

# Human Research Program Requirements Document

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## Human Research Program Revision G

March 2015



National Aeronautics and Space Administration  
Johnson Space Center  
Houston, Texas

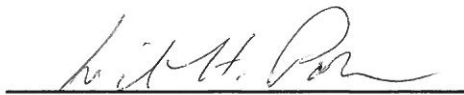
**Human Research Program  
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**PREFACE**

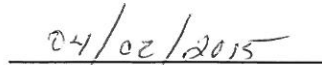
**HUMAN RESEARCH PROGRAM REQUIREMENTS DOCUMENT**

This document is the Human Research Program Requirements Document. The purpose of this document is to define, document, and allocate HRP requirements. The need to produce a Program Requirements Document (PRD) is established in HRP-47051A, Human Research Program – Program Plan, and is under configuration management control of the Human Research Program Control Board (HRPCB).

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**Human Research Program  
Requirements Document  
March 2015**

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## REVISION AND HISTORY PAGE

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Rev F.	Revision (Reference per SLSDCR-HRPCB-12-029-R1, EFF. 12-13-12)	02-22-13
Rev F, PCN-1	Page Change Notice Revision (Reference per SLSD-HRPCB-13-011, EFF. 08-20-13)	08-20-13
Rev G	Revision (Reference per HHPD-HRPCB-15-003, EFF. 03-12-15)	03-12-15

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## 1. INTRODUCTION

### 1.1 PURPOSE

This document defines, documents, and allocates the Human Research Program (HRP) requirements to the HRP Program Elements. It also establishes the flow of requirements from the Human Exploration and Operations Mission Directorate (HEOMD) and the Office of the Chief Health and Medical Officer (OCHMO) down to the various HRP Program Elements to ensure that human research and technology countermeasure investments support the delivery of countermeasures and technologies that satisfy HEOMD's and OCHMO's exploration mission requirements.

### 1.2 SCOPE

Requirements driving HRP work and deliverables are derived from the exploration architecture as well as Agency standards regarding the maintenance of human health and performance. Agency human health and performance standards will define acceptable risk for each type and duration of exploration mission. It is critical to have the best available scientific, operational and clinical evidence in setting and validating these standards. In addition, it is imperative that the best available evidence on preventing and mitigating human health and performance risks is incorporated into exploration mission and vehicle designs. These elements form the basis of the HRP research and technology development requirements and highlight the importance of HRP investments in enabling NASA's exploration missions.

HRP requirements are derived from the following documents:

- Human Exploration and Operations Mission Directorate (HEOMD) Strategic Implementation Plan;
- NPD 1001.0A, 2011 NASA Strategic Plan
- Human Exploration and Operations Mission Directorate (HEOMD) Program Commitment Agreement (PCA) with HRP
- NASA-STD-3001, NASA Space Flight Human System Standard, Volume 1: Crew Health; and
- NASA-STD-3001, NASA Space Flight Human System Standard, Volume 2: Human Factors, Habitability and Environmental Health.

This PRD defines the requirements of the HRP which are allocated to the following major Program Elements:

1. Behavioral Health & Performance (BHP),
2. Exploration Medical Capability (ExMC),
3. Human Health Countermeasures (HHC),

4. ISS Medical Projects (ISSMP),
5. Space Human Factors & Habitability (SHFH), and
6. Space Radiation (SR).

The requirements are further subdivided into the following three categories:

- Human system standards (section 4),
- Human health and performance risks (section 5), and
- Provision of enabling capabilities (section 6).

Where appropriate, the Program Elements further allocate requirements to their research and technology development portfolios. These allocations are documented in the Element Plans.

This document includes three appendices. Appendix A captures the acronyms used in this document. Appendix B encompasses additional HRP assumptions on Agency Design Reference Mission (DRM) categories to frame the research required for each of the human health and performance risks in its portfolio. Appendix C is a matrix of risk dispositions of all human spaceflight risks by DRM category and by in-mission/post-mission phase.

### **1.3 CHANGE AUTHORITY**

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



## 2. DOCUMENTS

### 2.1 APPLICABLE DOCUMENTS

The following documents of the specified revision or the latest revision if not identified, are applicable to the extent specified herein. Inclusion of applicable documents herein does not in any way imply any order of precedence.

**Table 1 – Applicable Documents**

<b>Document No.</b>	<b>Revision Date</b>	<b>Document Title</b>
NASA-STD-3001 Vol. 1, Rev A	July 2014	NASA Space Flight Human System Standard Volume 1, Revision A: Crew Health
NASA-STD-3001 Vol. 2	February 2011	NASA Space Flight Human System Standard Volume 2: Human Factors, Habitability and Environmental Health
NPD 1001.0B	March 2014	2014 NASA Strategic Plan
HRP-XPCA	August 2012	HEOMD Program Commitment Agreement (PCA) with HRP
	Draft, October 2012	Human Exploration and Operations Mission Directorate (HEOMD) Strategic Implementation Plan
HRP-47051B	February 2013	Human Research Program – Program Plan (Revision B-PCN1)
NPR 7120.5E	August 2012	NASA Space Flight Program and Project Management Requirements w/Changes 1-12
NPD 1000.0B	November 2014	NASA Governance and Strategic Management Handbook
NPD 8500.1C	December 2013	NASA Environmental Management
NPD 8910.1B	October 2009	Care and Use of Animals (Revalidated 6/25/13)
NPR 1080.1A	May 2008	Requirements for the Conduct of NASA Research & Technology (R&T)

**Table 1 – Applicable Documents**

<b>Document No.</b>	<b>Revision Date</b>	<b>Document Title</b>
NPR 2190.1B	December 2011	NASA Export Control Program
NPR 2810.1A	May 2006	Security of Information Technology (Revalidated with Change 1, dated May 19, 2011)
NPR 5810.1	July 2012	Standard Format for NASA Research Announcements (NRAs) and other Announcements for Grants and Cooperative Agreements (Updated w/Change 2, July 16, 2012).
NPR 7100.1	March 2003	Protection of Human Research Subjects (Revalidated 6/26/14)
NPR 7120.8	February 2008	NASA Research and Technology Program and Project Management Requirements (w/Change 3 dated 04/18/13)
NPR 8000.4A	December 2008	Agency Risk Management Procedural Requirements (Revalidated 1/29/14)
NPR 7123.1B	April 2013	NASA Systems Engineering Processes and Requirements
JSC 66705	May 2014	Human System Risk Management Plan

## 2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document. These reference documents may or may not be specifically cited within the text of the document.

**Table 2 – Reference Documents**

<b>Document No.</b>	<b>Revision Date</b>	<b>Document Title</b>
HRP-47053	March 2013	Human Research Program Science Management Plan (Revision E)

Table 2 – Reference Documents

Document No.	Revision Date	Document Title
HRP-47065	July 2014	Human Research Program Integrated Research Plan (Revision F) (electronically available at: <a href="http://humanresearchroadmap.nasa.gov/">http://humanresearchroadmap.nasa.gov/</a> )
JSC-28330	December 2013	Human Health and Performance Directorate Configuration Management Plan (Revision F)
N/A	N/A	HRP Risk Evidence Reports electronically available at: <a href="http://humanresearchroadmap.nasa.gov/evidence/">http://humanresearchroadmap.nasa.gov/evidence/</a>
NPD 1000.3D	January 2015	The NASA Organization w/Change 66
NPD 7100.8E	December 2012	Protection of Human Research Subjects (Revalidated with admin. changes 12/18/2012)
HRP-47069D	January 2015	Human Research Program Unique Processes, Criteria, and Guidelines (Revision D PCN-2)
S.1281	December 2005	National Aeronautics and Space Administration (NASA) Authorization Act of 2005
NASA/SP-2010-3407	January 2010	Human Integration Design Handbook
N/A	N/A	NASA Institutional Review Board Website - <a href="http://irb.nasa.gov/">http://irb.nasa.gov/</a>

### 3. HRP GOALS

This section reflects the HRP Goals and Objectives described in the HRP Program Commitment Agreement and HRP-47051, Human Research Program – Program Plan.

