

Habitability: an Evaluation

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SUMMARY

Habitability is one aspect of long-duration missions that becomes more important as the mission length increases. The impact of a poorly designed switch or lack of stowage area is different for a mission of six months compared to a mission of one week. With habitability and human factors studies which took place during the early phases of the Lunar-Mars Life Support Test Project (LMLSTP), each subsequent phase built on the previous, and the final designs were improved based on what was learned.

Information concerning habitability issues was solicited from crewmembers during LMLSTP Phases IIa and III. One format used to obtain information was the Space Operations Issues Reporting Tool, or SOIRT. A second was a “habitability issues” questionnaire containing 59 questions used to rate the acceptability of different habitability categories on a Likert scale, from 1 to 7. Shortly before each crew completed its mission, a debrief was held with each member individually. The completed questionnaire was used to address subject areas where a crew member had given a low rating for habitability.

Introduction

For both LMLSTP Phase IIa and Phase III, there were two distinct project objectives. The first objective was to gather information regarding habitability and human factors/crew interface issues. Any issues identified and noted during Phase IIa could lead to an improvement or change before the next chamber mission, Phase III. In addition, any habitability and human factors information collected can also be factored into the design and development of future test bed architecture and mission design. Ultimately, the knowledge gained through the Phase IIa and Phase III studies could lead to greater expertise for development of the actual long-term manned vehicle to Mars or elsewhere.

The second objective was a usability study on the use of the SOIRT, (see Appendix A for a copy of the SOIRT). Feedback and comments from the use of this

product can lead to improvement for future use during flight missions as well as use as a tool for simulated long-term missions that are held on the ground. This tool is designed to assist the responder in organizing thoughts about an issue and its possible solution.

Background of the Project

Habitability is one aspect of a long-duration mission that can become more important the longer the mission lasts. A poorly designed switch or lack of stowage area impacts differently a mission of six months versus a mission of one week. Habitability, or the quality of daily living, is a nebulous concept and is presumed to comprise the following elements: environment, architecture, mobility aids and restraints, food and drink, garments, personal hygiene, housekeeping, communication, and off-duty requirements (1). The habitability experienced during a space flight mission is greatly influenced by the presence and design of vehicle systems that interface with and support the crew. The living and working spaces within which the crew operates must provide both the essentials of life as well as the support necessary for the crew to be productive in accomplishing the mission (2). With habitability and human factors studies taking place during the early phases of LMLSTP, each phase can build on the previous, and the final designs can be improved based on what has been learned.

The purpose of the SOIRT is to provide a process for identifying human factors and habitability issues that may impact space crew operations and mission success. During extended-and long-duration missions, with which NASA has had limited experience, habitability is an important issue. Incidents or issues which would seem innocuous at home may interfere with performance in an isolated environment.

The SOIRT was developed a few years ago with the hope of flying it as a standard item on Shuttle missions. The project was approved in a peer review process but not funded. Now with very limited funding, the SOIRT prototype has been completed, has been tested by two Shuttle crews for usability, and has received positive feedback. However, this tool was used for the first time during the Phase IIa LMLSTP study.

Issues and/or concerns, including crew interaction with hardware and habitability, can be identified through the use of the SOIRT. Debriefings with the crew near the end of their mission also give an additional set of information on habitability issues. The added value of these tools is that any interface and habitability issues identified can be documented, which can then be used in the design of future crewed habitats developed for research into long-mission habitability.

The LMLSTP provided an opportunity to evaluate SOIRT in the real setting of extended-duration missions in order to identify the need for potential modifications to the tool. Appendix A includes screen views of the SOIRT.

Methods and Operations

Subjects

All crewmembers were encouraged to participate in this study in order to obtain a comprehensive list of issues. All crewmembers did participate – four for each mission.

Hardware

The only hardware used for support of the project was the standard computer system supplied to each crewmember. An electronic version of the SOIRT form was added to the standard computer software. Additionally, hard copies of the SOIRT were provided. Each crewmember was encouraged to use the evaluation tool as often as he or she felt a need.

SOIRT

The SOIRT is a means for describing human factors issues during space operations and long-duration ground missions. The SOIRT contains a brief introduction to the purpose of the SOIRT, and it is then divided into three sections. The first section, entitled “General Information,” contains spaces for personnel, location, time, date, and other information pertinent to the issue. The second section of the SOIRT is the “Description of Issue,” which includes a free-form area to describe the issue and a checklist of items. The checklist was divided into three general categories: “Environment,” “Human,” and “Equipment/Systems.” Personnel may check any of the items under each category that apply to the issue (many issues relate to more than one of the different categories). On-line definitions and examples are provided for each item. The third section of the SOIRT is “Causes & Possible Solutions.” There are three categories included in this section to indicate the severity of the issue and to gather data on ways to preclude occurrence or recurrence of the issue. The SOIRT user checks the appropriate category for this issue. There is also a space provided for the user to identify the cause of the issue and provide suggestions for preventing the issue in the future.

The SOIRT was provided in an electronic format on each crewmember’s personal computer and as hard copy. All crewmembers in Phase III chose to use the electronic format. In Phase IIa, five hard copies were filled out by the crew, four of which were filled out as a group effort. The output from the electronic SOIRT is in the form of a text file used by the investigator. Participants were encouraged to fill in a SOIRT form whenever the need arose.

Habitability Issues Questionnaire

The habitability issues questionnaire (see Appendix B) was developed to compile questions for the individual crewmember debriefs in any areas of habitability in which issues were found during their mission.

There were 59 questions that the crew used to rate the acceptability of their mission. The categories were human performance capabilities, the environment, communication, crew safety, health management, workstations, quarters and systems, hardware and equipment, clearances for operations, and scheduled activities. These categories were rated on a scale from 1 to 7, with 1 being “Completely Unacceptable” and 7 being “Completely Acceptable.” There was also a choice of N/A for “Not Applicable.”

An additional five open-ended questions addressed caution and warning, SOIRT, unplanned hardware modifications, noise, recreation, privacy, training, research, tasks and equipment, and other areas of concern not evaluated in the questionnaire.

Debrief

An hour-long debriefing was held with each crewmember while he or she was in the chamber. All crewmembers were asked the same set of questions (see Appendix C); however, some areas were covered more thoroughly depending on each crewmember’s responses. Individualized questions were also addressed covering any subject area where a crewmember had given a low rating on the habitability questionnaire.

