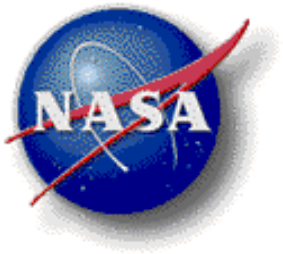
Human Health Countermeasures (HHC) Element Management Plan

Human Research Program

Rev B



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Verify this is the correct version before use.

Element Plan

Human Health Countermeasures (HHC) Program Element

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REVISION AND HISTORY PAGE

REV.	DESCRIPTION	PUB. DATE
Baseline	Initial Release (Reference per SLSDCR-HRPCB-09-002, EFF. 5-13-09) approved by the HRPCB	4/09
Rev A	Approved through HHC CB, but not HRPCB	
Rev B	Reflects new HHC organization. Removed references to the Constellation and Shuttle Programs. Changed references from ESMD and SOMD to HEOMD. Eliminates the HHC Element Requirements Document and the project plans for ECP and NxPCM. The FAP is removed from the HHC. Added Appendix D to baseline Risks and Gaps as Element requirements.	

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ELEMENT PLAN – HUMAN HEALTH COUNTERMEASURES

PART I: ELEMENT OVERVIEW

1.0 Introduction

NASA's Human Research Program (HRP) is an applied research and technology program within the Human Exploration and Operations Mission Directorate (HEOMD) that addresses human health and performance risk mitigation strategies in support of exploration missions. The HRP research and technology development is focused on the highest priority risks to crew health and safety with the goal of ensuring mission success and maintaining long-term crew health.

Crew health and performance standards, defined by the NASA Chief Health and Medical Officer (CHMO), set the acceptable risk level for exploration missions. The HRP conducts research to inform these standards as well as provide deliverables, such as countermeasures, that ensure standards can be met to maximize human performance and mission success.

The Human Health Countermeasures (HHC) Element was formed as part of the HRP to develop a scientifically-based, integrated approach to understanding and mitigating the health risks associated with human spaceflight. These health risks have been organized into four research portfolios that group similar or related risks. A fifth portfolio exists for managing technology developments and infrastructure projects. The HHC Element portfolios consist of:

- Vision and Cardiovascular
- Exercise and Performance
- Multisystem
- Bone
- Technology and Infrastructure

The HHC identifies gaps associated with the health risks and plans human physiology research that will result in knowledge required to more fully understand risks and will result in validated countermeasures to mitigate risks.

The Flight Analogs Project (FAP) will be moving out of the HHC beginning in FY13. The Bed Rest Standard Measures funding and oversight will remain with the HHC in the Technology and Infrastructure Portfolio. For FY12, the entire FAP will remain part of HHC and be managed as a part of the Technology and Infrastructure Portfolio. The current FAP project plan will remain in effect through FY12.

A separate project plan will be developed for the Digital Astronaut Project (DAP). Through computational simulation, the DAP provides human modeling services to the HHC research portfolios to assist in closing the HRP risks and gaps.

1.1 Purpose

The purpose of this Element Plan is to establish HHC objectives, management approach, roles and responsibilities, organization, and the relationships that are necessary to achieve the Element goals within the scope of the HRP Program Plan (HRP-47051). This Element Plan

complies with the requirements of NPR 7120.8 – NASA Research and Technology Program and Project Management. Changes to this Plan will be controlled by the HRP Control Board (HRPCB).

1.2 Objectives

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 research that HHC performs facilitates the HRP in either eliminating human health and performance risks and knowledge gaps, or confirming and guiding plans for the resolution of the risks and/or gaps.

The HHC objectives are a direct flow-down from program requirements in the HRP Program Requirements Document (PRD) (HRP-47052, Rev. E). These objectives may be grouped under three goals:

- Develop countermeasures and technologies to mitigate validated physiologic risks
- Develop technologies to reduce human system resource requirements
- Maintain Agency core competencies

Goal 1: Develop capabilities, necessary countermeasures, and technologies, focusing on mitigating the highest risks associated with human spaceflight for the various exploration missions.