#### 3.1 THE GOAL OF THE HRP IS TO PROVIDE HUMAN HEALTH AND PERFORMANCE COUNTERMEASURES, KNOWLEDGE, TECHNOLOGIES, AND TOOLS TO ENABLE SAFE, RELIABLE, AND PRODUCTIVE HUMAN SPACE EXPLORATION. THE SPECIFIC OBJECTIVES OF THE HRP ARE:

- 3.1.1 Develop capabilities, necessary countermeasures, and technologies in support of human space exploration, focusing on mitigating the highest risks to crew health and performance. Enable the definition and improvement of human spaceflight medical, environmental and human factors standards.
- 3.1.2 Develop technologies that serve to reduce medical and environmental risks, to reduce human systems resource requirements (mass, volume, power, data, etc.), and to ensure effective human-system integration across exploration mission systems.
- 3.1.3 Ensure maintenance of Agency core competencies necessary to enable risk reduction in the following areas: space medicine; physiological and behavioral effects of long-duration spaceflight on the human body; space environmental effects (including radiation) on human health and performance; and space human factors.

#### 4. HRP REQUIREMENTS RELATED TO HUMAN SYSTEM STANDARDS

##### 4.1 THE HUMAN RESEARCH PROGRAM (HRP) SHALL ENABLE THE DEVELOPMENT AND MODIFICATION OF NASA'S HEALTH, MEDICAL, HUMAN PERFORMANCE, AND ENVIRONMENTAL STANDARDS IN TIME FOR EXPLORATION MISSION PLANNING AND DESIGN.

*Rationale:* A first step in mitigation of human health and performance risks is the establishment of spaceflight human system standards. These standards are designed to address acceptable levels of human health and performance risks for exploration missions of varying complexity and duration. The OCHMO has established an initial set of standards that serves to guide the HRP in the expansion of its evidence base regarding human spaceflight health and performance risks. HRP sponsors research and technology development enabling development and modification of the OCHMO maintained standards.

Several different types of standards have been established by the OCHMO and documented in NASA-STD-3001, NASA Space Flight Human Systems Standards, Vol. 1 and Vol. 2. Specifically, the standards sets are listed below.

- Fitness-for-duty standards for maintaining the physiological and behavioral parameters necessary to perform the required tasks;
- Permissible outcome limits for the changes in health outcomes that are potentially affected by long-term exposure to the space environment;
- Permissible exposure limits for managing risks by controlling human exposure;
- Levels of care standards for guiding medical capabilities needed to respond to a medical contingency during exploration missions; and
- Human factors, habitability, and environmental standards to guide the development of spacecraft and systems so as to alleviate human health and performance impacts.

HRP will perform the research required to recommend new standards where current standards do not exist, or recommend updates to existing standards as evidence becomes available. The HRP requirements necessary to ensure the best possible evidence base in order to enable the development and modification of standards are included in this section:

- 4.1.1 The HHC shall perform the research necessary to enable the development and modification of the HHC standards sets documented in NASA-STD-3001, Vol.1 and Vol. 2.

- 4.1.2 The BHP shall perform the research necessary to enable the development and modification of the BHP standards sets documented in NASA-STD-3001, Vol.1 and Vol. 2.
- 4.1.3 The SR shall perform the research necessary to enable the development and modification of the SR standards sets documented in NASA-STD-3001, Vol.1 and Vol. 2.
- 4.1.4 The SHFH shall perform the research necessary to enable the development and modification of the SHFH standards sets documented in NASA-STD-3001, Vol.1 and Vol. 2.
- 4.1.5 The ExMC shall perform the research necessary to enable the development and modification of the ExMC standards sets documented in NASA-STD-3001, Vol.1 and Vol. 2.

## 5. HRP REQUIREMENTS RELATED TO HUMAN HEALTH & PERFORMANCE RISKS AND CONCERNS

The primary objective of the HRP is to enable prevention and mitigation of human health and performance risks to facilitate successful completion of exploration missions, and preservation of astronaut health over the long-term.

A risk is a health and performance item of interest that has a clear consequence and attendant likelihood supported by evidence. A concern is an item for which there is not sufficient evidence or quantifiable likelihood for a given design reference mission to support its status as a risk.

### Human System Risk Board

The OCHMO owns all human health and performance risks managed by the Human System Risk Board (HSRB) as described in the Human System Risk Management Plan (JSC-66705). The HSRB baselines risks supported by evidence and determines which risks require research as part of the mitigation strategy. For concerns, the HSRB makes the determination if more work is needed to seek out the minimum necessary spaceflight and terrestrial evidence to generate a likelihood and consequence (LxC) assessment. If the HSRB determines research is required to understand a concern or risk, or mitigate a risk, and if it is determined the research can be provided by HRP, the program will complete an analysis of the risk or concern and develop a research plan to further understand the risk or concern, inform standards, or develop mitigation or monitoring strategies for the risk. The HRP records these risks and concerns as requirements in the PRD.

### HRP Management Architecture to Address Risks and Concerns

As shown in Figure 1, the development of HRP content has been formulated around the management architecture of:



**Figure 1: HRP Management Architecture**

Evidence forms the basis for the existence of a risk to the human system. The individual risk research plans, that are compiled in the Integrated Research Plan (IRP), contain gaps in knowledge about characterizing or mitigating the risk, and the tasks to be carried out in order to produce the deliverables needed to fill the gaps and reduce the risk. HRP deliverables are generally 1) Knowledge - deliverables that add to the body of knowledge regarding the risk or concern, 2) Countermeasures – preventative and treatment actions taken to address a risk, 3) Technology Development - hardware and software that enable risk monitoring, prevention or treatment, 4) Operational Protocols - operational procedures and

methods that define a technique or process for mitigation of the risk, and 5) Guidelines, requirements, and standards – information that defines the acceptable levels of risk. Information generated by HRP that can inform the status of the risk and anticipated mitigations are documented in the HSRB Risk Summary.

The process for changing human health and performance risks is documented in HRP-47069, Human Research Program Unique Processes, Criteria, and Guidelines (UPCG) document.

**Risks and Concerns in the HRP Research Portfolio**

The current HRP human health and performance risks and concerns and applicable HRP Element assignments are listed in Tables 3 and 4. The tables contain the following information:

1. HRP Element: The Element(s) with primary responsibility for the research.
2. Title: Top level wording used to describe the risk or concern.
3. Short Title: An abbreviation of the title which is for HRP use only.
4. (*name*) Link to HRR: Specific weblinks to the IRP Human Research Roadmap (HRR) risk breakdown.

These risks and concerns reflect the current risk information presented at the HSRB level. At this time, there are 23 risks and 2 concerns approved at the HSRB for which research is to be performed by HRP. Each Element also has the ability to manage the research to a lower fidelity of risk topic breakdown through their respective research plans (see the HRR, <http://humanresearchroadmap.nasa.gov/> and the links provided in the tables below). The current disposition status of these risks is captured in Appendix C.

