

Human Research Program Requirements Document

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National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

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

Human Research Program Requirements Document

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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 (HH&P). Agency HH&P standards will define acceptable risks for each Design Reference Mission (DRM) category as defined by the Human System Risk Board (HSRB). 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 HH&P 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 Program Elements:

1. Exploration Medical Capability (ExMC),
2. Human Factors and Behavioral Performance (HFBP),
3. Human Health Countermeasures (HHC),
4. ISS Medical Projects (ISSMP), and
5. Space Radiation (SR).

The requirements are subdivided into the following three categories:

1. Human system standards (section 4),

2. Human health and performance risks (section 5), and
3. 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 the DRM categories to frame the research required for each of the HH&P 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 RESPONSIBILITY AND CHANGE AUTHORITY

This document is under Configuration Management (CM) control of the HRPCB. Changes to this document will result in the issuance of Page Change Notices (PCN) or a full re-issue of the document using the Change Request (CR) process. 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

Document No.	Document Title
NASA-STD-3001 Vol. 1, Rev A	NASA Space Flight Human System Standard Volume 1, Revision A: Crew Health
NASA-STD-3001 Vol. 2, Rev A	NASA Space Flight Human System Standard Volume 2: Human Factors, Habitability and Environmental Health
NPD 1001.0B	2014 NASA Strategic Plan
HRP-XPCA	HEOMD Program Commitment Agreement (PCA) with HRP
HRP-47051B	Human Research Program – Program Plan (Revision B-PCN1)
NPR 7120.5E	NASA Space Flight Program and Project Management Requirements w/Changes 1-15
NPD 1000.0B	NASA Governance and Strategic Management Handbook
NPD 8500.1C	NASA Environmental Management
NPD 8910.1B	Care and Use of Animals (Revalidated 6/25/13)
NPR 1080.1A	Requirements for the Conduct of NASA Research & Technology (R&T)
NPR 2190.1B	NASA Export Control Program
NPR 2810.1A	Security of Information Technology (Revalidated with Change 1, dated May 19, 2011)
NPR 5810.1	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	Protection of Human Research Subjects (Revalidated 6/26/14)
NPR 7120.8	NASA Research and Technology Program and Project Management Requirements (w/Change 4 dated 01/04/17)
NID 8000.108	Agency Risk Management Procedural Requirements
NPR 7123.1B	NASA Systems Engineering Processes and Requirements
JSC 66705	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

Document No.	Document Title
HRP-47053	Human Research Program Science Management Plan (Revision E PCN-1)
HRP-47065	Human Research Program Integrated Research Plan (Revision H PCN-3) (electronically available at: http://humanresearchroadmap.nasa.gov/)
JSC-28330	Human Health and Performance Directorate Configuration Management Plan (Revision F)
N/A	HRP Risk Evidence Reports electronically available at: http://humanresearchroadmap.nasa.gov/evidence/
NPD 1000.3E	The NASA Organization w/Change 15
NPD 7100.8E	Protection of Human Research Subjects (Revalidated with admin. changes 12/18/2012)
HRP-47069D	Human Research Program Unique Processes, Criteria, and Guidelines (Revision D PCN-2)
S.1281	National Aeronautics and Space Administration (NASA) Authorization Act of 2005
NASA/SP-2010-3407	Human Integration Design Handbook
N/A	NASA Institutional Review Board Website - http://irb.nasa.gov/

3 HRP GOAL AND OBJECTIVES

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 GOAL

The goal of the HRP is to provide HH&P countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration.

3.2 OBJECTIVES

The specific objectives of the HRP are:

- 3.2.1 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.
- 3.2.2 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.
- 3.2.3 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 NASA'S HEALTH, MEDICAL, HUMAN PERFORMANCE, AND ENVIRONMENTAL STANDARDS

The 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: Spaceflight human system standards are designed to address acceptable levels of HH&P 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. The standards sets are listed below.

1. Fitness-for-duty standards for maintaining the physiological and behavioral parameters necessary to perform the required tasks;
2. Permissible outcome limits for the changes in health outcomes that are potentially affected by long-term exposure to the space environment;
3. Permissible exposure limits for managing risks by controlling human exposure;
4. Levels of care standards for guiding medical capabilities needed to respond to a medical contingency during exploration missions; and
5. 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 the following:

- 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 HFBP shall perform the research necessary to enable the development and modification of the HFBP 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 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 HH&P RISKS AND CONCERNS

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 HH&P risks managed by the HSRB as described in the JSC-66705, Human System Risk Management Plan. 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:



Figure 1: HRP Management Architecture

Evidence forms the basis for the existence of a risk to the human system. The individual risk research plans, which 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 – preventive 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 Risk Summaries in the risk records maintained by the HSRB.

