant time *if* the study is perceived to be likely to produce meaningful results. Of course, the crew must thoroughly understand the project in order to appreciate it.

A secondary motivation for crewmember participation in HF studies is a desire for a better understanding of one's own traits, behaviours and psychophysiological change over time. This curiosity could be an excellent motivator for an exercise program, as long as the resulting data were provided to the participant in real time.

5.2 Remote Collaboration

It is very common in serendipitous analogue missions for serious communications problems to develop between the remote crew and the home base. Although, unfortunately, none of the F-XI LDM HF studies were looking for this effect, some examples of this phenomenon cropped up during this mission. One strategy NASA has adopted to avoid this problem is to require that the crew and mission support train together as much as possible, and to have an astronaut serve as CAPCOM (i.e. the primary point of communication) during the mission.

Because this is a consistently-observed known problem, it is unrealistic for analogue missions ***not*** to take precautions. All analogue mission plans should include such precautions, and the HF research community should focus on the effectiveness of counter-measures rather than on replications of the problem.

Communications latency was also a significant barrier to remote collaboration. During FX-I LDM, the latency was voluntarily simulated, and even though protocol violations were rare, each one reduced the sense of isolation. If the latency were built into the communications systems (with an option for real-time communications in case of emergency), the fidelity of the simulation would be increased significantly.

Collaborative software systems such as Prometheus are only valuable if used consistently by both the crew and the remote team. Thorough familiarization for both groups is essential for buy-in. Without such buy-in, communications can become fractured and difficult to review, which in turn can have a negative effect on mission success.

5.3 Scheduling

HF research should be considered a mission objective and scheduled as such. It places a significant burden on crewmembers and, if it is to be accomplished successfully, must be integrated into their workload before, during and after the mission. If it is not integrated, it will either be neglected, or it will become a stressor (and therefore a confounding factor) itself. HF tasks cannot be allowed to take over other time slots, especially those put aside for socializing or relaxing. Schedules can be flexible over the long term, but constant vigilance by both mission control and the crew is necessary to prevent “requirements creep”.

5.4 Crew selection vs. verification

There is a temptation in HF research to try to determine the characteristics (personality traits, gender, coping strategies etc.) of the ideal crewmember, or of the ideal crew – and indeed, some individual and crew characteristics have been shown to be strongly positive or negative in analogue situations. However, the experience of the F-XI LDM crew (supported by the results of FHFS-03) suggests that another approach might also be valuable. Once crews have been selected by the best means available, that selection could be tested in an analogue mission. The particular strengths and weaknesses of that particular crew could be observed, and countermeasures proposed and tested. Although this approach will not detect all potential problems, it will almost certainly eliminate a few.

6 CONCLUSIONS

FX-I LDM was a successful four-month-long designed analogue mission, simulating the exploration of the Martian surface. Seven HF studies were conducted, from which we were able to both derive the results of the specific studies, and learn valuable lessons on how best to conduct such studies in the future. In particular:

- Crews on long-duration missions will be unable to ‘suspend their disbelief’ for long, so conditions (work, hazards, remoteness, crew selection strategies etc.) should be as real as possible.
- Human factors studies require significant crew time and attention, and should be fully integrated into the work schedule.
- Communication and collaboration between a remote crew and ground-based support are rife with potential problems. Further study is recommended to find and test countermeasures and mitigation strategies.

In summary, long-term designed analogue missions can advance our understanding of human factors in space exploration. The FX-I LDM studies described here demonstrate this potential.

7 ACKNOWLEDGEMENTS

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9 FIGURES

Figure 1: FMARS surrounded by a rocky terrain and lit by the midnight sun in late August.

