Human Research Program
Lunar Human Research Requirements (LHRR)

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Human Research Program
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Submitted By:

7/25/11

Katherine R. Daues
Book Manager
Human Research Program

Date

Concurred By:

7/25/11

Katherine R. Daues
Manager, Program Integration
Human Research Program

Date

Approved By:

1 AUG 11

Dennis Grounds
Program Manager
Human Research Program

Date

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1.0 INTRODUCTION

1.1 PURPOSE

Biomedical research will be conducted during transit and on the surface of the Moon to prepare for extended stays on the Moon and to prepare for the exploration of Mars.

The objective of the Human Research Program (HRP) is to preserve the health and enhance performance of astronaut explorers. Specific objectives of the HRP include developing the knowledge, capabilities, and necessary countermeasures and technologies in support of human space exploration; focusing on mitigating the highest risks to crew health and performance; and defining and improving human spaceflight medical, environmental, behavioral, and human factors standards. [Exploration Architecture Requirements Document (EARD) Par 3.2.4]

1.2 SCOPE

The HRP is a research program developing knowledge leading to important products and deliverables to the Human Exploration and Operations Mission Directorate (HEOMD), the NASA Chief Medical Officer and other customers for the investigation and mitigation of the highest risks to astronaut health and performance in support of exploration missions. To execute the goal of mitigating risks to future exploration missions, the HRP must conduct research on the lunar missions. Toward that end, the HRP relies on the Agency's exploration architecture to provide resources to the HRP to facilitate that research.

This document contains a detailed description of the anticipated resource accommodations, interfaces, and environments to be provided by a lunar exploration program to support the HRP research in transit and on the lunar surface. Covered, specifically, are the requirements for mass and volume transport; crew availability; ground operations, baseline data collection, and payload processing; power, and data. Volumes and mass are given for transport of conditioned samples only. They do not account for the engineering solution that an exploration program would implement (refrigerator/freezer volume/mass).

This document does not account for requirements on a vehicle for transportation to and from the International Space Station (ISS). The ISS Program has supplied requirements for this mission.

Also, these requirements do not cover necessary exercise hardware. Nor does it include medical operations requirements for medical care kits, or other supplies. Medical Operations requirements will be identified in the exploration program's Medical Operations Requirements Document (MORD) and incorporated into the appropriate exploration program documents for implementation.

1.3 AUTHORITY

This document is under Configuration Management control of the Human Research Program Control Board (HRPCB). Changes to this document will result in issuance of change pages or a full re-issue of the document. Regular review of the LHRR and subsequent changes are necessary to maintain consistency with the evolving HEOMD strategies, goals, and objectives.

2.0 HUMAN RESEARCH PROGRAM RESEARCH REQUIREMENTS

All mass, volume, crew time, power, and data requirements are summarized in the Table 3.1 in the Appendices.

2.1 MISSION DURATIONS

2.1.1 The exploration architecture shall permit the acquisition of useable data sets from a minimum of 24 astronaut-subjects on lunar surface missions of sixty days or more to enable Mars surface missions.

Rationale: The Human Research Program (HRP) is actively working to address 31 major health and performance risks to human space exploration, each of varying criticality with respect to lunar and Mars missions. Since significant physiological changes in different organ systems in response to reduced gravity occur on the order of days as well as months, every crewed mission has HRP relevance, even the shorter missions. The cardiovascular, sensorimotor, and muscular systems may eventually reach a new steady-state within our flight duration experience base; bone loss, radiation-induced damage, immunological decline, and behavioral problems have increased monotonically, based on observations to date, as mission duration is extended. While both immediate and delayed physiological changes can be studied in long-duration missions, delayed changes cannot be studied in the shorter-duration missions. Early implementation of surface stays of at least sixty days on the moon will provide maximum benefit to HRP with a minimum of time *in situ*. HRP does not require any fixed number of astronaut-subjects at any particular surface stay duration before concurring on extending lunar surface stays up to a 180 day limit. HRP will require useable data sets from a minimum of 24 astronaut-subjects on lunar surface missions of sixty days or more to provide for rigorous statistical analysis of research results in order to enable Mars surface missions. Since understanding crew health problems and finding appropriate solutions are absolutely critical in order to embark on a mission to Mars, human research should be prioritized in lunar mission planning.