Procedure

Before the Phase IIa and the Phase III studies started, a half-hour overview briefing was given to the crew on the goals and objectives of the SOIRT, with the request that each crewmember sign the consent form. In addition, approximately a half-hour was taken per participating crewmember for instructions on filling in the SOIRT and to answer any questions or concerns the crewmember may have.

Approximately one hour for each crewmember was required during the last week of the chamber stay to answer the habitability issues questionnaire, which was used as a guide during the debrief. Additionally, one hour of time per crewmember was taken for the habitability debrief during the last week. The amount of time used to complete the SOIRT was not recorded. Thirteen SOIRT forms were filled in, and it is assumed not a great deal of time was spent on the activity.

No further data were gathered from crewmembers after they exited the chamber, with one exception. One debrief took place in two parts due to an interruption by an alarm sounding during the debrief. The second part took place after the end of the chamber stay.

There were no risks to the participants, since the only crew interface required was a standard computer. There were no constraints on the participants. All names were removed when the comments were combined by topic, and individual responses were not used.

Each crewmember completed the entire questionnaire during the chamber stay and participated in a debrief session the last week of the chamber stay, with the exception mentioned above.

There were five hard copy SOIRTs filled in with information pertaining to issues which the crew felt needed to be addressed; of these five, four had been filled in as a group effort in which all of the crew were involved in the development and documentation of the issues. Two SOIRTs related to issues of the private/sleep areas, covering comfort and privacy design. Another SOIRT addressed the design of the control button for the transfer lock. The fourth SOIRT covered the shower. The fifth SOIRT hard copy discussed the insufficient space for frozen foods.

All of the information discussed in the crew debriefing was taped and transcribed, resulting in more than 80 pages of typed material. This information has been integrated with the responses to the questionnaires and the filled-in SOIRTs. Overall, there are 20 topic areas covered, some with subtopics. This information (data) has been condensed, integrated, and combined to form a cohesive discussion about each topic area, and the following presents edited highlights of the data. Where suggested by crewmembers, requirements or recommendations have been included.

Table 1 summarizes the human factors and habitability topic areas and some of the specific issues within each topic area that are addressed in this section. The table lists the areas in the order in which they are discussed.

Table 3.2-1. Summary of issues addressed in each topic area

Topic Area	Issues	Topic Area	Issues
Environment	Temperature Ventilation Noise Odors**	Shower/Toilet	Shower water temperature and pressure Shower head design* Shower curtain* Height of commode above floor*
Stowage	Work and sleep areas Food pantry Medicine cabinet*	Labeling and Coding	Labeling of items transferred in and out* Establishment of a dedicated labeling system*
Clothing/Personal Belongings	Clothing supplies and laundry* Constraints*	Transfer Lock	Mechanical/electrical difficulties Transfer procedures Problems with varying diameter size
Tools/Maintenance	Laboratory bench* Hardware consumables* Portable workbench concept*	Caution and Warning/Emergency Systems	Facility emergency system* Alarms for specific emergencies* Lack of audible alarms* Alarm system** Alarm noise levels**
Housekeeping	Peroxide cleaner Task assignments* Carpet and soap dispenser problems Disposal item usage* Vacuum**	Procedures	Written vs. verbal procedures* Lack of procedures for some tasks*
Duties/Assignments	Assignment of roles* Definition of roles*	Lighting	Issues with first and second levels Lack of bed and bathroom lights
Communications	Comm boxes Personal communications	Performance	Increase in physical strength*
Exercise Equipment	Training*	Furnishings and Outfitting	Walls** Sleep areas* Floor grate** Chairs* Dining table* Power outlets* Workstations*
Hazards	Stairway Sharp edges Electrical issues* Cramped spaces*	Workstations	Lack of writing space Sharp edges* Hardware changeout* First-floor workstation**
Meals and Food	Cycles* Group meals* Galley space** Food selection** Water**		
Trash	Wet vs. dry - verbal procedures* Fecal trash		

*Mentioned only in Phase IIa **Mentioned only in Phase III
No asterisk indicates mentioned in both phases

Findings and Discussion

Note: The following information contained under each topic area is the subjective input from crewmembers (shown in italics). In some instances, all eight crewmembers gave inputs on the same topic; in other instances only one crewmember commented on a topic. All inputs were used. The recommendations that follow the crew comments are primarily based on those inputs. For a few topics, recommendations were made based on the author's knowledge about the topic.

ENVIRONMENT

Ventilation/Temperature

The environment – ventilation and temperature – was fine almost all of the time. Once or twice, it felt a little bit drier than normal or a little bit warmer than normal but not to the point where it was uncomfortable. In the airlock it was warm when people were exercising – even with the fans going.

The temperature was uncomfortable at night sometimes while sleeping. On each side of the hallway, one of the rooms gets the air first, before it goes on to the second room. If the crewmember closest to the ventilation system is cold, and/or if that ventilation system is closed down, air flow to the second room stops. The lack of ability to control the temperature and the airflow through each individual sleep area was a problem at times. Comments were made that without a fan it does tend to get a little stuffy in the sleeping areas.

The air composition, pressure, and ventilation were terrific. All the oxygen levels were within specification. The air was clean. There were no odors (for Phase IIa). The Phase III crew found that the odor from lifting the lid of the fecal collection container was overwhelming. In the bathrooms there was a vent and a charcoal filter on the commode to keep the odors down.

Recommendation: Procedures for reducing trash odors should be investigated. Similar to the fecal material transfers done twice a day, wet trash should be transferred twice daily.

Low Humidity

It was too dry. One crewmember's skin reacted to the dryness. Due to the dryness, it was easier to get scratches and/or cuts.

Noise

First Level

On the first level, there are a lot of pumps going on and off, and it is irritating. A real problem is the sink pumps under the bathroom sink. Those pumps come on and off for five minutes every half-hour. They basically don't have enough vibration insulation on them. They vibrate the whole cabinet. Then the cabinet leans up against the

shower, and the shower vibrates. It is all stainless steel and aluminum, so it makes quite a bit of noise. The Urine Crystallization Unit was found to be one of the units that was very loud and bothersome. The crew insulated a few places to reduce the noise level. One of the crewmembers adjusted the Urine Crystallization Unit so that it ran at night while everyone was on the third level and could not hear it.

The sump pump is a problem and can be heard when it is on. Closing the bathroom door helped.

On the first floor the noise of the systems, combined with the poor placement of the television speakers on the television, made it difficult to hear the TV.

If someone is having a heavy workout in the exercise area and wants to play loud music, it can be a problem. The music carries into the Level 1 common area and sometimes makes it difficult to communicate or watch TV.