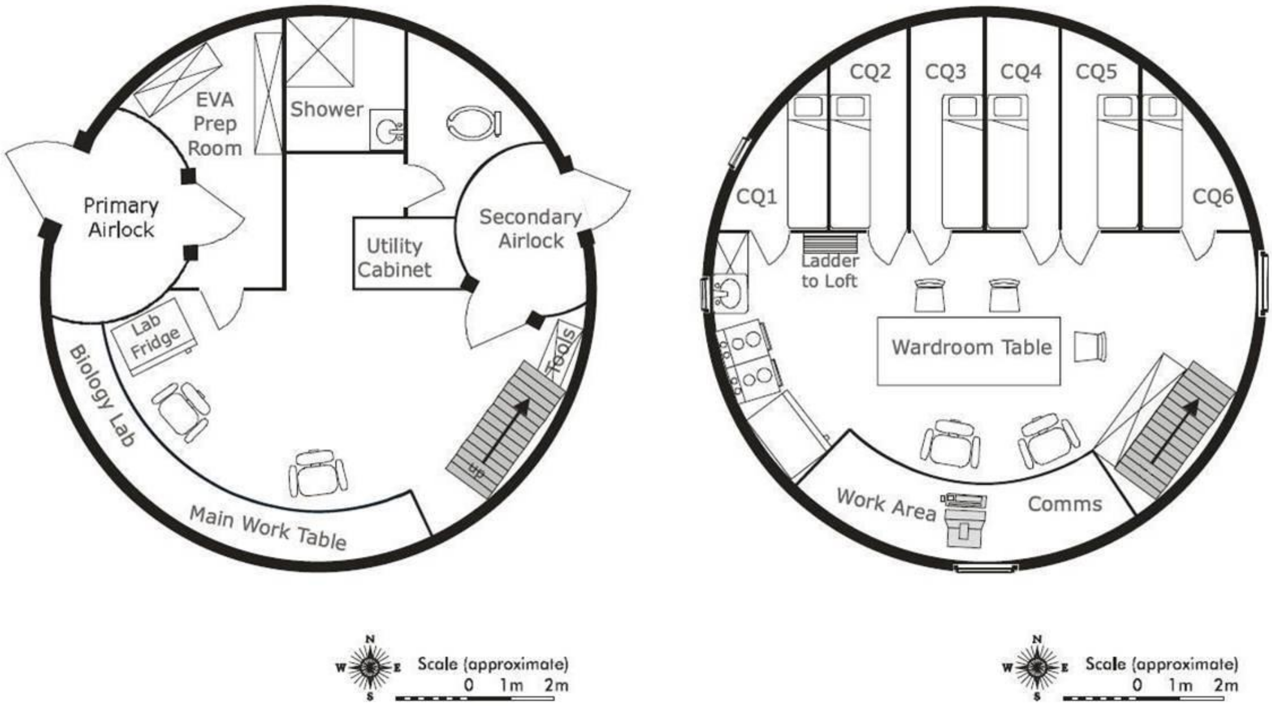

Figure 2: The layout of the FMARS habitat, with the ground floor on the left and the right. Note that the habitat is not airtight, and that the 'airlocks' are not functional (image from (Osburg, 2004 p3)).

Figure 3: Top left, crewmember exercising while looking out window at Haughton Impact Crater. Top right, crewmember during WinSCAT training at FMARS. Bottom left, the FMARS kitchen. Bottom right, CASPER PI (FHFS-04) explaining the use of the sleep study equipment during training at MDRS.