2.2 INTRAVEHICULAR VOLUME

2.2.1 The exploration architecture shall provide 30 liters/mission (0.03 m^3) of packed volume for HRP consumables and equipment transported from the Earth to the lunar surface on each lunar mission greater than 14 days.

Rationale: Some of the experiment protocols will include sample collection during the transit, thus driving the need for consumables and equipment in transportation vehicles (Earth/Moon transit vehicles and lunar descent/ascent vehicles). The 30 liters/mission (0.03 m^3) volume requirement is based upon the volume required to stow equipment and samples typically used for HRP risk reduction studies during spaceflight. The location of the stowage volume shall be easily accessible by the crew to minimize crew time needs.

2.2.2 The exploration architecture shall provide 8 liters/mission (0.08 m^3) of packed volume for HRP consumables and equipment transported from the Earth to the lunar surface on each lunar mission less than 14 days.

Rationale: Some of the experiment protocols will include sample collection during transit, thus driving the need for consumables and equipment in transportation vehicles. The 8 liters/mission (0.08 m^3) volume requirement is based upon the volume required to stow equipment and samples typically used for HRP risk reduction studies during spaceflight missions less than 14 days. The location of the stowage volume shall be easily accessible by the crew to minimize crew time needs.

2.2.3 The exploration architecture shall provide 2000 liters/mission (2 m^3) of volume for HRP consumables and equipment in the habitat.

Rationale: The outpost habitat will be used to house experiment equipment to conduct sample/specimen collection on crew during long-duration stays. The results of these experiments will inform risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. The 2000 liters/mission (2 m^3) volume requirement is derived from a suite of equipment required to cover the entire set of risks to be mitigated. The location of the stowage volume shall be easily accessible by the crew to minimize crew time needs.

2.2.4 The exploration architecture shall transport 6 liters/mission (0.006 m^3/mission) of material in cold stowage (+4°C) from the Earth to the lunar surface on each mission greater than 14 days and less than 60 days.

Rationale: Some experiment protocols will use consumables that require continuous conditioned stowage, in the transportation vehicles and the habitat, in order to maintain integrity. The loss of the thermal conditioning will result in complete loss of data for experiments that require the conditioned consumable. The location of the stowage volume shall be easily accessible by the crew to minimize crew time needs.

2.2.5 The exploration architecture shall transport 8 liters/mission (0.008 m^3/mission) of material in cold stowage (+4°C) from the Earth to the lunar surface on each mission greater than 60 days.

Rationale: Some experiment protocols will use consumables that require continuous conditioned stowage, in the transportation vehicles and the habitat, in order to maintain integrity. The loss of the thermal conditioning will result in complete loss of data for experiments that require the conditioned consumable. The location of the stowage volume shall be easily accessible by the crew to minimize crew time needs.

2.2.6 The exploration architecture shall transport 8 liters/mission (0.008 m^3/mission) of hardware or samples from the lunar surface to Earth on each mission less than 14 days.

Rationale: In addition to the biomedical samples, there may be cases in which certain measurement hardware items must be returned from the lunar surface. Examples are radiation sensors or badges, dust samples, etc. Every effort will be made to ensure that the volume is minimized. However, there will be cases in which small amounts of items (non-conditioned) are required to be returned from the lunar surface for analysis.

2.2.7 The exploration architecture shall transport 30 liters/mission (0.03 m^3/mission) of hardware or samples from the lunar surface to Earth on each mission greater than 14 days and less than 60 days.

Rationale: In addition to the biomedical samples, there may be cases in which certain measurement hardware items must be returned from the lunar surface. Examples are radiation sensors or badges, dust samples, etc. Every effort will be made to ensure that the volume is minimized. However, there will be cases in which small amounts of items (non-conditioned) are required to be returned from the lunar surface for analysis.