Otherwise, on the first level, there are no high frequencies and no irritating frequencies. It is a low-level calm.

Second level

The second level is very noisy because of the compressors and the blower out back. There is considerable noise because of the hardware. Long periods of concentration and thinking would be a problem on this level. It was hard to communicate on this level because of the noise. Crew did not want to spend time on the second level due to noise.

Third level

In the sleep areas, any sort of noise going on at a workstation or a telephone communication would be an irritant to the person adjacent to you. It would be easy to hear any sort of noise. If one crewmember was trying to sleep and was not a heavy sleeper, he/she would be awakened by someone's alarm clock, by phone calls and even by the other person rolling around in bed, as well as other normal sleeping noises. The transmission of noise through the walls was a problem. There should be some type of sound barrier between one sleep area and the next one.

There wasn't enough perceived privacy to have a personal conversation in the sleep area. Voices, music, and other noises can be heard very clearly from one sleep area to another.

Recommendation: Provide temperature control in each sleeping area so that each crewmember can adjust his/her sleeping area to the proper comfort zone. Provide more acoustic insulation between sleeping areas, and provide crewmembers with ear plugs or protection for future chamber tests. Earplugs should also be worn when working on the second level (the loudest level) for long periods of time. Loud equipment should be run at night and away from the sleep quarters. Equipment should be tested prior to a mission in an integrated operational setting, and predetermined noise levels should be identified as acceptable.

STOWAGE

Stowage was a problem brought up by all of the crewmembers. They had differing opinions about what the problem was, but there was a consensus that stowage was a problem.

Lacking was a stowage area to go along with the work areas. There were no places to store tools, filters, and other consumables. Additionally, file space was lacking. Cardboard boxes were used as substitute file space in some cases.

Just before the mission started, it was requested that some system be added to hang clothes. In the private sleep areas, hooks and some sort of small poles to hang clothes were added and were a great help because the lockers were full. Additionally, there was a strong need for more shelving in the crew quarters.

There was a formal plan for the stowage of food in a food pantry. The shelves in the pantry were extremely effective. For a 90-day test there would be a definite need for more freezer space for food. If there are to be perishables on future studies, more refrigerator space would be needed. The pantry stowage area behind the television/monitor was very difficult to access. The step was difficult to traverse while ingressing or egressing due to the limited height of the stowage area.

A bigger medicine cabinet was seen as necessary, both on the third-level urinal and the first-level urinal.

Recommendation: Provide stowage at work areas (e.g., bins, shelves, etc.). Provide more shelves in sleeping areas. Increase medicine cabinet volume. Pantry area-type stowage should be easy to access. Provide perhaps a table in which the top lifts up for stowage. Consider providing stowage beneath the tabletop accessible by lifting the top.

TOOLS AND MAINTENANCE

A laboratory bench was found to be a necessity that was not in the original plan. One was built on the second level before the start of Phase IIa and enhanced the working environment. The laboratory bench was not used for maintenance.

Hardware diagnostics were done, and there was a need for more voltmeters, specialized tools, different types of fittings, screws and bolts, and all the basic hardware consumables. Using the transfer lock, needed tools and supplies were sent in – even those not planned for in advance.

There were a few unexpected maintenance procedures. The microwave malfunctioned, and there were some problems on the air and water side that were phenomenal. A log was kept on the maintenance problems, but a report is not being written nor is it planned to be written.

There is a perceived strong need for some kind of portable maintenance workbench and/or a dedicated work area for maintenance. There was no problem

with using the dining table as a workbench at some times, but it did interfere occasionally.

Recommendation: A general workbench is required: provide a folding, movable/portable worktable. A maintenance log should be required.

HOUSEKEEPING

The only cleaner or disinfectant allowed was a spray bottle with peroxide. Housekeeping was a shared activity. When things got dirty, the person who cleaned them was the person whom it bothered the most. The system worked fairly well. The tasks that were neglected were the vacuuming and washing out the sinks in the first-level urinal area. Peroxide was not an effective cleaning agent and would be a problem for long-duration missions.

Housekeeping problems occurred because the carpet was fraying. Another problem occurred when the soap dispenser got slightly clogged and tended to spray a lot. A lot of soap sprayed all over the inside of the sink areas and on the walls and mirrors. The vacuum cleaner was difficult to carry up and down stairs.

Disposable items were used for eating and other meal activities, with the exception of some bowls and other utensils used for the microwave. The microwave was difficult to clean with just the peroxide in a spray bottle.

Requirement: A cleaning agent is required in addition to the peroxide disinfectant.

DUTIES AND ASSIGNMENTS

Roles had been assigned, but some of the duties were a little undecided within those roles. But for the most part, it was very clear to the crew what one's main areas of responsibility were. Assignment of major roles and responsibilities pre-test was found to be essential. Each crewmember understood his/her area of responsibility.

Recommendation: Role definition is necessary before start of mission.

COMMUNICATIONS

Personal

The time allocated for family conversations was sufficient. There were not any real restrictions, unless the family happened to visit or call during a press conference or similar activity. The telephone was preferred for a very personal conversation.

In some cases there was not enough perceived privacy to have a truly personal conversation. Crewmembers commented that it would have been nice to have a telephone in a different area where one can go for private conversations, like the "Cone of Silence" or something.

Most of the time, family communications were fine. “Viewpoint Pro” (video-conferencing software) instructions caused a problem sometimes. Very simple instructions were then provided to help out the family member or visitor.

The time spent with personal communication was sufficient.

With only one video-conferencing room, it could have created problems if family members for different crewmembers came in at the same time. On occasion, one crewmember completed a visit and found that another crewmember’s family was coming. But the area was evidently private enough.

Telephones

Sometimes one could hear other crewmembers on the telephones, especially in the adjacent sleep area. But it depended on the level and how loud they were talking. This perceived lack of privacy for telephone conversations bothered some crewmembers.

Control Room Communication

It was available at all times, and we had good communication with them.

The control room communication was readily available. Either the squawk boxes or the telephones were used for communication between the control room and the crew.

Some crewmembers felt the instruments for communication with the support crew were a problem. It may have been a training issue. If a person did not know where to place the microphone with respect to his/her mouth, the sound “broke up” and then understanding was limited to only parts of the sentence. For certain crewmembers, it never improved over the test duration.

EXERCISE EQUIPMENT

A great deal of time and effort was given to training on the resistive exercise device, itself, with respect to the computer because it is complicated. Not enough training was received on how to do the exercises properly. It took time and work to learn how to use the equipment properly.