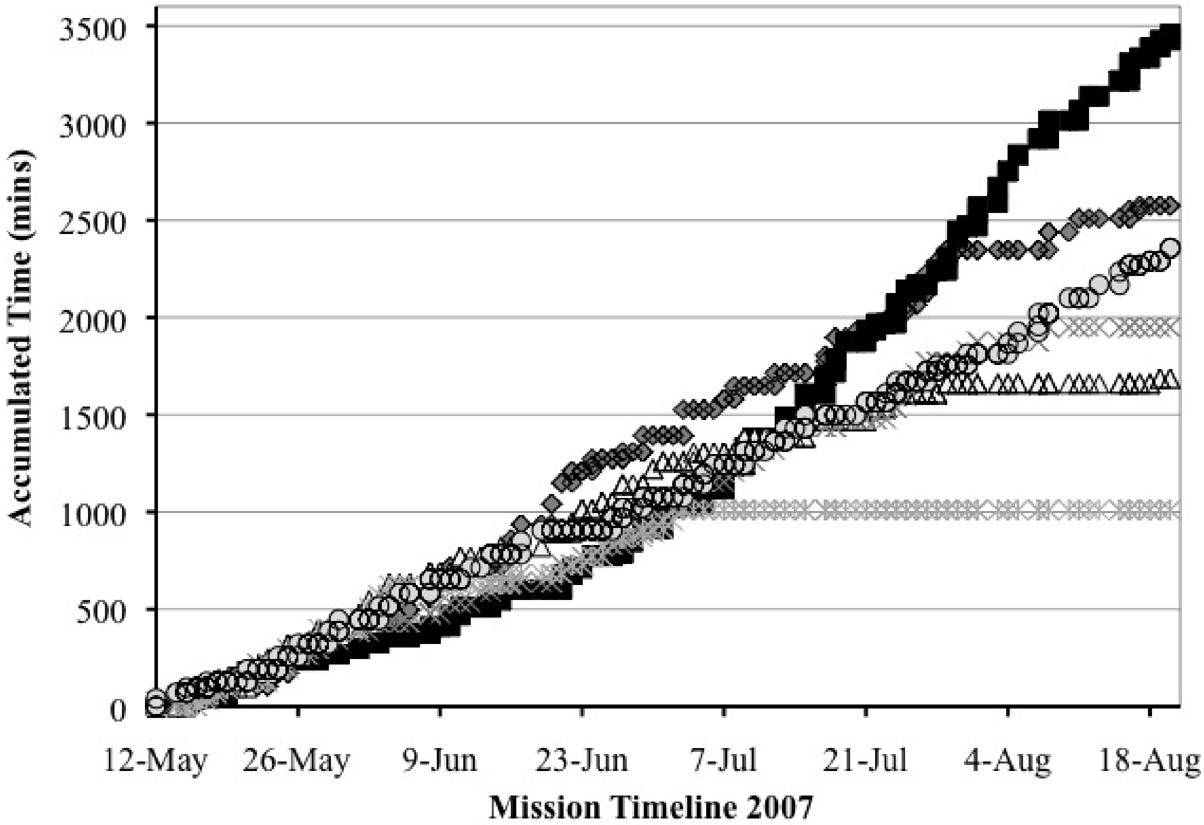

Figure 4: Accumulated exercise minutes by six subjects on F-XI LDM crew. Note that three of the six stopped exercising before the end of the expedition, one (green x) due to injury.

10 TABLES

Table 1: Crew responsibilities, genders, ages and academic backgrounds.

Crew responsibilities	Gender	Age	Academic Background
Geologist	M	24	Geology
Executive Officer, Safety Officer, Engineer	M	26	Engineering
Commander, Geologist	F	26	Geology
Chief Scientist	F	36	Computer Science, Astrobiology
Biologist	F	27	Biology
Chief Engineer, Medical Officer	M	38	Computer Science, Engineering
HF Lead, Engineer	M	27	Engineering

Table 2: Basic Daily Crew Schedule (previously appeared in (Bamsey et al, 2009)). Note that, although the crew as a whole would do two traverses per day, an individual crew member would usually do only one.

Activity	Time
Wake-up	6:30 - 7:30 AM
Breakfast	7:00 - 9:00 AM
Morning Meeting	8:00 - 9:00 AM
Traverse Preparation	9:00 - 9:30 AM
Traverse	9:30 - 1:30 PM
Habitat Tasks (Engineering/Science)	9:30 - 12:30 PM
Lunch	12:30 - 2:00 PM
Sample Analysis / Reporting	2:00 - 5:00 PM
Report Writing	5:00 - 6:00 PM
Dinner and Daily Debrief	7:00 - 8:00 PM
Traverse Planning / Report Writing	8:00 - 9:00 PM
Mission Support Window / Crew Fun	9:00 - 10:00 PM
Personal Time	10:00 - 11:00 PM
Sleep	11:30 PM

Table 3: Crewmember satisfaction with food relative to expectations and to their normal diet, where 5 = very satisfied and 1 = very unsatisfied.

N=6	Relative to expectations (st dev)	Relative to normal diet (st dev)
taste	4.7 (.5)	4.2 (.8)
nutrition	4.3 (.8)	3.7 (1)
texture	4.3 (.5)	3.3 (1)
variety	4.7 (.5)	4.2 (.4)
appearance	4.3 (.8)	4 (.9)
quantity	5 (0)	4.8 (.4)
effort	4.5 (.5)	4.3 (.8)

Table 4: Frequency of equipment use, where 1=never, 2=monthly, 3=weekly, 4=daily, 5=several times per day.

Equipment	Average frequency of use	Std Dev
refrigerator	3.8	1.6
breadmaker	3.1	0.2
microwave	4.7	0.5
toaster oven	2.9	1.2
Aerogrow gardens	1.8	1.0
stove top	3.4	0.5
oven	2.3	0.8
slow cooker	1.2	0.4
kettle	3.5	1.4
coffee grinder	2.9	1.1
coffee pot	3.1	1.1
yogotherm	1.3	0.5
sprout grower	1.5	0.8
electric skillet	1.2	0.4

Table 5: Work breakdown in hours from principal investigators of human factors studies (* not available, * part of ongoing PhD research)**

	TIME SPENT [Hours]					
	FHFS-01	FHFS-02	FHFS-03	FHFS-04	FHFS-06	FHFS-07
Proposal	30	2	2	16	8	1
Training	16	0	0	8	2	0
Ethics Approval	15	2	1	8	2	2
Team Meetings	6	8	1	12	4	0
During Mission	56	9	7	16	2	1
Transcription	210	***	0	20	***	10
Analysis	30	*	6	40	***	10
Papers	24	24	24	32	24	24
TOTAL TIME	387	45	41	152	42	48

Table 6: Crew time spent on human factors (units are minute per crewmember per day).