The process for changing HH&P 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 HH&P risks and concerns and applicable HRP Element assignments are listed in Tables 3 and 4. Tables 3 and 4 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. (Short Title) 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 Addressed by HRP

	HRP Element	Title
1	HHC	Risk of Orthostatic Intolerance During Re-Exposure to Gravity (Short Title: OI) OI Link to HRR
2	HHC	Risk of Injury and Compromised Performance Due to EVA Operations (Short Title: EVA) EVA Link to HRR
3	HHC	Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance (Short Title: Muscle) Muscle Link to HRR
4	HHC	Risk of Cardiac Rhythm Problems (Short Title: Arrhythmia) Arrhythmia Link to HRR
5	HHC	Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity (Short Title: Aerobic) Aerobic Link to HRR
6	HHC	Risk of Adverse Health Event Due to Altered Immune Response (Short Title: Immune) Immune Link to HRR
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) Sensorimotor Link to HRR
8	HHC	Risk of Spaceflight-Induced Intracranial Hypertension/Vision Alterations (Short Title: VIIP) VIIP Link to HRR
9	HHC	Risk of Decompression Sickness (Short Title: DCS) DCS Link to HRR
10	HHC	Risk of Reduced Crew Health and Performance Due to Hypobaric Hypoxia (Short Title: Exploration Atmosphere) Exploration Atmosphere Link to HRR <i>(To be added once developed)</i>
11	HHC	Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition (Short Title: Food & Nutrition) Food Link to HRR , Nutrition Link to HRR
12	HHC	Risk of Adverse Health Effects Due to Host-Microorganism Interactions (Short Title: Microhost) Microhost Link to HRR
13	ExMC	Risk of Adverse Health and Performance Effects of Celestial Dust Exposure (Short Title: Dust) Dust Link to HRR
14	ExMC	Risk of Adverse Health Outcomes and Decrements in Performance Due to In-flight Medical Conditions (Short Title: ExMC) ExMC Link to HRR
15	ExMC	Risk of Renal Stone Formation (Short Title: Renal) Renal Link to HRR
16	ExMC & HHC	Risk of Bone Fracture Due to Spaceflight Induced Changes to Bone (Short Title: Fracture) Fracture Link to HRR , Osteo Link to HRR
17	ExMC	Risk of Ineffective or Toxic Medications Due to Long Term Storage (Short Title: Stability) Stability Link to HRR
18	HFBP	Risk of Reduced Crew Performance and of Injury Due to Inadequate Human-System Interaction Design (Short Title: HSID) Hab Link to HRR , MPTask Link to HRR , HARI Link to HRR , HCI Link to HRR , Train Link to HRR

	HRP Element	Title
19	HFBP	Risk of Injury from Dynamic Loads (Short Title: Occupant Protection) Occupant Protection Link to HRR
20	HFBP	Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (Short Title: BMed) BMed Link to HRR
21	HFBP	Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload (Short Title: Sleep) Sleep Link to HRR
22	HFBP	Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (Short Title: Team) Team Link to HRR
23	SR	Risk of Adverse Health Outcomes and Performance Decrements Resulting from Space Radiation Exposure (Short Title: Radiation) CNS Link to HRR , ARS Link to HRR , Degen Link to HRR , Cancer Link to HRR

Table 4 – Human System Health and Performance Concerns Addressed by HRP

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

5.1 RISK ASSESSMENT METHODS

The HRP shall use qualitative and quantitative methods to assess the HH&P 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 is captured in the HSRB Risk Summaries.

- 5.1.1 The HFBP shall qualitatively or quantitatively assess the HFBP-applicable risks identified in Table 3.
- 5.1.2 The ExMC shall qualitatively or quantitatively assess the ExMC-applicable risks identified in Table 3.
- 5.1.3 The HHC shall qualitatively or quantitatively assess the HHC-applicable risks identified in Table 3.
- 5.1.4 The SR shall qualitatively or quantitatively assess the SR-applicable risks identified in Table 3.

5.2 HRP PROGRAM SCIENCE MANAGEMENT OFFICE (PSMO) SUPPORT

The HRP Program Science Management Office (PSMO) shall develop ways to improve the approaches for assessing the integration of HH&P 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.

5.3 COUNTERMEASURE AND TECHNOLOGY DEVELOPMENT

The HRP Elements shall develop countermeasures and technologies, or inform mission and vehicle requirements, to prevent or mitigate HH&P 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 that supports 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” or both.