2.2.8 The exploration architecture shall transport 30 liters/mission (0.03 m^3/mission) of hardware or samples from the lunar surface to Earth on each mission greater than 60 days.

Rationale: In addition to the biomedical samples, there may be cases in which certain measurement hardware items must be returned from the lunar surface. Examples are radiation sensors or badges, dust samples, etc. Every effort will be made to ensure that the volume is minimized. However, there will be cases in which small amounts of items (non-conditioned) are required to be returned from the lunar surface for analysis.

2.2.9 The Constellation architecture shall transport 3 liters/mission (0.003 m^3/mission) in frozen stowage (-80°C) from the lunar surface to Earth on each mission greater than 14 days and less than 60 days.

Rationale: Some experiment protocols will require conditioned stowage to maintain the integrity of the samples. Specimens that are stored on the lunar surface, in the descent/ascent vehicle and the habitat, under a cold or frozen condition will require conditioned transport to the Earth transit vehicle. Loss of the thermal conditioning will result in complete loss of data from the samples.

2.2.10 The exploration architecture shall transport 6 liters/mission (0.006 m^3/mission) in frozen stowage (-80°C) from the lunar surface to Earth on each mission greater than 60 days.

Rationale: Some experiment protocols will require conditioned stowage to maintain the integrity of the samples. Specimens that are stored on the lunar surface, in the descent/ascent vehicle and the habitat, under a cold or frozen condition will require conditioned transport to the Earth transit vehicle. Loss of the thermal conditioning will result in complete loss of data from the samples.

2.3 MASS TRANSPORT

2.3.1 The exploration architecture shall transport 30 kg/mission (30 liters/mission (0.03 m^3/mission)) of consumables and hardware from the Earth to the lunar surface for each mission greater than 14 days.

Rationale: Some of the experiment protocols will require sample/specimen collection on the lunar surface, thus driving the need for consumables and equipment to be transported to the lunar surface. The 30 kg/mission requirement is based upon the estimated mass needed to support the required HRP investigations during lunar missions greater than 14 days.

2.3.2 The exploration architecture shall transport 8 kg/mission (8 liters/mission (0.008 m^3/mission)) of consumables and hardware from the Earth to the lunar surface for each mission less than 14 days.

Rationale: Some of the experiment protocols will require sample/specimen collection on the lunar surface, thus driving the need for consumables and equipment to be transported to the lunar surface. The 8 kg/mission requirement is based upon the estimated mass needed to support the required HRP investigations during lunar missions less than 14 days.

2.3.3 The exploration architecture shall transport 6 kg/mission (6 liters/mission (0.006 m^3/mission)) of material in cold stowage (+4°C) from the Earth to the lunar surface for each mission greater than 14 days.

Rationale: Some of the experiment protocols will require sample/specimen collection on the lunar surface. Some reagents involved in taking the data have short shelf lives without being cooled or frozen (conditioned). Note that this is NOT an explicit requirement for a refrigerator. The requirement is for transport of material in cold stowage. Specific mission-by-mission requirements will determine the length of this cold stowage.

2.3.4 The exploration architecture shall transport 500 kg of experimental hardware and consumables for the initial outfitting of the habitat.

Rationale: The lunar habitat will be used to house experiment equipment to conduct sample/specimen collection on crew during long-duration stays. The results of these experiments will inform risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. It is anticipated that the experimentation will be far more intensive than the sortie timeframe. The requirement for 500 kg anticipates the suite of equipment required to perform this experimentation in the lunar habitat. It is consistent with the requirement for 1.5 kW of power and the volume requirement. The requirement is derived from a suite of equipment required to cover the entire set of human health and performance risks to be mitigated. This suite of equipment is anticipated to be delivered only once, and will remain at the lunar habitat as an analysis laboratory for multiple outpost missions. The deployment does not have to be conducted all at once, but can be implemented throughout the lunar habitat build-up phase.

2.3.5 The exploration architecture shall transport 30 kg/mission (30 liters/mission (0.03 m^3/mission)) of hardware or samples from the lunar surface to Earth on each mission greater than 14 days and less than 60 days.