Recommendation: Fully train on exercise equipment use as well as equipment control procedures prior to start of chamber stay.

HAZARDS

Stairway

- 1) There is an oxygen generator system that is right at the top of the steps. When the system’s drawers are pulled out, they are exactly over the steps. If someone came up the steps when the drawers were out, it created a dangerous situation. The situation actually resulted in a wound that drew blood.*
- 2) Sharp and/or rough edges on the stairway created problems for the crewmembers.*

Sharp Edges

- 1) *There is a hose clamp connector on the urine collection hose. During operation, it was necessary to put on and take off the funnel of the urine collection system. In turning the funnel into the connection, there is a relatively sharp edge on the connector hose that sliced fingers.*
- 2) *There was a hastily clipped-together addition to the resistive exercise device that provided a step for performing the heel raising exercises. It was thrown together at the last minute, has sharp edges, and has caused bloody ankles with the crew.*
- 3) *Crewmembers have had a lot of cuts from the rough edges of corners and cabinets.*

Crewmembers were shocked from contact with circuits that originally had covers on them but were taken off for one reason or another.

Crewmembers have hit their heads on the stairs and scraped their shins on the stairway. The design of the stairway was poor and hazardous.

Power left on while working on something was a problem at times.

Clip lights in the crew quarters became extremely hot when left on.

Food items had to be maneuvered in the convection oven while cooking. This caused crewmembers to burn their fingers. The oven should be sized for crew size and food system.

The cross structure of the seat frame on the aerial exercise equipment pinched fingers. A warning label should have been provided.

The storage area behind the TV is a tight space. Crewmembers scraped their backs on ceiling-hung hooks in the pantry storage area. The area had a low ceiling that did not allow crewmembers to stand up completely. Latch hooks were located at the point where one began to stand up when leaving the pantry area.

STRONG Recommendation: Wherever possible, hazards should be removed before human testing starts. For instance, provisions should be made such as providing an oven mitten.

MEALS AND FOOD

The 20-day cycle worked out well. There were assumptions that certain foods were going to taste a certain way, but they did not. With the cycle came the ability to change something that was liked or disliked. Tasting more potential foods before a study would be helpful. One crewmember would have liked a greater variety.

Some problems with the meals included burning a few items. Different items required different cooking times and temperatures, so cooking them at the same time was a challenge. With only one microwave oven and one convection oven,

baking temperatures were being compromised. Either the temperature was balanced (incorrect for each item) or baked at different times (then complete meal not ready at once). It was difficult to cook an entire meal at one time.

Only dinner was eaten together as a group. Breakfast and lunch were not. Since different crewmembers woke at different times, breakfast was eaten alone. At lunch time crewmembers were busy with other things, and it was difficult to eat together.

Recommendation: The total food system – including types of food, number of crewmembers, quantity of food, number and quality of ovens, and cooking times – has to be considered collectively.

It was difficult to clean dishes using the small amount of water allotted.

Recommendation: A low-volume sink which recycles water should be developed.

SHOWER AND TOILET

Shower Water

It was found that, to some extent, the temperature was unacceptable. It was too hot in a lot of cases and did not quickly readjust to a medium temperature. The shower knob was not acceptable. It was hard to get the correct temperature. It is a problem because of the tight water restriction. Such a long adjustment time resulted in wasting a lot of water to get the right temperature. The amount of water (six pounds) was sufficient and was not an issue WHEN the shower temperature was good.

Recommendation: Turn the temperature down on the hot water tank to where the maximum, if it is running hot, will not be scalding or near scalding, or redesign how the water is delivered. Scalding water is also a safety issue.

Shower Design

The shower head was too short, and the user had to stand right up against the wall of the shower.

The water pressure was low.

The shower curtain was replaced midway through the test. It was basically falling apart. It did not have adequate grommets to withstand heavy use.

Recommendation: The shower head should be extended and/or adjustable to accommodate people of different heights.

Toilet

The urine collection system is separate from the fecal collection system. The first floor facility included the urine and the fecal collection systems, while the third floor had only the urine collection system.

The commode, itself, was a little too high, with its legs a little too long. The toilet was difficult to use and it took time to adjust to it. The toilet was designed to be

high so that the space underneath could be used for storage; this space was used to store a general-use bucket. It took some time to adjust, because the user is sitting up relatively high while going to the bathroom. What the crew ended up doing was using the bucket as a footstool in order to sit in a more natural position.

The privacy in toilet area was acceptable to the crew.

Recommendation: Toilet redesign should be done with an emphasis on ergonomics and anthropometrics.

TRASH

There were two types of trash: wet trash and dry trash. Fecal trash was separate. And all of it was passed out of the chamber. There were no trash or odor problems inside the chamber after the realization in the beginning of the test that the wet trash should be passed out once a day.

Initially, the fecal trash didn't have to go out everyday, but the carbon filter was expended in IIa as in III and resulted in strong odors. After that problem, the fecal trash went out every day also.

There is a lack of clarity on the definition of dry trash versus wet trash. The definition was no clearer at the end of the test than at the start.

Recommendation: Need clear definition of wet and dry trash. Require that each crewmember understand the difference.

The trashcan in the galley had a regular lid. The lid had to be touched in order to throw trash away during meal preparation. This resulted in an unsanitary condition during meal preparation.

Recommendation: The galley should be supplied with a trash can that has a foot control for its lid. A lid which pivots open easily would also be acceptable.

LABELING AND CODING

Only occasionally, items passed through the transfer lock were labeled sufficiently, such as which water samples were to be taken at which time.

There was no labeling or coding system in place, although one was developed by the crew throughout the test period. There were no labels. One thing that was defined very clearly was the mailbox. It was used very successfully for all incoming mail.

It is strongly suggested that a set of procedures be established, advising the crew early in the mission that it should define locations where things will always be placed. This is especially important when there are two or three different crewmembers expecting supplies or a large variety of items coming in for them. Supplies and hardware items should have planned locations established before the start of the mission. Another reason that there were difficulties is that there is not adequate storage for the variety of items that were needed. There is a tool space, but it is small and inefficient. There are not enough lockers. The crew

talked about each crewmember having his/her own locker or cabinet on the first level, because there is a variety of items lying around for each crewmember and not enough space to keep it. There was a need for more dedicated storage for certain things. This should be based on what the crew would like to have in different areas.