- 5.3.1 The HFBP shall develop countermeasures and technologies, or provide research evidence to inform mission and vehicle requirements, to prevent or mitigate adverse outcomes of HFBP-applicable risks identified in Table 3.
- 5.3.2 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.
- 5.3.3 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.
- 5.3.4 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.

5.4 DEVELOPMENT OF METHODS AND TECHNOLOGIES TO MONITOR AND TREAT

The HRP Elements shall develop methods and technologies to monitor and treat adverse outcomes of HH&P 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.

- 5.4.1 The HFBP shall develop methods and technologies to monitor and treat adverse outcomes of HFBP-applicable risks identified in Table 3.
- 5.4.2 The ExMC shall develop methods and technologies to monitor and treat adverse outcomes of ExMC-applicable risks identified in Table 3.
- 5.4.3 The HHC shall develop methods and technologies to monitor and treat adverse outcomes of HHC-applicable risks identified in Table 3.
- 5.4.4 The SR shall develop methods and technologies to monitor indicators of adverse outcomes of SR-applicable risks identified in Table 3.

5.5 PROVISION OF SUPPORTING EVIDENCE

The HRP Elements shall provide evidence to support a determination of status for a concern.

Rationale: Elements provide evidence to the HSRB to help determine 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.

- 5.5.1 The HFBP shall provide evidence to support determination of status for HFBP-applicable concerns identified in Table 4.
- 5.5.2 The ExMC shall provide evidence to support determination of status for ExMC-applicable concerns identified in Table 4.
- 5.5.3 The HHC shall provide evidence to support determination of status for HHC-applicable concerns identified in Table 4.
- 5.5.4 The SR shall provide evidence to support determination of status for SR-applicable concerns identified in Table 4.

6 HRP REQUIREMENTS RELATED TO ENABLING CAPABILITIES

6.1 PROVISION OF ENABLING CAPABILITIES

The HRP shall provide enabling capabilities 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 HH&P.

- 6.1.1 The ISSMP shall integrate and plan for the execution of HRP research tasks requiring access to space or flight analog environments.

Rationale: Access to space research platforms (i.e. 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 and 5. The ISSMP serves as the service and interface to integrate across all HRP Elements, and optimize the research plans requiring analog access. The ISSMP ensures that data generated are returned to the investigator.

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.

- 6.1.2 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 PRESERVATION AND MAINTENANCE OF CORE TECHNICAL CAPABILITIES AND EXPERTISE

The HRP shall ensure preservation and maintenance of core technical capabilities 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 to humans due to spaceflight. This requirement involves sustaining and maintaining a dedicated scientific and management workforce, publicly documenting the evidence and a robust external scientific community to provide stability over the multi-decadal implementation of the vision for space exploration. The core competencies are necessary to facilitate the following:

Strategic planning. The identification and prioritization of the risks to the human system and development and execution of long-range research plans to quantify, prevent, and mitigate risks, and treat adverse outcomes requires competency of both the internal and external research communities to ensure proper and focused direction.

Acquisition development, planning, and execution. Acquisition of research and technology development 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 HRP community as much 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 capabilities of the Program Elements and adjust where appropriate.

6.3 COMPLIANCE WITH APPLICABLE DOCUMENTS

The HRP Elements 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 or NPD applicability falls upon each individual Element and 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 OPTIMIZATION OF METHODS AND TECHNOLOGIES

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 HFBP 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 ExMC shall develop methods and technologies to reduce human systems resource requirements (mass, volume, power, crew time, etc.).

APPENDIX A: ACRONYMS AND ABBREVIATIONS

AM	Ascent Module
ARS	Acute Radiation Sickness
Bmed	Behavioral Conditions & Psychiatric Disorders
CM	Crew Module, Configuration Management
CNS	Central Nervous System
CR	Change Request
DCS	Decompression Sickness
Degen	Degenerative
DM	Descent Module
DRM	Design Reference Mission
DSH	Deep Space Habitat
e.g.	For Example
EDL	Entry, Descent, and Landing
ESD	Exploration Systems Development
EVA	Extravehicular Activity
ExMC	Exploration Medical Capability
g	Gravity
Hab	Habitat
HARI	Human & Automation/Robotic Integration
HCI	Human-Computer Interaction
HEOMD	Human Exploration and Operations Mission Directorate
HFBP	Human Factors and Behavioral Performance
HH&P	Human Health & Performance
HHC	Human Health Countermeasures
HMTA	Health & Medical Technical Authority
HRP	Human Research Program
HRPCB	Human Research Program Control Board
HRR	Human Research Roadmap
HSRB	Human System Risk Board
iMED	Integrated Medical Evidence Database
IMM	Integrated Medical Model
IRP	Integrated Research Plan
ISS	International Space Station
ISSMP	ISS Medical Projects
IVD	Intervertebral Disc
JSC	Johnson Space Center
L1	First Lagrangian Point
L2	Second Lagrangian Point
LAS	Launch Abort System
LEO	Low Earth Orbit
LSDA	Life Sciences Data Archive
MCC	Mission Control Center
Microhost	Host-Microorganism
MPCV	Multi-Purpose Crew Vehicle
MPTASK	Mission, Process, and Task