Rationale: In addition to the biomedical samples, there may be cases in which certain measurement hardware items must be returned from the lunar surface. Examples are radiation sensors or badges, dust samples, etc. Every effort will be made to ensure that the mass is minimized. However, there will be cases in which small amounts of items (non-conditioned) are required to be returned from the lunar surface for analysis.

2.3.6 The exploration architecture shall transport 30 kg/mission (30 liters/mission (0.03 m^3/mission)) of hardware or samples from the lunar surface to Earth on each mission greater than 60 days.

Rationale: In addition to the biomedical samples, there may be cases in which certain measurement hardware items must be returned from the lunar surface. Examples are radiation sensors or badges, dust samples, etc. Every effort will be made to ensure that the mass is minimized. However, there will be cases in which small amounts of items (non-conditioned) are required to be returned from the lunar surface for analysis.

2.3.7 The exploration architecture shall transport 3 kg/mission (3 liters/mission (0.003 m^3/mission)) in frozen stowage (-80°C) from the lunar surface to Earth on each mission greater than 14 days and less than 60 days.

Rationale: Some of the experiment protocols will require sample/specimen collection on the lunar surface. There are cases in which a biomedical experiment sample/specimen must be conditioned to preserve its scientific value since they degrade at room temperature. Samples/specimens that require conditioning (e.g., frozen samples returned from the lunar surface) must be conditioned throughout all phases of the mission to maintain their integrity. Note that this is NOT an explicit requirement for a freezer. The requirement is for transport of material in cold stowage. Efforts are underway to reduce this requirement through dried-blood chemistry, however, at present it is not anticipated that the entire necessary suite of analytes will remain stable in dried form in the oxidative and radiation environment of the lunar mission. Dried chemistry presently is effective for urine samples and some mineral markers in blood such as calcium. Currently, it is not effective for the large array of proteins, lipids and other biomarkers that may be necessary for the conduct of research on the lunar surface. These biomarkers are important for understanding the physiological response to fractional gravity, and developing and validating countermeasures that could be employed on longer-duration exploration missions.

2.3.8 The exploration architecture shall transport 7 kg/mission (7 liters/mission (0.007 m^3/mission)) in frozen stowage (-80°C) from the lunar surface to Earth on each mission greater than 60 days.

Rationale: Some of the experiment protocols will require sample/specimen collection on the lunar surface. There are cases in which a biomedical experiment sample/specimen must be conditioned to preserve its scientific value since they degrade at room temperature. Samples/specimens that require conditioning (e.g., frozen samples returned from the lunar surface) must be conditioned throughout all phases of the mission to maintain their integrity. Note that this is NOT an explicit requirement for a freezer. The requirement is for transport of material in cold stowage. Efforts are underway to reduce this requirement through dried-blood chemistry, however, at present it is not anticipated that the entire necessary suite of analytes will remain stable in dried form in the oxidative and radiation environment of the lunar mission. Dried chemistry presently is effective for urine samples and some mineral markers in blood such as calcium. Currently, it is not effective for the large array of proteins, lipids and other biomarkers that may be necessary for the conduct of research on the lunar surface. These biomarkers are important for understanding the physiological response to fractional gravity, and developing and validating countermeasures that could be employed on longer-duration exploration missions.

2.3.9 The exploration program shall return to the HRP 100 grams of dust to Earth from each location on the lunar surface to which a mission is conducted.

Rationale: Studies of the potential toxicity of lunar dust have been based on a limited number of lunar dust samples gathered during the Apollo era. Because lunar dust toxicity may vary with the physical and chemical content and dust from different lunar regions vary in composition, relevant questions cannot be answered until the diversity of lunar dust mineralogy and morphology have been more thoroughly evaluated. Samples from multiple, different sites must be evaluated to address the potential diversity in toxicity.

2.4 CREW AVAILABILITY

2.4.1 The exploration architecture shall provide an average of 10 hours per week of crew time for HRP research during each lunar mission less than 14 days.