Trace: HRP PP (HRP-47051) Section 1.2.1

Objective 2.1: Quantify the human health and performance risks associated with human spaceflight for exploration missions.
Trace: HRP PRD (HRP-47052) Section 5.1

Objective 2.2: Develop countermeasures and technologies to prevent or mitigate adverse outcomes of human health and performance risks.
Trace: HRP PRD (HRP-47052) Section 5.2

Objective 2.3: Develop countermeasures and technologies to monitor and treat adverse outcomes of human health and performance risks.
Trace: HRP PRD (HRP-47052) Section 5.3

Goal 2: Develop technologies that serve to reduce medical risks, to reduce human systems resource requirements, and to ensure effective human system integration.

Trace: HRP PP (HRP-47051) Section1. 2.1

Objective 3.1: Develop technologies to reduce human systems resource requirements (mass, volume, power, data, etc.)
Trace: HRP PRD (HRP-47052) Section 6.4

Goal 3: Maintain NASA's core competency in space life sciences.

Trace: HRP PP (HRP-47051) Section 1.2.1

Objective 4.1: Ensure processes and products comply with the NASA policy directives and NASA procedural requirements.
Trace: HRP PRD (HRP-47052) Section 6.3

Successful achievement of Element objectives will be determined through annual review by the HHC Standing Review Panels (SRPs) based upon: definition and clarity of requirements identified, implementation plan and review processes, maturity of deliverables, validation and operational availability of deliverables for implementation, transition of end-item program Element deliverables to customer programs, mitigation of physiologic risks, retirement of risks/gaps, and potential generation of new risks/gaps.

Specific deliverables resulting from these Element objectives will enhance the understanding of physiologic needs, improve availability of effective countermeasures for selection, and make available innovative technologies for diagnosis and intervention in space.

1.3 Mission Description

The HRP was formed to manage research investments focused on investigating and mitigating the highest risks to astronaut health and performance in support of exploration missions (HRP-47051). The HRP provides deliverables that specifically support NASA's exploration architecture. The HHC Element maintains an active engagement with the organizations developing concepts for mission architectures. The HHC studies the design reference missions (DRMs) that provide a framework to identify key capabilities and important guiding drivers and assumptions, thus enabling the HHC to focus research questions on topics highly relevant to NASA's future activities.

1.4 Customer and Stakeholder Definition and Advocacy

The HHC supports HEOMD efforts in executing exploration missions.

The HHC generates outcomes and products for the following primary customers as part of the HRP. These are: (1) Human Exploration and Operations Mission Directorate (HEOMD), (2) Office of Chief Health and Medical Officer (OCHMO) and its assigned Health and Medical Technical Authority (HMTA) and (3) exploration and vehicle development projects.

The major stakeholders of HHC products are the HRP, Chief Health and Medical Officer, flight surgeons, the ISS Program, the Astronaut Office, Flight Control Teams, and spacecraft development project offices. Other stakeholders include: the NASA Science Mission Directorate, the JSC Space Life Sciences Directorate (SLSD), the Human Adaptation & Countermeasures Division (HACD), the Habitability & Environment Factors Division (HEFD), the Space Medicine Division (SMD), the National Space Biomedical Research Institute (NSBRI), and the external research and technology (R&T) community.

1.5 Element Authority

The HRP is divided into 6 major Elements identified in Figure 1-1. An Element consists of the aggregation of related portfolios and research tasks focused toward developing products that reduce risks to the crew. The HHC is divided into four research portfolios as identified in Section 1.6.1. Each portfolio is characterized as an integrated set of tasks designed to deliver a product or set of products to a designated customer on a specified date.

The HRP Program Plan delegates management of the HHC to the Johnson Space Center (JSC). The HHC management team organizationally resides within the SLSD at the JSC. Overall

management of the HHC is assigned to an Element Manager (EM) within the HACD of the SLSD at the JSC.