There was a continual resupply, and the space left when something was used was immediately filled up with the replacement. Most of the things that came in were used and then passed back out. They were therefore usually left on the common area or left directly next to the transfer lock door. That was actually very successful. Things that needed to be done right away were left on the table, easily noticed, and it did not require much effort tracking people down to make sure they knew about it. Things that were left right by the transfer door were also written down on the transfer list. So if a transfer came around, it was ready to go; that was very effective.

Since things constantly go in and out, a dedicated labeling system for lockers probably would not have helped much, because the labeling would require many changes. The kinds of things that come in and out quickly would not require labeling. It would be helpful to have a dedicated labeling system for the kinds of things that were not needed very often and that were resupplied through a transfer. Every crew should decide where it wants to store items and then go ahead and label those areas.

Some things were labeled well. There were a couple of systems that were missing a few labels that were needed for identification purposes – e.g., the water systems.

When items were passed through the transfer lock into the chamber (e.g., equipment for an experiment), everything was labeled adequately. It was normally labeled with a name and could be directed to the correct person.

Recommendation: Before the mission, allow each crew to thoroughly plan where to stow supplies and hardware that are not constantly passed in and out. Have crew establish dedicated labeling system for these items.

TRANSFER LOCK

Mechanically and electrically, there were difficulties transferring things in or out. The electrical signal that allows the outer door to open malfunctioned once, and the button to open the outer door also malfunctioned.

Other problems with the transfer had more to do with procedures. In the beginning of the test, there were no clear transfer guidelines. Transfer operations were learned real-time while they were performed. There was trouble knowing what was acceptable to transfer out. One would have to check with all other three crewmembers for each transfer. It took two weeks to determine a procedure to transfers items out.

Things did not always have labels. However, most of the items transferred had labels on them. There was a communication system set up to read what was coming in or going out of the control room. And then the crew would agree to, or acknowledge, what was coming in.

Occasionally, a few last-minute additions were transferred, and if the right person was not there to handle it, then it is possible that the item was set aside.

The biggest problem with transfers was when the incoming tray was overstuffed. The pass-through diameter on the inside was a little bit smaller than the diameter on the outside. That made a few transfers out of the chamber extremely difficult. The crew sometimes needed to reach in and reposition items so that everything would make it through the smaller diameter.

Recommendation: Specify a location to store “transferred in” items until all crewmembers can retrieve them. Redesign the transfer lock so the diameter is the same throughout.

CAUTION AND WARNING OR EMERGENCY SYSTEMS

There are two distinct parts to the warning or emergency systems. The facility emergency system sounds an alarm when one of the sensors goes off, such as combustible gases, fire, or smoke. The second system is the alarms on the computer screens for specific systems. If a system became off-nominal, there would be a notification on the computer screen. There was not a problem with the system alarms, but an additional, audible alarm for those on the computer would be good to have.

The alarms for the facility were a different matter. If a facility emergency system alarm was activated, crewmembers would not know why. Only the control room would have knowledge of the anomaly. There was no way to know if there was a trace contaminant in the air or a spark that set off the UV detector. The crew had no way of knowing what it was dealing with and had no control. The crewmembers thought there should be some type of indication to the crew in the chamber so they would have knowledge of the situation. A panel that displays the problem and its source is needed so that the seriousness of the problem can be ascertained by the crew.

Additionally, there is a need for some audible alarms to notify a crewmember if something is wrong with some equipment. That could help eliminate the necessity of some support staff.

Recommendation: There is a need for a panel that displays the problem and its source so the cause and seriousness of the problem can be ascertained. A read-out about a problem in each crewmember’s room (and on all levels) would be useful. Additionally, there is a need for some audible alarms to notify a crewmember if something is wrong with a piece of equipment. These things could help eliminate the necessity of some of the people being on the outside. Alarm notifications on computer screens should include audible alarms.

It is difficult for a crewmember who is exercising in the airlock to hear the communications with the external support crew from the main chamber’s first-level squawk box. The noise of the exercise machines doesn’t allow this.

Recommendation: There should be consideration of a squawk box in the airlock.

PROCEDURES

There were few written procedures for operations throughout the chamber stays. There were some verbal procedures with unplanned tasks. Some tasks were worked from previous experience.

Some procedures given were hard to follow.

Recommendation: Standardize procedure formats, and familiarize crew with this format prior to the start of the chamber stay.

LIGHTING

Lighting needs to be improved on the first and second levels. For Office of Public Affairs (PAO) events, there was not enough lighting. Extra lights had to be brought down to the first level for the events.

There are no independent lights in the upstairs bathroom. In order to see, it was necessary to turn on the hall light which sends a lot of light into the other people's rooms at night. Additionally, since all urination is recorded, a light in the toilet area is a necessity.

A bed light would have been helpful. Getting in and out of the top bunks was difficult. It was found to be necessary to bring in an incandescent light for the personal workstation since the general room lighting is not as optimal as a task light while reading, writing, etc.

The lighting was poor on the second level because the lights are set up differently, due to the hardware on that level. Work lights were necessary on the second level. With their use, illumination was not a problem.

Flashlights and work lights were necessary and useful.

Recommendation: Add an independent light in the upstairs bathroom, even if it is a night-light or a low-intensity light.

Include a bed light. With the top bunks, getting in and out is difficult.

Include incandescent task lighting for the workstations and more lighting for PAO events.

A few incandescent lights could simulate evening or morning sunlight on levels I and III.

PERFORMANCE

Physical

Physical performance capabilities went up considerably – most likely due to the regular exercise program. There was a quantifiable change in physical strength from week to week. Strength changes were quantified, since performance on the resistance machine was tracked.

Cognitive Skills

No changes were noted at all for Phase IIa. One crewmember in Phase III felt that cognitive skills were improved because there was a greater awareness of his/her surroundings. The Phase III crew suggested tasks were done more efficiently in the chamber than outside of the chamber.

FURNISHINGS AND OUTFITTING

Walls and Ceilings

The sound insulating foam frequently fell off the walls and ceilings. Many times, the Velcro holding the foam in place failed. Other times, the foam was held in place by friction only and fell out when bumped or jostled.

Chairs

The chairs in the lounge (first level) and the chairs in the sleep area were acceptable. But they do not move much, and they do not lean back.

The chairs in the dining area should be more adjustable so one can lounge in them. They are pretty rigid and should be flexible. The chairs are acceptable for meals but not for watching a movie or trying to relax. They are not very comfortable over a long period of time. Chairs frequently rolled into a grate in the floor.

The furniture could all be improved. The crew spent a lot of time in the area of the table and chairs. A couch where one could stretch out a little bit more would have been a welcome addition. More comfortable chairs should be used for future tests.