Rationale: A small level of experimentation will occur on lunar sortie missions. Assuming approximately a 1-week mission, the HRP will not require over 10 hours on this type of mission. It is assumed that the experimentation will be conducted in the descent/ascent vehicle, EVA, and with some data acquired in transit. The requirement is meant to cover operations during surface stays and during transport.

2.4.2 The exploration architecture shall provide an average of 20 hours per week of crew time for HRP research during each lunar mission greater than 14 days.

Rationale: During pre-outpost missions, the experimentation will be conducted in the descent/ascent vehicle, EVA, and with some data acquired in transit. The lunar habitat will be used to house experiment equipment for crew data collection during long-duration stays. The results of these experiments will inform risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. The long-duration aspects will increase the opportunities to observe long-term physiologic changes and validate countermeasures for long-duration missions in fractional gravity. This requirement is meant to cover operations during surface stays and during transport.

2.4.3 The exploration architecture shall ensure that all crew members are available to participate in human research experiments (subject to informed consent).

Rationale: The lunar habitat will be used to house experiment equipment for crew data collection during long-duration stays. The results of these experiments will inform risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. To achieve statistical significance of the experimental results, a high "n" must be used. Ensuring that all crew members are available to participate in human research experiments will optimize the "n" that can be obtained. It is recognized that the participation of crew members is subject to informed consent. The intent of this requirement is for the exploration architecture to not build in an operational constraint that would automatically preclude a crew member from participation in human research.

2.5 OPERATIONS

2.5.1 The exploration architecture shall provide the capability and facilities for the collection of human subject baseline data pre-launch and post landing of the Earth transit vehicle.

Rationale: Baseline data collection (BDC) facilities must be provided near the launch and landing site to facilitate collection of biomedical data just prior to and after the flight. Upon landing, without this capability, rapid adaptation to the 1-g environment will mask critical data that could be obtained.

2.5.2 Ground, BDC, and payload processing facilities shall be equivalent to those historically used for KSC Shuttle operations.

Rationale: Lunar activities are expected to be similar to HRP activities currently performed at KSC. The KSC operations supported both long and short duration missions.

2.5.3 Timelines for post flight data collection shall be managed to ensure adequate time to collect research data from crew members.

Rationale: Currently post-flight data collection time is highly constrained. Mission planners should recognize this constraint and build schedules to accommodate BDC collection time.

2.5.4 The exploration architecture shall provide access to the crew for participation in HRP applied research activities, including crew payload operations training and baseline data collection. Baseline data collection shall start twelve months prior to their increment and end twelve months after their return.

Rationale: This requirement is to ensure that crew scheduling recognizes the need to provide access to those crew members participating in human research experiments. This access extends beyond the confines of the mission. While data collection for human research often occurs several days to several months before and after the mission, some research activities require the baseline data collection up to one year preflight and one year post-flight. Samples may be taken from the crew periodically during the pre- and post-flight timeframes. With an internationally-coordinated system, crew members' time may have to be spread between different countries prior to the launch or post landing. This requirement is to ensure that the crew is available for BDC prior to launch and post landing.

2.5.5 The exploration architecture shall ensure that the thermal integrity of the returned thermal samples is maintained until delivery to the HRP.

Rationale: Conditioned samples/specimens returned to the Earth shall be maintained at the appropriate stowage temperature throughout the return phase and up to the point of hand over to the investigator. The samples will be transferred from the habitat to the descent/ascent vehicle, from the descent/ascent vehicle to the Earth transit vehicle, and removed from the Earth transit vehicle and delivered to the investigator in a manner that maintains the required conditioned state. This requirement ensures that the samples will remain conditioned throughout the duration of the landing and delivery phases.

2.5.6 The exploration architecture shall provide late loading capability prior to launch of L-12 hours for conditioned reagents.

Rationale: Some experiment protocols will require sample/specimen collection on the lunar surface. Reagents with short shelf lives will be obtained or produced as close to launch as possible to reduce the risk for expiration before use due to a launch delay/scrub without change-out or delay in the start of the sampling session. The late load requirement supports maximizing the shelf life duration during the mission by allowing the science team to obtain the short shelf life reagents as close to launch as possible. Delay/scrub scenarios will be addressed in lower level requirements.