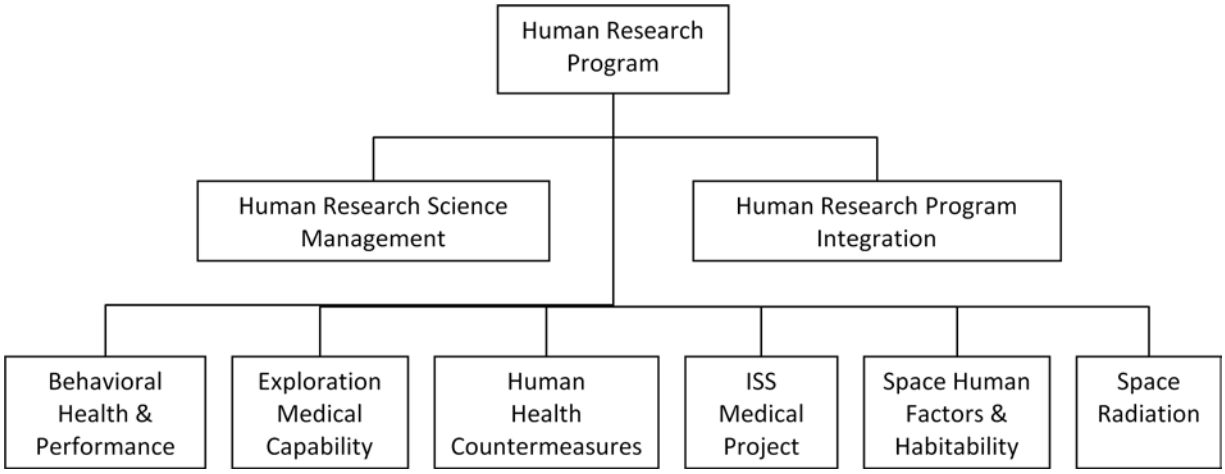

Figure 1-1: Human Research Program structure.

As described in the HRP Program Plan, overall responsibility for the HRP lies with the Program Manager and Deputy Program Manager. The HRP has funding authority for the HHC, approves the Element Management Plan, and has final approval of delivered products.

The HRP Program Plan authorizes the Element Manager (EM) and Element Scientist (ES) to execute the Element according to the procedures and policies of the Agency, HEOMD, HRP, JSC, and the respective Field Centers. The HHC develops and maintains inter-Center agreements, coordinates all R&T tasks, maintains performance metrics and schedules, and supports the HRP in the development of future strategic direction. The EM and ES have full authority to make and implement decisions that meet scientific objectives of the Element, are within assigned resources, do not have a direct impact on control milestones, nor impact resources, schedule, or objectives of another Element. If any of these criteria cannot be met, then the decision must be elevated to the next higher level of authority.

1.6 Management

To ensure the HRP deliverables can be ready in time to support NASA's exploration mission needs, the HRP applies project management principles to the management of all HRP activities. The EM is responsible for overall performance of the Element as well as performing the tasks necessary to enable research tasks within the Element. The ES is responsible for the scientific content and direction within the Element. The ES will provide recommendations to the HRP regarding selection of NASA Research Announcement (NRA) awards and performance of research studies that meet the HRP requirements and address Agency needs, goals, and objectives. Integration within the HHC is the responsibility of the EM and ES. The EM and ES work as a team to manage all of the various activities in an effective manner. The ES provides recommendations to the EM regarding selection and performance of research studies that meet the HRP requirements and address Agency needs, goals and objectives.

Integration across the Elements is the responsibility of the Program Manager and Chief

Scientist, and they are supported by Element coordination. Integration within an Element is the responsibility of the EM and ES. For example, the HHC's EM and ES integrate research and products across various HHC portfolios to deliver an integrated set of deliverables focused on risk management and countermeasure development.

1.6.1 Structure

The Element management structure provides a single focal point to develop a scientifically-based integrated approach to understanding, projecting, and mitigating the crew health risks associated with spaceflight. This provides an environment wherein research efforts can be properly planned, conducted, and maintained. Oversight of the HHC is the responsibility of the HRP. The HHC, as a multi-portfolio Element, identifies issues that span across portfolios and divisions to enhance shared capabilities and prevent duplication of efforts. The organizational structure of the HHC can be found in Figure 1-2.