PROJECT	TIME SPENT [mins/CM/week]
FHFS-01 Comm.	43.8
FHFS-01 Exercise	152.1
FHFS-02 Group Dyn.	13.3
FHFS-03 Cog.+Hab.	32.6
FHFS-04 CASPER	15.8
FHFS-06 Mars Time	140.0
FHFS-07 Food Prep.	1.1
TOTAL	**398.6**

Table 7: Time requirements matrix for original four human factors projects.

STUDY #	TITLE	REQUIREMENTS
FHFS-01	Measure and evaluation of support interventions based on distance communication technologies and of physical training on relevance, feasibility and perceived efficacy.	*__Brief questionnaire__/20 min./pre; *__TCSS__ (support sessions)/45 min. X 6; *__Evaluation__ (cam-email-chat)/15min.X6; *__Physical__ fitness;BMI/pre/post; *__Polar watch__ training; *Personalized __training program__/3X-week; *__Critical incident__ log/diary *__Debriefing session__/45 min./ post.
FHFS-02	Analysis of group dynamics- perception of situational factors (heterogenous and international) and its impact on crew interaction and perception of behavior and performance of crew members.	*__PHQ__ */30 min./pre;* *__DFOS__ */20 min./pre-post;* *__POMS__*/10 min./pre-Xmonth-post;* *__GES__ */10 minutes/6* ***X.***
FHFS-03	Analysis of the station environment habitability, of crew member cognitive performance and changes in group dynamics	*__PHADES__ */once last day mission;* *__MASCOT__*/once a week;* *__AMPS__*/pre-once/month-post.*
FHFS-04	CASPER The use of cardiac autonomic activity as a surrogate marker for sleep in a space analogue environment.	*__5 nights baseline__ data/*pre;* *__15 nights__ Lifeshirt/*3blocks-5;* *__5 nights__ post-mission/*post* *PDA __diary__

Table 8: Evaluation of FMARS human factors studies by crew including mean value and standard deviation.

			FHFS-01	FHFS-02	FHFS-03	FHFS-04	FHFS-06	FHFS-07
QUESTION	**Q1**	How effective do you feel this study was? (1 = very effective, 5 = not effective at all)	2.7 ± 0.6	3.3 ± 0.8	2.4 ± 1.4	1.6 ± 0.8	1.4 ± 0.8	1.7 ± 0.8
	Q2	How much did this study interfere with your daily routine? (1 = not at all, 5 = a lot)	2.4 ± 0.8	2.1 ± 0.9	2.3 ± 0.5	3.1 ± 1.3	3.7 ± 1.3	2.9 ± 1.1
	Q3	How relevant is this study for human exploration of space? (1 = very relevant, 5 = not relevant at all)	1.7 ± 0.5	2.1 ± 0.7	1.7 ± 0.5	1.3 ± 0.5	1.0 ± 0.0	1.3 ± 0.5
	Q4	How relevant is the FMARS location for conducting this study? (1 = very relevant, 5 = not relevant at all)	1.5 ± 0.8	1.7 ± 0.8	1.6 ± 0.8	1.4 ± 0.8	1.0 ± 0.0	1.7 ± 1.1
	Q5	Did this study offer insight to your own routine/psychology? (1 = very insightful, 5 = not insightful at all)	3.3 ± 1.4	3.4 ± 1.2	3.1 ± 1.3	2.0 ± 1.0	1.4 ± 0.5	2.4 ± 1.4
	Q6	Did this study influence or change your daily routine/ psychology? (1 = Changed a lot, 5 = did not change at	3.4 ± 0.7	3.7 ± 1.3	3.7 ± 1.1	2.4 ± 1.1	2.0 ± 1.2	3.0 ± 1.4
	Q7	Will your participation in this study influence your routine/ psychology at home? (1 = definitely, 5 = not at all)	3.3 ± 1.4	4.0 ± 1.2	3.6 ± 1.5	3.4 ± 1.5	3.6 ± 1.6	3.1 ± 1.6

Table 9: Evaluation of overall FMARS human factors studies by crew including mean values and standard deviations.