N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NEA	Near-Earth Asteroid
NPD	NASA Procedural Directive
NPR	NASA Procedural Requirements
OCHMO	Office of the Chief Health and Medical Office
OI	Orthostatic Intolerance
Osteo	Osteoporosis
PCA	Program Commitment Agreement
PCN	Page Change Notice
PD	Pharmacodynamics
PEL	Permissible Exposure Limit
PK	Pharmacokinetics
PPBE	Planning, Programming, Budgeting, and Execution
PRD	Program Requirements Document
PSMO	Program Science Management Office
Rev.	Revision
R&T	Research and Technology
REM	Robotics and EVA Module
SA	Spacecraft Adaptor
SEV	Space Exploration Vehicle
SL	Suit Lock/Suit Port
SLSD	Space Life Sciences Directorate
SM	Service Module
SR	Space Radiation
STD	Standards
TBD	To Be Determined
TEI	Trans-Earth Insertion
U.S.	United States
UPCG	Unique Processes, Criteria, and Guidelines
VIIP	Visual Impairment/Intracranial Pressure
Vol.	Volume

APPENDIX B: DRM DESCRIPTIONS AND ASSUMPTIONS

The HSRB identifies several DRM categories against which HH&P 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: JSC 66705, Human System Risk Management Plan

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 HH&P 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

- 1/6th 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

- 3/8th 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 all the human system risks in the HSRB risk portfolio, a subset of which is worked by HRP. The disposition for each risk is given by operations or long term health consequence, and by DRM category.

Green – low/very low consequence Yellow – low to medium consequence Red – high consequence *The LxC colors are per the HSRB baseline March 2017.*

Human Spaceflight Risks	In-Flight Operations						Long-term Health					
	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation
	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years
<u>VIIP</u>	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
<u>Renal Stone Formation</u>	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
<u>Inflight Medical Conditions</u>	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation
<u>Cardiac Rhythm Problems</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
<u>Acute and Chronic CO₂</u>	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
<u>Cognitive or Behavioral Conditions</u>	Accepted with Monitoring	Requires Mitigation	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation
<u>Space Radiation Exposure</u>	Accepted	Accepted	Accepted	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with PELs	Accepted with PELs	Accepted with PELs	Requires Mitigation	Requires Mitigation	Requires Mitigation
<u>Inadequate Food and Nutrition</u>	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Requires Mitigation
<u>Medications Long Term Storage</u>	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
<u>Bone Fracture</u>	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize
<u>EVA Operations</u>	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation
<u>Psychosocial Adaptation within a Team</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring
<u>Inadequate Human-System Interaction Design</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Standard Refinement, May Require Mitigation	Standard Refinement, May Require Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
<u>Injury from Dynamic Loads</u>	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Requires Mitigation
<u>Hypobaric Hypoxia</u>	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with Monitoring	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data
<u>Sleep Loss</u>	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
<u>Toxic Exposure</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring	Accepted with Monitoring
<u>Altered Immune Response</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
<u>Host-Microorganism Interactions</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
<u>Reduced Aerobic Capacity</u>	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
<u>Reduced Muscle Mass, Strength</u>	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
<u>Sensorimotor Alterations</u>	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Standard Refinement	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
<u>Electrical Shock</u>	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired
<u>Hearing Loss Related to Spaceflight</u>	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
<u>Injury from Sunlight Exposure</u>	Accepted / Low Probability	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
<u>Urinary Retention</u>	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
<u>Back Pain</u>	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	N/A	N/A	N/A	N/A	N/A	N/A
<u>Decompression Sickness</u>	Accepted	Accepted	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
<u>Celestial Dust Exposure</u>	N/A	N/A	TBD	Accepted	TBD	TBD	N/A	N/A	TBD	Accepted	TBD	TBD
<u>Orthostatic Intolerance</u>	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
<u>Intervertebral Disc Damage</u>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
<u>Unpredicted Effects of Medication</u>	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A