**Table 3 – Human System Health and Performance Risks**

	HRP Element	Title
1	HHC	Risk of Orthostatic Intolerance During Re-Exposure to Gravity (Short Title: OI) <a href="#">OI Link to HRR</a>
2	HHC	Risk of Injury and Compromised Performance Due to EVA Operations (Short Title: EVA) <a href="#">EVA Link to HRR</a>
3	HHC	Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance (Short Title: Muscle) <a href="#">Muscle Link to HRR</a>
4	HHC	Risk of Cardiac Rhythm Problems (Short Title: Arrhythmia) <a href="#">Arrhythmia Link to HRR</a>



Table 3 – Human System Health and Performance Risks

	HRP Element	Title
5	HHC	Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity (Short Title: Aerobic) <a href="#">Aerobic Link to HRR</a>
6	HHC	Risk of Adverse Health Event Due to Altered Immune Response (Short Title: Immune) <a href="#">Immune Link to HRR</a>
7	HHC	Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Space Flight (Short Title: Sensorimotor) <a href="#">Sensorimotor Link to HRR</a>
8	HHC	Risk of Spaceflight-Induced Intracranial Hypertension/Vision Alterations (Short Title: VIIP) <a href="#">VIIP Link to HRR</a>
9	HHC	Risk of Decompression Sickness (Short Title: DCS) <a href="#">DCS Link to HRR</a>
10	HHC	Risk of Reduced Crew Performance Due to Hypobaric Hypoxia (Short Title: Exploration Atmosphere)  Exploration Atmosphere Link to HRR ( <i>To be added once developed</i> )
11	HHC & SHFH	Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition (Short Title: Food & Nutrition)  <a href="#">Food Link to HRR</a> , <a href="#">Nutrition Link to HRR</a>
12	SHFH	Risk of Reduced Crew Performance Due to Inadequate Human-System Interaction Design (Short Title: HSID)  <a href="#">Hab Link to HRR</a> , <a href="#">Task Link to HRR</a> , <a href="#">HARI Link to HRR</a> , <a href="#">HCI Link to HRR</a> , <a href="#">Train Link to HRR</a>
13	SHFH	Risk of Adverse Health and Performance Effects of Celestial Dust Exposure (Short Title: Dust)  <a href="#">Dust Link to HRR</a>
14	SHFH	Risk of Adverse Health Effects Due to Host-Microorganism Interactions (Short Title: Microhost)  <a href="#">Microhost Link to HRR</a>

**Table 3 – Human System Health and Performance Risks**

	<b>HRP Element</b>	<b>Title</b>
15	SHFH	Risk of Injury from Dynamic Loads (Short Title: Occupant Protection) <a href="#">Occupant Protection Link to HRR</a>
16	ExMC	Risk of Adverse Health Outcomes and Decrements in Performance Due to In-flight Medical Conditions (Short Title: ExMC) <a href="#">ExMC Link to HRR</a>
17	ExMC	Risk of Renal Stone Formation (Short Title: Renal) <a href="#">Renal Link to HRR</a>
18	ExMC	Risk of Bone Fracture Due to Spaceflight Induced Changes to Bone (Short Title: Fracture) <a href="#">Fracture Link to HRR</a> , <a href="#">Osteo Link to HRR</a>
19	ExMC	Risk of Ineffective or Toxic Medications Due to Long Term Storage (Short Title: Stability) <a href="#">Stability Link to HRR</a>
20	BHP	Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (Short Title: BMed) <a href="#">BMed Link to HRR</a>
21	BHP	Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload (Short Title: Sleep) <a href="#">Sleep Link to HRR</a>
22	BHP	Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (Short Title: Team) <a href="#">Team Link to HRR</a>
23	SR	Risk of Space Radiation Exposure on Human Health (Short Title: Radiation) <a href="#">CNS Link to HRR</a> , <a href="#">ARS Link to HRR</a> , <a href="#">Degen Link to HRR</a> , <a href="#">Cancer Link to HRR</a>

**Table 4 – Human System Health and Performance Concerns**

	HRP Element	Title
1	HHC	Concern of Clinically Relevant Unpredicted Effects of Medication (Short Title: PK/PD). <a href="#">PK/PD Link to HRR</a>
2	HHC	Concern of Intervertebral Disc Damage Upon and Immediately After Re-Exposure to Gravity (Short Title: IVD) <a href="#">IVD Link to HRR</a>

### **5.1 THE HRP SHALL USE QUALITATIVE AND QUANTITATIVE METHODS TO ASSESS THE HUMAN HEALTH AND PERFORMANCE RISKS ASSOCIATED WITH HUMAN SPACEFLIGHT FOR EXPLORATION MISSIONS.**

*Rationale:* In many cases, there is a large uncertainty associated with the risk due to lack of controlled spaceflight (or ground analog) experimental evidence. This HRP requirement is to determine the likelihood and consequences of the risks using, at minimum, qualitative means, and implementing quantitative methods when data are available to support a meaningful assessment. The uncertainties associated with these quantities should be narrowed to the target values identified by each standard or to the greatest extent practical to facilitate risk mitigation through proper decisions for exploration hardware and software design and mission design. The risk assessment information produced by HRP informs the HSRB risk record and is synposized in the Risk Summaries.

- 5.1.1 The HRP Program Science Management Office (PSMO) shall develop ways to improve the approaches for assessing the integration of human health and performance risks associated with human spaceflight for exploration missions.

*Rationale:* The risks often have inter-relationships and interdependencies. The PSMO must evaluate the risks to identify and quantify these inter-relationships and interdependencies, and provide an assessment of the risks from an integrated perspective. This will help focus HRP efforts and ensure proper decision making.

- 5.1.2 The BHP shall qualitatively or quantitatively assess the BHP-applicable risks identified in Table 3.
- 5.1.3 The ExMC shall qualitatively or quantitatively assess the ExMC-applicable risks identified in Table 3.

- 5.1.4 The HHC shall qualitatively or quantitatively assess the HHC-applicable risks identified in Table 3.
- 5.1.5 The SHFH shall qualitatively or quantitatively assess the SHFH-applicable risks identified in Table 3.
- 5.1.6 The SR shall qualitatively or quantitatively assess the Space Radiation-applicable risks identified in Table 3.

**5.2 THE HRP ELEMENTS SHALL DEVELOP COUNTERMEASURES AND TECHNOLOGIES, OR INFORM MISSION AND VEHICLE REQUIREMENTS, TO PREVENT OR MITIGATE ADVERSE OUTCOMES OF HUMAN HEALTH AND PERFORMANCE RISKS.**

*Rationale:* Each risk is written with respect to an adverse outcome. The intent of the HRP is to prevent the adverse outcome from occurring through development and validation of novel countermeasures (devices, drugs, procedures, etc.), providing research evidence to the mission and vehicle design processes, and developing design requirements that will mitigate the adverse outcome. In this context, “mitigate” means “reduce the severity or reduce the probability of the adverse outcome.”

- 5.2.1 The BHP shall develop countermeasures and technologies, or provide research evidence to inform mission and vehicle requirements, to prevent or mitigate adverse outcomes of BHP-applicable risks identified in Table 3.
- 5.2.2 The ExMC shall develop countermeasures and technologies, or provide research evidence to inform mission and vehicle requirements, to prevent or mitigate adverse outcomes of ExMC-applicable risks identified in Table 3.
- 5.2.3 The HHC shall develop countermeasures and technologies, or provide research evidence to inform mission and vehicle requirements, to prevent or mitigate adverse outcomes of HHC-applicable risks identified in Table 3.
- 5.2.4 The SHFH shall develop countermeasures, technologies, tools, requirements, and design guidelines, or provide research evidence to inform mission and vehicle requirements, to prevent or mitigate adverse outcomes of SHFH-applicable risks identified in Table 3.
- 5.2.5 The SR shall develop countermeasures and technologies, or provide research evidence to inform mission and vehicle requirements, to prevent or mitigate adverse outcomes of SR-applicable risks identified in Table 3.

**5.3 THE HRP ELEMENTS SHALL DEVELOP METHODS AND TECHNOLOGIES TO MONITOR AND TREAT ADVERSE OUTCOMES OF HUMAN HEALTH AND PERFORMANCE RISKS.**

*Rationale:* If a risk cannot be mitigated adequately, the human must be monitored for indicators of an adverse outcome, and treatment methods should be developed.

- 5.3.1 The BHP shall develop methods and technologies to monitor and treat adverse outcomes of BHP-applicable risks identified in Table 3.
- 5.3.2 The ExMC shall develop methods and technologies to monitor and treat adverse outcomes of ExMC-applicable risks identified in Table 3.
- 5.3.3 The HHC shall develop methods and technologies to monitor and treat adverse outcomes of HHC-applicable risks identified in Table 3.
- 5.3.4 The SHFH shall develop methods and technologies to monitor and treat adverse outcomes of SHFH-applicable risks identified in Table 3.
- 5.3.5 The SR shall develop methods and technologies to monitor indicators of adverse outcomes of SR-applicable risks identified in Table 3.