With the limited amount of space in the chamber, it is not going to be possible to have another set of chairs, unless they are of the fold-away, plastic type. And those normally are not very comfortable anyway.

The four chairs upstairs in the sleep quarters have improper back support, and the seat, itself, was too deep. The chairs on the first level should probably be on wheels and be much lighter. The crew spent a lot of time relaxing in the evening and sometimes experienced sore backs from the chairs on the first level.

Dining Table

The dining table on the first level was used for meals and work. It was also used as an area for public affairs activities with the cameras. For the camera arrangement the crew sat around that table. It was also used as a workbench for mechanical repair tasks. The dining table was also used for filling out forms, writing in journals, and other paperwork tasks. The table was used often for a variety of tasks, such as working on the micro-water samples. Everyone was careful to try not to take up the whole table if others were going to need it.

It would be nice to have a workbench that could fold up or pop out, one that could handle some weight. One that would be big enough to be worthwhile to get stuff off the dining table.

Bed

The beds were, for the most part, comfortable. At first it took some adjustment; they were not queen-sized, premium-quality mattresses. They felt relatively hard at first, but after two or three days one adjusted and was fine after that. It was a little difficult getting in and out of the bed.

Sleep Areas

Tight quarters. The space needs to be utilized more efficiently for storage. Shelving needs to be added. The drawers for stowage of the clothes have hinges; they open up, and they swing down. If not careful, they come down and smash on your head. They also make a lot of noise and disturb others who are sleeping. The cabinet to hold clothes can be improved; it is really noisy.

Some fold-away stools are needed in the rooms upstairs. If somebody visits in your room, he/she has to stand. And if two crewmembers are looking over some documents or looking at something on the computer, for a period of a half-hour they are standing or kneeling.

One cannot sit on a top bunk, and on the bottom bunks there is a headroom problem. Therefore, both options are uncomfortable. If there was a fold-away stool, it could be used in the sleep area: unfold it when wanted and stow it when not wanted. There would be room to stow a stool.

One crewmember did have a back injury associated with the exercise device. That crewmember perceived the recovery to be a little bit longer than normal and attributed that to the bed and, to some extent, the chair at the workstation. The crewmember compensated by using some towels for additional lumbar support, but that did not seem to help much. Over time, the crewmember's back improved.

One crewmember brought a bed recliner frame with webbing straps that one can put a pillow on to recline in bed. The crew all remarked that it would be nice to have some sort of lounging recliner capability downstairs while watching a two-hour movie or socializing – maybe an adjustable futon bed.

Power Outlets

There was an insufficient supply of utility outlets/plugs, and some had to be brought into the chamber during the stay. They were needed for the telephone, the cameras, and other pieces of equipment that require power. Power strips were used, and a lot of electrical things ended up getting plugged into one outlet, which caused some logistical problems.

Computer Workstations

The workstations were “terrific.” Everything was considered in the design. A little more work space would have helped, however. Keeping the keyboard underneath the desktop helped. When working on tasks such as scheduling and budgets, with papers spread out, there was a definite shortage of work area.

On the first level, there is a need for a better workstation. There was some trouble with the sliding keyboard. Crewmembers would bang their knees on that. There were sharp edge issues. What is needed is a physically bigger workstation and a more efficient work space.

A dedicated storage area would have been a nice addition for holding the two-way camera equipment. A storage area for floppies, electronic storage devices, batteries, and such would also be helpful.

The crew would have liked:

- *A place to relax and be comfortable, to watch a movie without sitting in a hard chair.*
- *Colored pictures on the walls as well as carpeting on the third level. The insulation is completely white.*
- *Brighter pictures on the first level to cover up the purple insulation.*
- *Resolution of wire and cable management issues.*
- *More electrical outlets.*
- *More switch guards. There are a lot of switches, electrical and nonelectrical, that are not protected.*

SIGNIFICANCE

Phase III experienced an occurrence of the same or similar problems experienced during Phase IIa. Complaint about the transfer lock, while a nuisance, is not an engineering problem for a Mars mission, nor is it life threatening. Safety and health issues (i.e., sharp edges, noise levels, etc.) should be addressed before another chamber test is considered. Common safety practices and standard design goals should always be followed when a chamber test is planned.

The topics of poor communication, emergency alarms, size of ovens, inability to clean a surface, sharp edges, no stowage space, noise, odors, poor lighting, etc., are issues that should be carefully and systematically studied. These technologies/topics are those that will be of serious consequence and import during an actual long-term mission. While for different reasons, interrupted and/or poor communication will be the reality on a mission to Mars. For example, the inability to find a solution to clean a surface could lead to health problems. Noise levels that are unacceptable could lead to permanent problems. Constantly finding the oven too small or inadequate and lacking privacy could result in short tempers and low morale during an actual long-term mission.

The LMLSTP had as its primary goal the testing of the regenerative life support systems. The LMLSTP was a long project and went through many iterations. These two habitability studies, for Phase IIa and Phase III, were only two of many such studies to help define requirements and resolve human factors issues in long manned missions. The subjective inputs from the crew on the issues of human factors and habitability should increase our awareness of habitability concerns, which will lead to better design for each new long-term crewed mission.

The LMLSTP gave us opportunities to study the behavior and performance of the different crews. Subjective input from the crews gave us added knowledge for future vehicle designs with the goal to enhance productivity. The human component in a system for a long-term mission must be planned in and integrated fully into the design process.

Building on what has been learned from these studies and information from ensuing studies will yield the knowledge to design a facility that can serve as an analog for a Mars mission. Of course, if used as an analog, care must be taken to change operations to reflect the constraints of a real space mission. Tasks, such as transferring items in and out twice a day, would have to be eliminated to reflect the realities of life on a long-term mission. The higher level of autonomy representative of potential Mars mission operations, with all of the inherent resupply, logistics, and communications restraints, would have to be considered. Additionally, mission designers would have to ensure that all the necessary tools, diagnostic equipment, and other support supplies are factored into the planning of the mission.

Acknowledgments

Thanks must go to the wonderful Lockheed Martin support during this project. Dr. Jurine Adolf accomplished the task of putting the SOIRT on the crewmembers' computers. Ms. Jacquie Minton gave invaluable support during the information-gathering part of the project.

References

1. NASA Johnson Space Center. 1975. Skylab habitability experiment M487: Habitability/crew quarters (NASA TMX-58163). Houston TX: NASA.
2. Bond R, Campbell P. 1995. Operational monitoring of Mir habitability (PIPS Database #810530). Internal NASA Document.