2.5.7 The exploration architecture shall ensure that the thermal integrity of the launched thermal supplies and reagents are maintained until used for research by the HRP.

Rationale: Conditioned supplies and reagents launched from the Earth shall be maintained at the appropriate temperature throughout the transit phase and up to the point of utility. This requirement assures that reagents are stored under the appropriate conditions to protect and preserve shelf life.

2.6 POWER

2.6.1. The exploration architecture shall provide a keep-alive power level and associated thermal rejection capability sufficient to maintain the integrity of the conditioned reagents and samples throughout all phases of the mission.

Rationale: There are cases in which a biomedical experiment sample/specimen must be conditioned to preserve its scientific value. Samples/specimens that require conditioning (e.g., frozen samples returned from the lunar surface) must be conditioned throughout all phases of the mission. If the solution for providing the conditioning requires power, then the appropriate keep-alive power and thermal rejection capability must be provided. This requirement is structured to ensure that the samples/specimens remain conditioned, rather than requiring a specific level of keep-alive power. If a design solution is developed that would allow for preserving the integrity of the conditioned samples/specimens, but does not require keep-alive power all of the time, then the essence of the requirement can still be accomplished.

2.6.2 The exploration architecture shall provide an interface panel with 180 W of power available to support periodic experiment data collection in the Earth transit vehicle and the descent/ascent vehicle.

Rationale: This requirement allows for deployment of small electronic hardware for data collection throughout the mission. This requirement allows for the power capability to support this equipment. It is not anticipated that these hardware items would draw power for the duration of the mission. Rather, they would most often draw power for the times associated with the crew time dedicated to the experimentation. The 180 W of power is in addition to the power/thermal rejection capacity required for the exploration program to maintain thermal conditioning of the HRP samples.

2.6.3 The exploration architecture shall provide the associated thermal rejection capability to the cabin air to support 180 W to support periodic experiment data collection in the Earth transit vehicle and the descent/ascent vehicle.

Rationale: This requirement allows for deployment of small electronic hardware for data collection throughout the mission. This requirement allows for the thermal rejection capability to support this equipment. It is no t anticipated that these hardware items would draw power for the duration of the mission. Rather, they would most often draw power for the times associated with the crew time dedicated to the experimentation. The thermal rejection capability is in addition to the power/thermal rejection capacity required for the exploration program to maintain thermal conditioning of the HRP samples.

2.6.4 The exploration architecture shall provide 1.5 kW of continuous power to support HRP science operations in the habitat.

Rationale: The lunar habitat will be used to house experiment equipment to collect data on the crew during long-duration stays. The results of these experiments contribute to the risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. The 1.5 kW of power requirement is derived from a suite of equipment required to cover the entire set of risks to be mitigated. The power capability is in addition to the power/thermal rejection capacity required for the exploration program to maintain thermal conditioning of the HRP samples

2.6.5 The exploration architecture shall provide 1.5 kW of thermal rejection capability to support HRP science operations in the habitat.

Rationale: The lunar habitat will be used to house experiment equipment to obtain data on the crew during long-duration stays. The results of these experiments contribute to the risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. The 1.5 kW thermal rejection requirement is derived from a suite of equipment required to cover the entire set of human health and performance risks to be mitigated. The thermal rejection capability is in addition to the power/thermal rejection capacity required for the exploration program to maintain thermal conditioning of the HRP samples

2.7 DATA

2.7.1 The exploration architecture shall provide 1 Mb/s uplink for an average of fifteen minutes/day to HRP payload equipment during the transport phase of all lunar missions.

Rationale: Some experiment hardware will require interaction from the ground to upload instructions, procedures, or reconfigure software. The 1 Mb/s maintains the capability to do this. Some data points will occur during the transport phase of the missions. Also, some changes may occur to protocols as a result of observed data from previous data points. Thus the requirement exists for uplink capability during the transport phase of the mission. The intent of the requirement is to provide the capability for the uplink. The fifteen minutes /day is meant to be an average over the course of the mission. In some cases, an uplink of a large file may exceed fifteen minutes.