#### **5.4 THE HRP ELEMENTS SHALL PROVIDE EVIDENCE TO SUPPORT A DETERMINATION OF STATUS FOR A CONCERN**

*Rationale:* As per the annual review cycle for risks and concerns, each concern must be assessed to allow for the determination by the HSRB of any possible change in status. Evidence that the Elements provide help the determination if a concern should remain a concern, be recognized as a risk, or be recognized as a topic which does not require further resources to address. An Element does not need to wait a full year if evidence is available to support a status discussion with the HSRB.

- 5.4.1 The BHP shall provide evidence to support determination of status for BHP-applicable concerns identified in Table 4.
- 5.4.2 The ExMC shall provide evidence to support determination of status for ExMC-applicable concerns identified in Table 4.
- 5.4.3 The HHC shall provide evidence to support determination of status for HHC-applicable concerns identified in Table 4.
- 5.4.4 The SHFH shall provide evidence to support determination of status for SHFH-applicable concerns identified in Table 4.
- 5.4.5 The SR shall provide evidence to support determination of status for SR-applicable concerns identified in Table 4.

- 6. HRP REQUIREMENTS RELATED TO PROVISION OF ENABLING CAPABILITIES**
- 6.1 THE HRP SHALL PROVIDE THE ENABLING CAPABILITY TO FACILITATE HUMAN SPACE EXPLORATION WITH RESPECT TO THE HUMAN SYSTEM.**

*Rationale:* Ensuring human exploration requires some infrastructure or activities that do not readily fall into a specific research and technology development category. The requirements below are intended to provide NASA with the necessary infrastructure or capabilities to implement the research and technology work required to update, inform, and validate standards and to address the risks relevant to human exploration.

In the course of research and technology development, each HRP Element may encounter the need to perform studies in a ground-based space analog environment (e.g., bed-rest facility, Antarctica). Each Element, with support from ISSMP, is responsible for the selection and/or validation of the appropriate analogs and the necessary planning, integration, and execution. Large resource commitments to analog facilities must be reflected in the Element Research Plan so that the cost-benefit to the HRP is clear.

- 6.1.1 The ISSMP shall plan, integrate, and execute HRP research tasks requiring access to space or flight analog environments to address standards or reduce or eliminate human health and performance risks.

*Rationale:* Access to space research platforms [the ISS and all ISS visiting vehicles that transport crew and/or cargo to and from the ISS] and flight analogs is required to study and/or validate many of the items in sections 4.0 and 5.0. The ISSMP serves as the service to integrate across all other HRP Elements, and optimize the research plans requiring access to space and flight analogs. The ISSMP provides the interface to the spaceflight and analog programs to ensure that the research is properly planned, integrated, and executed with the required data returned to the investigator.

- 6.1.2 The PSMO and the NASA medical community shall provide a data integration and management function to ensure proper handling of and access to HRP data.

*Rationale:* Access to data is critically important to advancing the state of knowledge of the human system in space. A data integration and management function includes the proper archiving of historical research data [e.g., the Life Sciences Data Archive (LSDA)] and organizing medical and research data to provide proper security levels, allow access by

query, and to provide tools to allow analysis of evidence (e.g., Integrated Medical Model and the Integrated Medical Evidence Database).

**6.2 THE HRP SHALL ENSURE PRESERVATION AND MAINTENANCE OF CORE TECHNICAL CAPABILITY AND EXPERTISE IN HUMAN RESEARCH AND TECHNOLOGY DEVELOPMENT.**

*Rationale:* The core competencies are those which are necessary to maintain and nurture an understanding of the existing evidence base regarding risks and adverse outcomes to humans due to spaceflight. This core competency involves sustaining and maintaining a dedicated scientific and management workforce, publically documenting the evidence and a robust external scientific community. Preservation and maintenance of this capability is necessary to provide stability over the multi-decadal implementation of the vision for space exploration. This core competency is necessary to facilitate the following:

Strategic planning. Identification and prioritization of the risks to the human system and development of long-range plans to quantify, prevent, mitigate, and treat the adverse outcomes requires competency of both the internal and external community to ensure proper direction to the research community for focusing their effort.

Acquisition development, planning, and execution. Acquisition of research and technology development is an inherently governmental function that requires core expertise within the civil service to ensure that the U.S. Government remains a “smart buyer” with respect to research and technology development for the human system.

Operations support for near-real time and real-time operational decisions involving the human system and environment. Laboratory facilities and the expertise to run them and interpret results are necessary to support an ongoing evaluation of the human system response to the space environment and to support the medical operations function during a mission. This involves utilizing the internal community as possible, and to some extent, facilitating the participation of the external community where uniquely specialized expertise must be sought.

The requirement is written at the HRP level and not specifically allocated to the Program Elements. However, the Program Elements shall provide inputs regarding their core competency needs and issues. As part of the annual Planning, Programming, Budgeting, and Execution (PPBE) process, Program Management will review the core technical capability of the Program Elements and adjust where appropriate.

**6.3 EACH HRP ELEMENT SHALL ENSURE THAT THEIR PROCESSES AND PRODUCTS COMPLY WITH THE NASA POLICY DIRECTIVES AND NASA PROCEDURAL REQUIREMENTS LISTED IN THE TABLE OF APPLICABLE DOCUMENTS IN SECTION 2.1.**

*Rationale:* Table 1 includes the NASA Policy Directives (NPD) and NASA Procedural Requirements (NPR) specifically referenced by HRP-47051, HRP Program Plan. This requirement explicitly states which NPR and NPD are applicable to the HRP and ensures that the requirement is flowed down to the Program Element level. Identification of specific NPR/NPD applicability falls upon each individual Element/Project when the Project Plan is defined. The intent of this requirement is to ensure HRP compliance with these documents within the normal processes and product development ongoing in the HRP.

#### **6.4 THE HRP ELEMENTS SHALL DEVELOP METHODS AND TECHNOLOGIES TO REDUCE HUMAN SYSTEMS RESOURCE REQUIREMENTS (MASS, VOLUME, POWER, DATA, ETC.).**

*Rationale:* Methods and technologies that reduce the human systems resource requirements for mass, volume, power, data, etc. must be developed to reduce the overall exploration resource requirements. Each HRP research element must focus the research on producing countermeasures and technologies that fit within the extremely limited resource envelopes anticipated for the exploration mission. An example is the reduction in time dedicated to exercise prescriptions. Present exercise prescriptions present a large burden on the overall mission timeline.

- 6.4.1 The HHC shall develop methods and technologies to reduce human systems resource requirements (mass, volume, power, crew time, etc.).
- 6.4.2 The BHP shall develop methods and technologies to reduce human systems resource requirements (mass, volume, power, crew time, etc.).
- 6.4.3 The SR shall develop methods and technologies to reduce human systems resource requirements (mass, volume, power, crew time, etc.).
- 6.4.4 The SHFH shall develop methods and technologies to reduce human systems resource requirements (mass, volume, power, crew time, etc.).
- 6.4.5 The ExMC shall develop methods and technologies to reduce human systems resource requirements (mass, volume, power, crew time, etc.).