Appendix 3.2-A

Information presented in the SOIRT

pcSOIRT - [General Information]

File Window Help

Press the **Tab** key to move from one field to the next.

Personal

Last Name / Code		First Name	
Job Title		Mail Code	
Phone #		Email Address	

Issue Information

Date		Time	
Mission (if applicable)		Location	

Specify your role at the time of the issue [e.g. test conductor, subject, etc.]:

Specify the role of other persons involved in the issue:

Page 2 of 4 FILENAME.TXT **Clear Form** **Previous** **Next**

pcSOIRT - [Description of Incident]

File Window Help

Write a description of the issue below. Include information that you feel is important for identification of the issue.

Use the list below to help structure your description of the issue, *paying particular attention to the category headings*. Under each category, check each item that applies (many will overlap in the different categories). When selecting items, determine whether each item, or the lack of the item contributed to the issue.

Click and hold the right mouse button on any item to see a definition of that item.

1. Environment <input type="checkbox"/> lighting <input type="checkbox"/> noise level <input type="checkbox"/> vibration <input type="checkbox"/> temperature <input type="checkbox"/> available space <input type="checkbox"/> air quality/pressure <input type="checkbox"/> gravity <input type="checkbox"/> housekeeping <input type="checkbox"/> other	2. Human <input type="checkbox"/> visual <input type="checkbox"/> auditory <input type="checkbox"/> tactile <input type="checkbox"/> physical size <input type="checkbox"/> mobility <input type="checkbox"/> endurance <input type="checkbox"/> strength <input type="checkbox"/> comfort <input type="checkbox"/> physical stress/fatigue	<input type="checkbox"/> hygiene <input type="checkbox"/> memory <input type="checkbox"/> mental processing <input type="checkbox"/> sensory overload <input type="checkbox"/> cultural differences <input type="checkbox"/> language differences <input type="checkbox"/> procedures/training <input type="checkbox"/> other	3. Equipment / Systems <input type="checkbox"/> design <input type="checkbox"/> labels <input type="checkbox"/> controls/input devices <input type="checkbox"/> displays <input type="checkbox"/> warnings <input type="checkbox"/> accuracy <input type="checkbox"/> processing speed <input type="checkbox"/> reliability <input type="checkbox"/> other
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Page 3 of 4 ANON_ADD.TXT **Clear Form** **Previous** **Next**

Appendix 3.2-A continued

pcSDIRT - [Causes and Possible Solutions]

File Window Help

Using the buttons below, please select the category of the issue.

Issue Category

Category I - Minor modifications to design or training procedures required to rectify situation.

Category II - Significant modifications to design or training are required to rectify situation.

Category III - Complete hardware and/or software redesign are required to rectify situation.

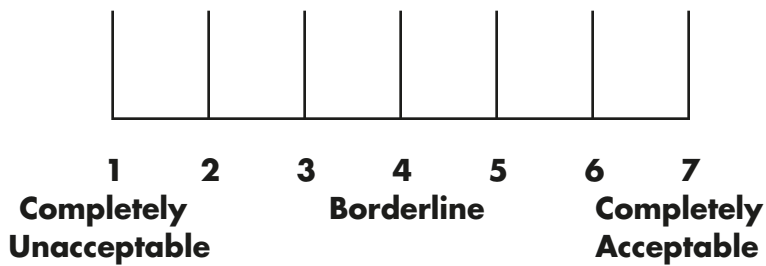
Below, provide information that might help identify the cause of the issue, and suggestions for preventing recurrence of this issue in the future.

Examples (Click & hold)

Page 4 of 4 ANON_A01.TXT Clear Form Previous Save and Exit

Appendix 3.2-B

Questionnaire - Lunar-Mars Life Support Test Project (LMLSTP) Habitability Issues



Use the above scale to rate the acceptability of the environment in terms of its compliance with the following design considerations.

Appendix 3.2-B continued

Rate the overall acceptability of any changes you experienced with the following human performance capabilities (enter N/A if no change was experienced):

- | | |
|-------------------|--------------------------|
| 1. ____ Vision | 5. ____ Reaction time |
| 2. ____ Olfaction | 6. ____ Motor skills |
| 3. ____ Taste | 7. ____ Strength |
| 4. ____ Hearing | 8. ____ Cognitive skills |

Rate the overall acceptability of the environment based on the following:

- | | |
|--|--------------------------|
| 9. ____ Noise | 13. ____ Humidity |
| 10. ____ Lighting | 14. ____ Temperature |
| 11. ____ Odor | 15. ____ Contaminants |
| 12. ____ Ability to control
temperature | 16. ____ and/or humidity |

Rate the acceptability of the following:

17. ____ Crew communication
18. ____ Communication with Control Room
19. ____ Personal communication (family)

Rate the acceptability of the following systems with respect to crew safety:

- | | |
|---------------------|------------------------------------|
| 20. ____ Mechanical | 22. ____ Fire detection/protection |
| 21. ____ Electrical | 23. ____ Emergency equipment |

Rate the acceptability of the following health management methods:

- | | |
|--------------------|----------------------------------|
| 24. ____ Nutrition | 28. ____ Preventive medical care |
| 25. ____ Water | 29. ____ Diagnostic medical care |
| 26. ____ Sleep | 30. ____ Medical treatment |
| 27. ____ Exercise | |

Rate the acceptability of the following:

- | | |
|---------------------------------|--|
| 31. ____ Personal | 33. ____ Displays and controls |
| 32. ____ Labeling and
coding | 34. ____ Control station (first floor) |

Appendix 3.2-B continued

Rate the acceptability of the following quarters and systems:

- | | |
|--|---------------------------------|
| 35. ____ Personal hygiene | 42. ____ Hallways |
| 36. ____ Body waste management (first floor) | 43. ____ Passthrough |
| 37. ____ Body waste management (third floor) | 44. ____ Recreation |
| 38. ____ Crew quarters | 45. ____ Trash |
| 39. ____ Galley and wardroom | 46. ____ Stowage |
| 40. ____ Exercise area | 47. ____ Preventive maintenance |
| 41. ____ Staircase | 48. ____ Diagnostic maintenance |

Rate the acceptability of the following hardware and equipment:

- | | |
|----------------|-------------------|
| 49. ____ Tools | 50. ____ Clothing |
|----------------|-------------------|

Rate the acceptability of clearances for operations performed within the following:

- | | |
|--------------------|----------------------|
| 51. ____ Staircase | 53. ____ Passthrough |
| 52. ____ Hallways | |

Rate the acceptability of workload in terms of scheduled activities in the following areas:

- | | |
|-------------------------------------|------------------------------------|
| 54. ____ Procedures for experiments | 56. ____ Recreational time (other) |
| 55. ____ Maintenance | |

57. Provide any comments on the operation of the caution and warning system. For example: sound and number of tones, lights, text on caution and warning (C&W) panel, and frequency of alarm annunciation.