2.7.2 The exploration architecture shall provide 100 Mb/s downlink for an average of fifteen minutes /day for HRP payload equipment during the transport phase of all lunar missions.

Rationale: Some experiment hardware will require downlink of high-resolution images and video and sample data analysis. The 100 Mb/s maintains the capability to do this. Some data collection will occur during the transport phase of the missions. In some cases data analysis on the ground must occur to determine the course of future data collection during the mission. Thus, these data must be downlinked rather than stored for return. The fifteen minutes /day is meant to be an average over the course of the mission. In some cases a downlink of a large file may exceed fifteen minutes to downlink.

2.7.3 The exploration architecture shall provide 1 Mb/s uplink for an average of thirty minutes /day to HRP payload equipment in the lunar habitat.

Rationale: The lunar habitat will be used to house experiment equipment to collect data on crew during long-duration stays. The results of these experiments contribute to the risk mitigation efforts for future Mars missions or for longer-duration stays on the lunar surface. It is anticipated that the experimentation will be more intensive in the lunar habitat thus the uplink average is increased to thirty minutes /day. Some experiment hardware will require interaction from the ground to upload instructions, procedures, or reconfigure software. The 1 Mb/s maintains the capability to do this. Some changes may occur to protocols as a result of observed data from previous collection activities. Thus, the requirement exists for uplink capability rather than programming on the ground for a pre-planned protocol. The thirty minutes /day is meant to be an average over the course of the mission. In some cases an uplink of a large file may exceed thirty minutes to uplink.

2.7.4 The exploration architecture shall provide 100 Mb/s downlink for an average of thirty minutes /day for HRP payload equipment in the lunar habitat.

Rationale: The lunar habitat will be used to house experiment equipment to collect data on crew during long-duration stays. The results of these experiments contribute to the risk mitigation efforts for future Mars missions, or for longer-duration stays on the lunar surface. Some experiment hardware will require downlink of high-resolution images and video and sample data analysis. It is anticipated that the experimentation will be more intensive in the lunar habitat, thus the downlink average is increased to thirty minutes /day. In some cases data analysis on the ground must occur to determine the course of future data takes during the mission. Thus, these data must be downlinked rather than stored for return. The 100 Mb/s maintains the capability to do this. The thirty minutes /day is meant to be an average over the course of the mission. In some cases a downlink of a large file may exceed thirty minutes to downlink.

3.0 APPENDICES

3.1 TABLES

	Mission Duration			<14 days	>14 & <60 days	>60 days
Criteria		Experimental Equipment and Consumable Types		Recommended Requirements	Recommended Requirements	Recommended Requirements
Mass transport/mission	Earth - Lunar					
		Conditioned (kg)	4°C	0	6	6
			-80°C	0	0	0
		Non-conditioned (kg)		8	30	30
	Lunar - Earth					
		Conditioned (kg)	4° C	0	0	0
			-80°C	0	3	7
		Non-conditioned (kg)		8	30	30
Volume transport/mission	Earth - Lunar					
		Conditioned (l)	4°C	0	6	8
			-80°C	0	0	0
		Non-conditioned (l)		8	30	30
	Lunar - Earth					
		Conditioned (l)	4°C	0	0	0
			-80°C	0	3	6
		Non-conditioned (l)		8	30	30
Crew Time						
		(hours/week)		10	20	20
Power	Transportation Vehicles			180W	180W	
	Habitat					1.5kW
Data	Uplink			1 Mbps	1 Mbps	1 Mbps
	Downlink			100 Mbps	100 Mbps	100 Mbps

3.2 LIST OF ACRONYMS

BDC	Baseline Data Collection
MORD	Medical Operations Requirements Document
EARD	Exploration Architecture Requirements Document
HEOMD	Human Exploration and Operations Mission Directorate
HRP	Human Research Program
HRPCB	Human Research Program Control Board
ISS	International Space Station
LHRR	Lunar Human Research Requirements
TBR	To be resolved