**APPENDIX A – ACRONYMS AND ABBREVIATIONS**

A	Accepted	HARI	Human & Automation/Robotic Integration
AM	Ascent Module		
ARED	Advanced Resistive Exercise Device	HCI	Human-Computer Interaction
ARS	Acute Radiation Sickness	HEOMD	Human Exploration and Operations Mission Directorate
BHP	Behavioral Health & Performance	HHC	Human Health Countermeasures
BMD	Bone Mineral Density	HMTA	Health & Medical Technical Authority
Bmed	Behavioral Conditions & Psychiatric Disorders	HRP	Human Research Program
BR	Bioastronautics Roadmap	HRPCB	Human Research Program Control Board
CLIFF	Clinical Findings Forum	HRR	Human Research Roadmap
CHMO	Chief Health & Medical Officer	HSRB	Human System Risk Board
CMO	Chief Medical Officer	HZE	High energy particles
CNS	Central Nervous System	IMM	Integrated Medical Model
DCS	Decompression Sickness	IRP	Integrated Research Plan
Degen	Degenerative	ISS	International Space Station
DM	Descent Module	ISSMP	ISS Medical Projects
DRM	Design Reference Mission	IVD	Intervertebral Disc
DSH	Deep Space Habitat		
DXA	Dual-energy X-ray Absorptiometry	JBMR	Journal of Bone and Mineral Research
		JSC	Johnson Space Center
ECLSS	Environmental Control and Life Support System	LEO	Low Earth Orbit
e.g.	For Example	LET	Linear Energy Transfer
EDL	Entry, Descent, and Landing	LSDA	Life Sciences Data Archive
EVA	Extravehicular Activity		
ExMC	Exploration Medical Capability	MCC	Mission Control Center
		Microhost	Host-Microorganism
		MPCV	Multi-Purpose Crew Vehicle
GCR	Galactic Cosmic Rays	MRID	Medical Requirements Integration Documents
Hab	Habitat		

NASA	National Aeronautics and Space Administration	R&T	Research and Technology
		REM	Robotics and EVA Module
NEA	Near-Earth Asteroid	RMAT	Risk Mitigation Analysis Tool
NPD	NASA Procedural Directive		
NPR	NASA Procedural Requirement	SEV	Space Exploration Vehicle
		SHFH	Space Human Factors & Habitability
OCHMO	Office of the Chief Health and Medical Office	SMO	Science Management Office
OI	Orthostatic Intolerance	SPDM	Special Purpose Dexterous Manipulator
Osteo	Osteoporosis	SR	Space Radiation
PCA	Program Commitment Agreement	SSRMS	Space Station Remote Manipulation System
PEL	Permissible Exposure Limit		
Pharm	Pharmacology	TBS	To Be Specified
PPBE	Planning, Programming, Budgeting, and Execution	TEI	Trans-Earth Insertion
PRD	Program Requirements Document	U.S.	United States
PVT	Psychomotor Vigilance Task	UPCG	Unique Processes, Criteria, and Guidelines
QCT	Quantitative Computed Tomography	VIIP	Visual Impairment/Intracranial Pressure
QT	Q wave/T wave interval	Vol.	Volume

## APPENDIX B – DESIGN REFERENCE MISSION DESCRIPTIONS AND ASSUMPTIONS

The Human System Risk Board (HSRB) identifies several Design Reference Mission (DRM) categories against which human health and performance risks are to be evaluated and the OCHMO risk posture developed. These DRM categories are shown in Figure 2.

DRM Categories	Mission Duration	Gravity Environment	Radiation Environment	Earth Return
Low Earth Orbit	6 months	Microgravity	LEO - Van Allen	1 day or less
	1 year	Microgravity	LEO - Van Allen	1 day or less
Deep Space Sortie	1 month	Microgravity	Deep Space	< 5 days
Lunar Visit/Habitation	1 year	1/6g	Lunar	5 Days
Deep Space Journey/Habitation	1 year	Microgravity	Deep Space	Weeks to Months
Planetary Visit/Habitation	3 years	Fractional	Planetary*	Months

\*Planet has no magnetic poles, limited atmosphere

Source: *Human System Risk Management Plan (JSC-66705)*

### Figure 2: HSRB DRM Categories

Examples of missions that would fall into the DRM categories:

Low Earth Orbit: ISS6, ISS12, Commercial Suborbital, commercial visits to ISS, future commercial platforms in LEO

Deep Space Sortie: MPCV test flights, moon fly around or landing, visits to L1/L2, deep space excursion

Lunar Visit/Habitation: Staying on the surface more than 30 days (less than 30 days would be similar)

Deep Space Journey/Habitation: L1/L2 habitation, asteroid visit, journey to planets

Planetary Visit/Habitation: Living on a planetary surface, Mars & extended journey to and from in microgravity

These DRM categories provide a framework to identify key capabilities and important guiding drivers and assumptions to help HRP focus its research questions on topics relevant to NASA's future activities. Although these mission types share similar human health and performance challenges, each also

includes specific challenges that depend on the nature of the mission and the mission development schedule. The HRP research and technology development plan/schedule/framework is phased to supply appropriate deliverables in time to meet the challenges of each mission type.

At this time, the current DRM parameters defined in the Human System Risk Management Plan are still in development. In order to guide HRP in properly developing and maturing operations concepts that will inform requirements for the design and operation of space vehicles and habitats, additional parameters are needed.

This section provides additional assumptions pertaining to general aspects of the specific missions for which HRP is focusing research plan development, and is intended to complement agency DRM information. This list hopes to define a more useful set of mission guidelines that HRP can utilize in its research planning and risk assessment. These DRM assumptions provide the bounding conditions and trade space for defining future spaceflight capabilities and key performance drivers required to achieve mission objectives. Information regarding the Space Exploration Vehicle (SEV), Deep Space Habitat (DSH), and Robotics and EVA Module (REM) were obtained from ESD 10012, Exploration Systems Development (ESD) Concept of Operations. Information about missions supported by the Commercial Crew Program is from CCT-DRM-1110, Revision Basic-3, Crew Transportation System Design Reference Missions.

## **Low Earth Orbit (LEO): ISS 6-Month Mission Assumptions**

### **Crew Size**

- 4 crew members (will have interaction with additional 4 ISS crew members that will be in 6-month rotation cycle)

### **Mission Duration**

- 6 months (including transit)

### **Gravity Environment**

- Microgravity

### **Radiation Environment**

- LEO – Van Allen Belt

### **Earth Return**

- 1 day or less

### **Role of Ground Support / Mission Control Center (MCC)**

- Real-time communication
- Ground personnel support provided real time
  - On-board operations (e.g. monitoring/controlling systems during the crew sleep period, operating or assisting the operation of robotic systems)
  - Managing and replanning schedule as necessary
  - Training support (e.g., medical evaluations using ultrasound can be performed with real time support from a flight surgeon)

### **Resupply and Sample Return**

- 1 resupply mission (e.g. for consumables and spare parts and sample return)

### **Crew Habitation**

- Soyuz spacecraft transportation to/from ISS
- Commercial crew carrier sized for a minimum of 4 people
- ISS volume is approximately 388 cubic meters

### **Crew Timeline/Activities**

- Crew sleep, pre/post sleep activities to include galley operations and personal hygiene, exercise, review/development of crew planned activities/schedule
- Science/payload operations and vehicle system management/maintenance as required
- Interaction with ground control center
- 1-2 EVAs per increment in a nominal mission

**Exercise Equipment**

- Available equipment that will allow the crew to perform current exercise prescriptions

**HRP Constraints/Implied Requirements**

- Adequate vehicle or habitat shielding, dosimetry, and operational procedures in place to prevent exposures above 30-day permissible dose limits

**Pre/Post Mission Assumptions**

- Some HRP investigations will allow flexibility in their requirements for significant crew time in the immediate post-flight measurements (R+1 week especially).
- Medical testing conducted during the first week postflight will occur as usual.
- Requirements with minimal crew time commitments (e.g., blood, urine and saliva collections) may still be performed.

## **Low Earth Orbit (LEO): ISS 12-Month Mission Assumptions**

### **Crew Size**

- 2 crew members (will have interaction with additional 4 ISS crew members that will be in 6-month rotation cycle)

### **Mission Duration**

- 12 months (including transit)

### **Gravity Environment**

- Microgravity

### **Radiation Environment**

- LEO – Van Allen Belt

### **Earth Return**

- 1 day or less

### **Role of Ground Support / Mission Control Center (MCC)**

- Real-time communication
- Ground personnel support provided real-time
  - On-board operations (e.g., monitoring/controlling systems during the crew sleep period, operating or assisting the operation of robotic systems)
  - Managing and replanning schedule as necessary
  - Training support (e.g., medical evaluations using ultrasound can be performed with real time support from a flight surgeon)

### **Resupply and Sample Return**

- 1-2 resupply missions (e.g., for consumables and spare parts and sample return)

### **Crew Habitation**

- Soyuz spacecraft transportation to/from ISS
- Commercial crew carrier sized for a minimum of 4 people
- ISS volume is approximately 388 cubic meters.