QUESTION		ALL STUDIES
Q1	How effective do you feel this study was? (1 = very effective, 5 = not effective at all)	1.9 ± 0.7
Q2	How much did this study interfere with your daily routine? (1 = not at all, 5 = a lot)	2.4 ± 0.8
Q3	How relevant is this study for human exploration of space? (1 = very relevant, 5 = not relevant at all)	1.3 ± 0.4
Q4	How relevant is the FMARS location for conducting this study? (1 = very relevant, 5 = not relevant at all)	1.3 ± 0.6
Q5	Did this study offer insight to your own routine/psychology? (1 = very insightful, 5 = not insightful at all)	2.2 ± 1.0
Q6	Did this study influence or change your daily routine/ psychology? (1 = Changed a lot, 5 = did not change at	2.6 ± 1.0
Q7	Will your participation in this study influence your routine/ psychology at home? (1 = definitely, 5 = not at all)	3.0 ± 1.3

11 Appendix A: Acronyms

Acronym	What it stand for	Type	Reference	Goal
FMARS	Flashline Mars Arctic Research Station	Site		To offer an opportunity to study mission operations and human factors in a semi-realistic environment, and contribute to the design of missions to explore the Moon and Mars.
F-XI LDM	FMARS XI Long Duration Mission	Mission		To provide a unique insight into human factors issues for long-duration space exploration.
HF	Human Factors	Research area		To understand the human aspect of space exploration, in order to optimize future mission efficiency and success.
ISS	International Space Station	Site		To serve as an orbital laboratory, advancing research in the physical, biological and human sciences.
MDRS	Mars Desert Research Station	Site		To investigate how to live and work under Mars mission constraints.
MarsREM	Mars Radiation Environment Modeling	Research project		To understand the radiation environment of Mars, and Mars-like places on Earth.
FHFS	FMARS human factors studies	Previous and present studies		To provide examples of the kinds of HF studies that can only be carried out as part of long-term designed analogue mission with integrated operations and illustrate the value of such studies.
TCSS	Telecommunication & Support Session	Survey		To evaluate the value of communications technologies for crews working in extreme environments under stress and isolation related to long duration.
PI	Principal investigator	Role		To be the lead scientist or engineer for a particular well-defined science (or other research) project.
PHQ	Personal History Questionnaire	Survey	(Lapierre, 2010)	To capture the background and personal history of an individual crewmember.
FMARS-OS	Flashline Mars Arctic Research Station Opinion Survey	Survey	(Lapierre, 2010)	To capture the opinions and attitudes of an individual crewmember.

POMS	Profile of Mood States	Survey	Proprietary: https://ecom.mhs.com/%28sjhjxk55ac43bcjubgdvff55%29/product.aspx?RptGrpID=POM	To capture the current mood of an individual crewmember.
GES	Group Environment Scales	Survey	Proprietary: http://www.mindgarden.com/products/gescs.htm	To evaluate environmental influences within groups.
PHADES	Planetary Habitat Analog Design Efficiency Survey	Survey	http://www.gtmars.us/C47-research.html	To assess station environment habitability. Instrument developed by Georgia Tech University for 2007 MDRS rotation. Unpublished.
WinSCAT	Spaceflight Cognitive Assessment Tool for Windows	Computerized test	http://lsda.jsc.nasa.gov/scripts/experiment/exper.cfm?exp_index=1363	To evaluate cognitive performance.
DST	Decision Speed Test	Computerized test	No longer available online	To document and quantify the effect of sleep disruption on one aspect of cognitive performance: decision speed.
RTT	Reaction Time Test	Computerized test	http://www.mathsisfun.com/games/reaction-time.html	To document and quantify the effect of sleep disruption on one aspect of cognitive performance: reaction time.
SAG	Science Advisory Group	Group		To plan and manage the program for the initial human factors program selection.
EVA	Extra Vehicular Activity	Activity		n/a
ATV	All-Terrain Vehicle	Equipment		n/a
NEO-PI FFA	Neo Personality Inventory, Five Factors Approach	Survey	Proprietary: Costa, PT, Jr,.McCrae, RR. NEO Five-factor Inventory, Psychological Assessment Resources, Inc. 1978, 1985, 1989, 1991.	To chart a personality using five independent dimensions.
CASPER	Cardiac Adapted Sleep Parameter Electrocardiogram Recorder	Equipment, Study		To monitor sleep disruption unobtrusively.
TVP	Textured Vegetable Protein	Food		n/a

CAPCOM	Capsule Communicator	Role		To be the main point of communication on the ground for the crew.