58. Please provide any comments regarding the SOIRT.

Appendix 3.2-C

Phase III Chamber Crew - Habitability Debrief Questions

PROCEDURES

- What specific difficulties occurred during any crew procedures? (ex. communication between the crew)
- In what ways could this be improved?

AIRLOCK TRANSFERS

- Did you experience any difficulty with the translation of items to and from the chamber via the airlock?
- Did you experience any difficulty locating items inside the chamber?

ANTHROPOMETRICS

- Were there any issues in the chamber related to hardware, chairs, beds, etc. not fitting your body size/shape?

HUMAN PERFORMANCE CAPABILITIES

- Did you experience:
 - Changes in your strength?
 - Changes in your motor skills? Fine vs. gross?
 - Changes in your cognitive skills?

NATURAL AND INDUCED ENVIRONMENTS*Atmosphere Composition and Pressure*

- Was the chamber ventilation acceptable? Was the chamber temperature comfortable? Would you like to have the capability of adjusting the chamber temperature yourself?
- Were there ever any unpleasant odors in the chamber atmosphere?
- Do you have any other comments on the atmosphere inside the chamber?

Acoustics

- Did you use any noise-suppressing devices (e.g., ear covers, ear plugs) during your sleep and during non-sleep periods? Did they affect the quality of your sleep, either positively or negatively?
- Did the effect of noise increase or decrease with your time spent in the chamber?
- Did noise interfere with your concentration? How often? Ability to monitor Control Room-Chamber communications? How often?

Personal Communication

- Did you experience any problems with the communication system during family conferences?

Appendix 3.2-C continued

- Were you provided sufficient privacy during family conferences?
- How often were you provided the opportunity for family conferences?
How long did each family conference last? Was this sufficient?

Other Communication

- Was Control Room communication readily available at all times?

CREW SAFETY

- Talk about the Caution and Warning system a little bit. Where does the alarm sound (e.g., chamber, control room, or both?), and what is the procedure once it sounds?
- Were any false alarms activated during your chamber run? If so, how often? If so, what was the procedure for discovering the cause of the alarms? Do you feel that this procedure could be improved?
- Did you find any sharp edges in the chamber? (Mentioned bedposts) Did they cause any hazardous conditions? If so, did you consciously have to avoid them?
- Do you feel that the emergency equipment was sufficient? (Mentioned that there was no first aid kit? and no fire extinguisher) Do you have any suggestions for other emergency equipment that you feel is important?
- Were there any electrical hazards in the chamber that you identified? If so, did you or another crewmember repair those hazards?
- Were there any other hazards (e.g., mechanical, thermal) you noted?

HEALTH MANAGEMENT

Food

- Was your food selection adequate? Were there enough choices? Was there always enough food?
- Did the food inventory system help you keep track of the food?
- Did you experience any problems heating food in the microwaves? If so, do you have any suggestions for eliminating this problem?
- Were meals typically eaten together at specific times and if so, did this cause any problems for the crew in preparing and heating food for all four at one time?

Water

- Was the taste and temperature of the drinking water acceptable?
- Was the shower water acceptable in terms of temperature and hardness or softness?

ARCHITECTURE

Lighting

- Was the lighting sufficient for all tasks and if not what alternatives did you use? (portable lighting, flashlights?)

Appendix 3.2-C continued

- Was portable lighting easily utilized wherever needed (i.e., power and restraints available to install the portable lighting)?
- Did lighting levels change on each level of the chamber? (If yes, did your eyes need to adjust to the change?)

WORKSTATIONS

- Did you encounter any problems at any of the various workstations such as:
 - Illumination
 - Ventilation
 - Control/display placement and integration
 - Configuration
 - Communication
 - Access to power or other utilities

LABELING AND CODING

- Did you find sufficient labels, decals, and placards on items such as experimental equipment, food, personal items and so on to easily determine the item and how it should be used, and if not, how could this be improved?
- When items were passed through the airlock, was everything well labeled so you knew what it was and what you should do with it?

ACTIVITY CENTERS*Shower*

- Did you feel that the shower system was sufficient, or is some additional means of full-body cleansing desirable? Waste Collection System (WCS)
- Did you experience any difficulties using the chamber toilet?

Crew Quarters

- Privacy
 - Did you feel a need for more privacy than what was available in the chamber?
 - How did you achieve your desired level of privacy?
- Sleep Accommodations
 - Did you experience difficulties sleeping in your quarters? If so, why?

Wardroom

- Was the dining table on the first floor used a lot? Was it used exclusively for meals or for work as well?

Exercise Equipment

- Did you prefer using the resistive device or the ergometer? Would you have preferred different exercise equipment? If so, why?
- Did you feel that you had sufficient time to exercise on the days you were scheduled to exercise?

Appendix 3.2-C continued*Trash Management Facility*

- Was there a need for trash to be stored in the chamber, or did it all get passed through the airlock as it accumulated?
- Did trash cause any odor problems inside the chamber?

Stowage Facility

- Was there a sufficient number of stowage facilities?
- Was there a formal stowage plan for each type of item being stowed?
- Did you have a stowage area for personal hygiene and other personal items? Was it sufficient?
- Describe a system for stowage that you would want on longer chamber runs.

HARDWARE AND EQUIPMENT*Tools*

- What were the most commonly used tools? What diagnostic equipment was used?
- Was the complement of tools available sufficient for required tasks? If not, what additional items would be needed?

Crew Personal Equipment/Clothing

- Did you feel that you lacked any personal equipment that may have been too large to pass through to you after the chamber was locked?

DESIGN FOR MAINTAINABILITY

- What unexpected maintenance procedures did you have to perform?
- Were you trained for them ahead of time, or did real-time training occur?
- Were there any crew safety issues during maintenance procedures?

HOUSEKEEPING

- Do you have any comments on the housekeeping procedures?

CULTURAL/GENDER DIFFERENCES

- Did any gender issues arise?

GENERAL

- What other advice would you have for us on how to improve habitability within the chamber?