### **Crew Timeline/Activities**

- Crew sleep, pre/post sleep activities to include galley operations and personal hygiene, exercise, review/development of crew planned activities/schedule.

- Science/payload operations and vehicle system management/maintenance as required
- Interaction with ground control center
- Up to 4 EVAs per crew member in a nominal mission

**Exercise Equipment**

- Available equipment that will allow the crew to perform current exercise prescriptions.

**HRP Constraints/Implied Requirements**

- Adequate vehicle or habitat shielding, dosimetry, and operational procedures in place to prevent exposures above 30-day permissible dose limits.

**Pre/Post Mission Assumptions**

- Some HRP investigations will allow flexibility in their requirements for significant crew time in the immediate post-flight measurements (R+1 week especially).
- Medical testing conducted during the first week postflight will occur as usual.
- Requirements with minimal crew time commitments (e.g., blood, urine and saliva collections) may still be performed.



## **Deep Space Sortie Mission Assumptions**

### **Crew Size**

- 4 crew members

### **Mission Duration**

- 1 month (including transit)

### **Gravity Environment**

- Microgravity

### **Radiation Environment**

- LEO – Van Allen Belt

### **Earth Return**

- Less than 5 days

### **Role of Ground Support / MCC**

- Communication delay of about 2.5 seconds round trip
- Ground personnel support provided in near real-time
  - On-board operations (e.g., monitoring/controlling systems during the crew sleep period)
  - Managing and replanning schedule as necessary
  - Training support (e.g., medical evaluations using ultrasound can be performed with near real-time support from a flight surgeon)
- No ground support in terms of ‘watching over the shoulder’ during robotics operations

### **Crew Habitation**

- **MPCV:**
  - Consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adaptor (SA) and a Launch Abort System (LAS). The CM provides a habitable pressurized volume to support crew members and cargo during all phases of a given mission.
  - Includes flight suits designed for the different roles required to allow crew members to perform launch, entry, exploration and extravehicular servicing and repair operations.
- **Lunar Lander:**
  - Consists of a three-module vehicle configuration - the Descent Module (DM), the Ascent Module (AM), and a Suit Lock/Suit Port (SL) module. The suit ports minimize the time required for the crew members to don suits and begin surface EVA, and minimize atmosphere losses.
- **EVA Deep Space Suit:**

- Allows crew members to perform exploration and extravehicular servicing and repair operations. The suit provides life support, environmental protection and communications capability to the EVA crew member while allowing sufficient mobility to perform dexterous EVA tasks.
- The Block 1 EVA Deep Space Suit is a separate suit element from the MPCV flight suits and is configured for microgravity EVA capability, designed for upper body mobility and worksite stabilization. The Block 2 EVA Surface Suit provides surface EVA capability on objects with a gravity field and no atmosphere, such as the Moon.
- **Space Exploration Vehicle (SEV):**
  - Combines a pressurized cabin and crew member support equipment, a propulsion/consumables unit, and robotic support packages.
  - Provides habitation during transit, serves as an excursion spacecraft at mission destinations, provides a robotic and robot-assisted exploration capability, and provides simultaneous EVA capability for two crew members.
  - Includes a system for physically securing the vehicle to external objects (e.g. NEAs, satellites), dexterous manipulators for scientific and servicing/repair operations, and an astronaut positioning system to facilitate EVA operations.

### Sample Return

- All monitoring for microbial or toxic hazards must be performed on board.
- Sample return capability may be available for a very limited amount driven by MPCV or Lunar Lander vehicle stowage capability.

### Crew Timeline/Activities

- **Transit:**
  - Crew sleep, pre/post sleep activities to include galley operations and personal hygiene, exercise, review/development of crew planned activities/schedule.
  - Science/payload operations (dependent on upmass capabilities) and vehicle system management/maintenance as required
  - Interaction with ground control center
  - No planned or contingency EVAs during transit time
- **Surface Operations:**
  - TBD EVAs per crew member
  - EVA crew members egressing from the vehicle through an airlock or suitport provided capability
  - Paired EVAs that maximize the scientific and operational value of the mission.

### Communication Delays

- Around 2.5 seconds round trip while on the lunar surface

**Crew Logistics/Food**

- No mission resupply to replenish the crew with logistical requirements during the entire mission. All consumables and spare parts must be available from the habitable volume.
- MPCV and Lunar Lander module will have a food galley with the required capabilities for the crew to prepare their meals. Majority of the food storage will be contained in the Lunar Lander module under the required food storage constraints.

**Exercise Equipment**

- Available equipment that will allow the crew to perform current exercise prescriptions.

**HRP Constraints/Implied Requirements**

- Adequate vehicle or habitat shielding, dosimetry, and operational procedures in place to prevent exposures above 30-day permissible dose limits.

**Pre/Post Mission Assumptions**

- TBD post-flight Baseline Data Collection will still be required, similar to ISS post-flight protocols.

## **Lunar Visit/Habitation Mission Assumptions**

### **Crew Size**

- 4 crew members

### **Mission Duration**

- 1 year (including transit)

### **Gravity Environment**

- 1/6<sup>th</sup> Earth gravity

### **Radiation Environment**

- Lunar

### **Earth Return**

- 5 days

### **Role of Ground Support / MCC**

- Communication delay of about 2.5 seconds round trip
- Ground personnel support provided in near real-time
  - On-board operations (e.g. monitoring/controlling systems during the crew sleep period)
  - Managing and replanning schedule as necessary
  - Training (e.g., medical evaluations using ultrasound can be performed with near real-time support from a flight surgeon)
- No ground support in terms of 'watching over the shoulder' during robotics operations

### **Crew Habitation**

- **MPCV:**
  - Consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adaptor (SA) and a Launch Abort System (LAS). The CM provides a habitable pressurized volume to support crew members and cargo during all phases of a given mission.
  - Includes flight suits designed for the different roles required to allow crew members to perform launch, entry, exploration and extravehicular servicing and repair operations.
- **Lunar Lander:**
  - Consists of a three-module vehicle configuration - the Descent Module (DM), the Ascent Module (AM), and a Suit Lock/Suit Port (SL) module. The suit ports minimize the time required for the crew members to don suits and begin surface EVA, and minimize atmosphere losses.

- **EVA Deep Space Suit:**
  - Allows crew members to perform exploration and extravehicular servicing and repair operations. The suit provides life support, environmental protection and communications capability to the EVA crew member while allowing sufficient mobility to perform dexterous EVA tasks.
  - The Block 1 EVA Deep Space Suit is a separate suit element from the MPCV flight suits and is configured for microgravity EVA capability, designed for upper body mobility and worksite stabilization. The Block 2 EVA Surface Suit provides surface EVA capability on objects with a gravity field and no atmosphere, such as the Moon.

### **Robotics**

- **Robotics and EVA Module (REM):**
  - Provides infrastructure necessary for extravehicular human and robotic operations, transportation element maintenance and repair, movement of equipment and payloads, anchoring or tethering of external bodies (e.g. satellite), extraction of cargo, and deployment of payloads in Earth orbit for independent entry.
  - Consists of a suitlock with two suitports, at least one robotic arm with a grapple fixture and EVA positioning end effectors, an international docking system standard interface, an external equipment pallet, a crew lock, and mounting points to which elements and payload hardware can be mounted.

### **Sample Return**

- All monitoring for microbial or toxic hazards must be performed on board.
- Sample return capability may be available for a very limited amount driven by MPCV or Lunar Lander vehicle stowage capability.

### **Crew Timeline/Activities**

- **Transit:**
  - Crew sleep, pre/post sleep activities to include galley operations and personal hygiene, exercise, review/development of crew planned activities/schedule.
  - Science/payload operations (dependent on upmass capabilities) and vehicle system management/maintenance as required
  - Interaction with ground control center
  - No planned or contingency EVAs during transit time
- **Surface Operations:**
  - TBD EVAs per crew member
  - EVA crew members egressing from the vehicle through an airlock or suitport provided capability
  - Paired EVAs that maximize the scientific and operational value of the mission.

**Communication Delays**

- Around 2.5 seconds round trip while on the lunar surface

**Crew Logistics/Food**

- No mission resupply to replenish the crew with logistical requirements during the entire mission. All consumables and spare parts must be available from the habitable volume.
- MPCV and Lunar Lander module will have a food galley with the required capabilities for the crew to prepare their meals. Majority of the food storage will be contained in the Lunar Lander module under the required food storage constraints.

**Exercise Equipment**

- Available equipment that will allow the crew to perform current exercise prescriptions.

**HRP Constraints/Implied Requirements**

- Adequate vehicle or habitat shielding, dosimetry, and operational procedures in place to prevent exposures above 30-day permissible dose limits.
- It is assumed that the Mars DRM will follow Level of Care Five standards in NASA-STD-3001 Vol. 1 for crewmember training and caliber: "The training and caliber of the caregiver shall be at the physician level, due to the exclusively autonomous nature of the mission."

**Pre/Post Mission Assumptions**

- TBD post-flight Baseline Data Collection will still be required, similar to ISS post-flight protocols.

## **Deep Space Journey/Habitation Mission Assumptions**

### **Crew Size**

- 3 crew members

### **Mission Duration**

- 1 year (including transit)

### **Gravity Environment**

- Microgravity

### **Radiation Environment**

- Deep space

### **Earth Return**

- Weeks to months

### **Role of Ground Support / MCC**

- Communication delay of up to 30 seconds
- Ground personnel support provided in overall 'batch mode' rather than immediate or real time
  - On-board operations (e.g., monitoring/controlling systems during crew sleep with some delay, some delay in supporting operation of robotics systems)
  - Managing and replanning schedule with some delay
  - Training (e.g., training materials sent in 'batch mode', some delay in support from a flight surgeon for medical evaluations such as ultrasound)

### **Crew Habitation**

- **MPCV:**
  - Consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adaptor (SA) and a Launch Abort System (LAS). The CM provides a habitable pressurized volume to support crew members and cargo during all phases of a given mission.
  - Includes flight suits designed for the different roles required to allow crew members to perform launch, entry, exploration and extravehicular servicing and repair operations.
- **Space Exploration Vehicle (SEV):**
  - Combines a pressurized cabin and crew member support equipment, a propulsion/consumables unit, and robotic support packages.
  - Provides habitation during transit, serves as an excursion spacecraft at mission destinations, provides a robotic and robot-assisted exploration capability, and provides simultaneous EVA capability for two crew members.

- Includes a system for physically securing the vehicle to external objects (e.g. NEAs, satellites), dexterous manipulators for scientific and servicing/repair operations, and an astronaut positioning system to facilitate EVA operations.
- **Deep Space Habitat (DSH):**
  - Provides a pressurized environment in which crew members live and work during extended transit phases and while at exploration destinations for longer duration missions.
  - Provides all of the resources necessary to support the crew members during this timeframe and carries additional supplies and spares for the rest of the stack. The DSH can be divided into separable pressurized volumes, with each section having at least one docking port capable of supporting crew members transfer and accommodating either the MPCV and/or SEV vehicles.
  - During integrated stack operations, the DSH provides life support functions throughout the docked habitable elements. The DSH provides radiation protection and is expected to include crew member accommodations such as food preparation, cleaning equipment, photography equipment, and exercise equipment. Pressurized logistics and spares are stowed as well.

### **Robotics**

- **Robotics and EVA Module (REM):**
  - Provides infrastructure necessary for extravehicular human and robotic operations, transportation element maintenance and repair, movement of equipment and payloads, anchoring or tethering of external bodies (e.g. satellite), extraction of cargo, and deployment of payloads in Earth orbit for independent entry.
  - Consists of a suitlock with two suitports, at least one robotic arm with a grapple fixture and EVA positioning end effectors, an international docking system standard interface, an external equipment pallet, a crew lock, and mounting points to which elements and payload hardware can be mounted.

### **Sample Return**

- All monitoring for microbial or toxic hazards must be performed on board.
- No sample return will be possible.

### **Crew Timeline/Activities**

- **Transit:**
  - Crew sleep, pre/post sleep activities to include galley operations and personal hygiene, exercise, review/development of crew planned activities/schedule.
  - Science/payload operations (dependent on upmass capabilities) and vehicle system management/maintenance as required



- Interaction with ground control center
- No planned or contingency EVAs during transit time
- **Surface Operations:**
  - TBD EVAs per crew member
  - During EVA activities, crew will be augmented with robotic support, and will be able to perform NEA surface operations only utilizing their robotics capabilities.
  - Vehicle design will provide a physical containment area for surface samples to isolate the crewmembers from any Asteroid surface materials that they may bring back to Earth.
  - Surface operations will subject the EVA crew to a possible microgravity field while on the surface.

### **Communication Delays**

- Expect communication delays between the crew and the ground control center to increase from zero during Low Earth Orbit (LEO) to up to approximately 30 seconds at NEA arrival, with the same duration impact during return to Earth.
- Due to the communication delay, the crew is expected to perform autonomous operations as required.

### **Crew Logistics/Food**

- No mission resupply to replenish the crew of logistical requirements during the entire mission. All consumables and spare parts must be provided at the start of the mission and available from the habitable volume.
- Habitation module will have a food galley with the required capabilities for the crew to prepare their meals. Food storage will be contained in the habitation module under the required food storage constraints.

### **Exercise Equipment**

- Available equipment that will allow the crew to perform current exercise prescriptions.

### **HRP Constraints/Implied Requirements**

- Adequate vehicle or habitat shielding, dosimetry, and operational procedures in place to prevent exposures above 30-day permissible dose limits.
- It is assumed that the Mars DRM will follow Level of Care Five standards in NASA-STD-3001 Vol. 1 for crewmember training and caliber: "The training and caliber of the caregiver shall be at the physician level, due to the exclusively autonomous nature of the mission."

### **Pre/Post Mission Assumptions**

- TBD post-flight Baseline Data Collection will still be required, but protocols will need to consider degree of crew de-conditioning after a 1-yr mission.

## **Planetary Visit/Habitation Mission Assumptions**

### **Crew Size**

- 6 crew members

### **Mission Duration**

- Total mission duration from launch to crew return approximately 3 years
- Transfer to and from Mars on the order of 6 months, the stay on the Martian surface on the order of 18 months

### **Gravity Environment**

- 3/8<sup>th</sup> Earth Gravity and microgravity

### **Radiation Environment**

- Planetary (i.e., planet has no magnetic poles, limited atmosphere)

### **Earth Return**

- Months

### **Role of Ground Support / MCC**

- Communication delay of up to 22 minutes to Mars surface.
- Ground personnel support provided in overall 'batch mode' rather than immediate or real-time.
  - On-board operations (e.g. monitoring/controlling systems during crew sleep with significant delay - crew must be able to stabilize systems for all contingencies for up to 44 minutes without any ground assistance, significant delay in supporting operation of robotic systems - autonomous operations during the communication delay)
  - Managing and replanning schedule with significant delay
  - Training (e.g., training materials sent in 'batch mode', significant delay in support from a flight surgeon for medical evaluations such as ultrasound)

### **Crew Habitation**

- **MPCV:**
  - Consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adaptor (SA) and a Launch Abort System (LAS). The CM provides a habitable pressurized volume to support crew members and cargo during all phases of a given mission.
  - Includes flight suits designed for the different roles required to allow crew members to perform launch, entry, exploration and extravehicular servicing and repair operations.
- **Deep Space Habitat (DSH):**

- Provides a pressurized environment in which crew members live and work during extended transit phases and while at exploration destinations for longer duration missions.
- Provides all of the resources necessary to support the crew members during this timeframe and carries additional supplies and spares for the rest of the stack. The DSH can be divided into separable pressurized volumes, with each section having at least one docking port capable of supporting crew members transfer and accommodating either the MPCV and/or SEV vehicles.
- During integrated stack operations, the DSH provides life support functions throughout the docked habitable elements. The DSH provides radiation protection and is expected to include crew member accommodations such as food preparation, cleaning equipment, photography equipment, and exercise equipment. Pressurized logistics and spares are stowed as well.
- **Surface Habitat:**
  - *(Details to be added once available.)*

### **Crew Timeline/Activities**

- **Transit:**
  - Crew sleep, pre/post sleep activities to include galley operations and personal hygiene, exercise, review/development of crew planned activities/schedule.
  - Science/payload operations (dependent on upmass capabilities) and vehicle system management/maintenance as required
  - Interaction with ground control center
  - No planned or contingency EVAs during transit
- **Surface Operations:**
  - General outline of crew activities established before the launch, but updated throughout the mission. Outline contains detailed activities to ensure initial crew safety, basic assumptions for initial science activities, schedule of periodic vehicle and system checkout, and plan for certain number of sorties. The crew will plan specific activities derived from the general objectives defined on Earth.
  - Landing operations expected to be fully automated with minimal crew interaction during the landing sequence.
  - Crew will be in a recumbent position during all Entry, Descent, and Landing (EDL) operations.
  - After crew acclimation period of a few weeks, initial surface activities would focus on transitioning from a “Lander mode” to a fully functional surface habitat.
  - During the 18-month stay on the Martian Surface, the six (6) crewmembers are expected to perform multiple EVAs and interact as directly as possible with the planet. Field work to be completed in the

vicinity of the surface base via EVAs assisted by pressurized and unpressurized rovers.

- Mars surface EVAs would be conducted by a minimum of two people and maximum of four.
- If unpressurized rovers are used, an additional operational constraint would be imposed on the EVA team.
- If one rover is used, the EVA team would be constrained to operate within rescue range of the surface base.

### **Communication Delays/Dropouts**

- Expected communication delays between the crew and the ground control center will increase from zero during LEO to up to 6-8 minutes at Mars arrival with the same duration impact during return to Earth. During the Mars surface operations, these delays could go up to 22 minutes.
- Due to the communication delay, the crew is expected to perform autonomous operations as required.
- Due to communication delays and periods of unavailable communication, the crew is expected to perform autonomous operations as required.

### **Crew Logistics/Food**

- The mission to Mars will consist of the crew habitation modules listed above (MPCV, DSH) and surface habitat.
- All consumables and spare parts must be provided at the start of the mission and available from the habitable volume.
- Food carried aboard the transit habitat includes transit consumables needed for the round-trip journey plus contingency consumables required to maintain the crew should all or part of the surface mission be aborted.
- If the crew is forced to return to the orbiting vehicle, which would be used as an orbital “safe haven” until the Trans-Earth Insertion (TEI) window opens, any contingency food remaining onboard the crewed vehicle would be jettisoned prior to the TEI burn to return home.
- The habitation module will have a food galley with the required capabilities for the crew to prepare their meals. Food storage will be contained in the cargo module under the required food storage constraints.

### **Resupply and Sample Return**

- No mission resupply to replenish the crew of logistical requirements.
- All monitoring for microbial or toxic hazards must be performed on board.
- Sample return feasibility still to be determined.

### **Exercise Equipment**

- Available equipment that will allow the crew to perform current exercise prescriptions.

**HRP Constraints/Implied Requirements**

- During Mars atmosphere entry (5-g), crew will be in a recumbent position until landing operations are complete. The vehicle design will not require the crew to be in an upright standing posture during entry.
- Countermeasures that support the Orthostatic Intolerance (OI) will be provided in support to any OI related events (e.g., Mars atmosphere entry).
- Adequate vehicle or habitat shielding, dosimetry, and operational procedures in place to prevent exposures above 30-day permissible dose limits.
- It is assumed that the Mars DRM will follow Level of Care Five standards in NASA-STD-3001 Vol. 1 for crewmember training and caliber: "The training and caliber of the caregiver shall be at the physician level, due to the exclusively autonomous nature of the mission."

**Pre/Post Mission Assumptions**

- TBD post-flight Baseline Data Collection will still be required, but protocols will need to consider degree of crew de-conditioning after a 3-yr mission.

## **APPENDIX C – HUMAN RISK DISPOSITIONS FOR ALL DRMS**

Each risk is to be reviewed annually by the HSRB and a determination made of the risk posture for each DRM category. This posture is reached after discussion about the likelihood and consequence mapping on the LxC tables of the Risk Summaries and is communicated via the Risk Disposition and Risk Disposition Rationale fields. The assessment considers if a risk can be accepted as is or if further mitigation effort is warranted (see JSC 66705, paragraphs 3.4.1 through 3.4.5).

The following chart summarizes and depicts the risk dispositions for the complement of HSRB risks that are worked by HRP. The disposition for each risk is given by operations or long term health consequence, and by DRM category. A disposition of “A” means an “Accepted” risk posture. A disposition of “RM” means a “Requires Mitigation” risk posture.

Concerns are not included on this chart. Since concerns do not yet have a likelihood or consequence assessed, their placement on a risk matrix to identify relative severity (red, yellow, green) is not possible.

## HSRB Risk Dispositions\* for all DRMs

Human Spaceflight Risks	In Mission Risk - Operations						Post Mission Risk – Long Term Health					
	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/Habitation	Deep Space Journey/Habitation	Planetary	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/Habitation	Deep Space Journey/Habitation	Planetary
	6 Months	12 Months	30 Days	1 Year	1 Year	3 Years	6 Months	12 Months	30 Days	1 Year	1 Year	3 Years
VIIP	A	A	A	A	RM	RM	A	A	A	A	RM	RM
Renal Stone Formation	A	A	A	A	RM	RM	RM	RM	RM	RM	RM	RM
Inadequate Food and Nutrition	A	A	A	A	A	RM	A	A	A	A	A	RM
Risk of Space Radiation Exposure	A	A	A	A	A	A	A	A	A	RM	RM	RM
Medications Long Term Storage	A	A	A	A	A	RM	A	A	A	A	A	RM
Inflight Medical Conditions	A	A	A	RM	RM	RM	A	A	A	RM	RM	RM
Cognitive or Behavioral Conditions	A	RM	A	RM	RM	RM	A	A	A	A	A	RM
Risk of Bone Fracture	A	A	A	A	A	RM	A	A	A	A	A	A
Human-System Interaction Design	A	A	A	RM	RM	RM	A	A	A	A	A	A
Team Performance Decrement	A	A	A	A	RM	RM	A	A	A	A	A	A
Reduced Muscle Mass, Strength	A	A	A	A	A	RM	A	A	A	A	A	RM
Reduced Aerobic Capacity	A	A	A	A	A	RM	A	A	A	A	A	RM
Sensorimotor Alterations	A	A	A	RM	RM	RM	A	A	A	A	A	RM
Injury from Dynamic Loads	A	A	RM	RM	RM	RM	A	A	RM	RM	RM	RM
Sleep Loss	A	A	A	A	RM	RM	A	A	A	A	RM	RM
Altered Immune Response	A	A	A	A	A	RM	A	A	A	A	A	RM
Celestial Dust Exposure	N/A	N/A	TBD	A	TBD	TBD	N/A	N/A	TBD	A	TBD	TBD
Host-Microorganism Interactions	A	A	A	A	A	RM	A	A	A	A	A	RM
Injury Due to EVA Operations	A	A	A	RM	A	RM	A	A	A	RM	RM	RM
Decompression Sickness	A	A	RM	A	RM	A	A	A	A	RM	A	RM
Hypobaric Hypoxia	RM	RM	A	RM	RM	RM	RM	RM	A	RM	RM	RM
Orthostatic Intolerance	A	A	A	A	A	A	A	A	A	A	A	A
Cardiac Rhythm Problems	A	A	A	A	RM	RM	A	A	A	A	A	A

A – Accepted RM- Requires Mitigation

Green – low/very low consequence

Yellow – low to medium consequence

Red – high consequence

\* The LxC colors are per the HSRB risk records as of February 2015. Most risk dispositions are from the risk records, but a subset were determined outside of the HSRB risk process in JSC 66705 since the process itself underwent evolution during use. This information will be updated as applicable.