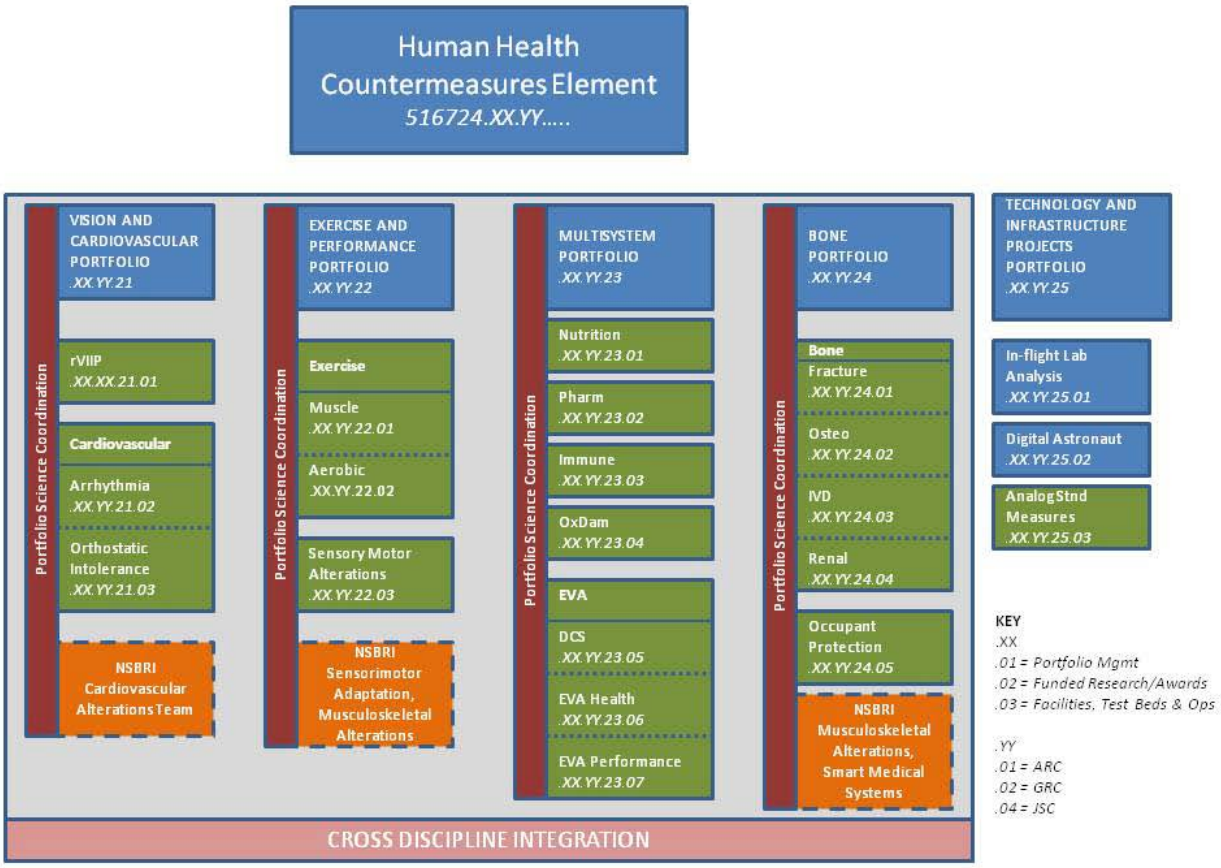

Figure 1-2: HHC Program Element Structure.

Acronyms used on chart:

rVIIP	*research Visual Impairment and Intracranial Pressure*
NSBRI	*National Science Biomedical Research Institute*
OxDam	*Oxidative Stress and Damage*
EVA	*Extravehicular Activity*
DCS	*Decompression Sickness*

Osteo	*Osteoperosis*
IVD	*Intervertebral Disc Damage*
Renal	*Renal Stone*

1.6.2 Roles and Responsibilities

The HRP management team provides oversight of the execution of the Element, reviews the Element with the EM/ES team at least once each quarter, reviews interim deliverables, and provides guidance about the deliverables, resolves issues between the EM and the ES, resolves intra-HRP Element conflicts, overlaps and gaps, identifies opportunities for intra-HRP collaborations, cost or risk mitigations, and other strategies to improve performance and HRP success.

The HHC management team provides oversight of the execution of the portfolios within HHC; reviews the portfolios with the Portfolio Manager and Lead Scientists team at least once each quarter; reviews interim deliverables and provides guidance about the deliverables; resolves issues between the Portfolio Manager and Lead Scientists; resolves intra-HHC conflicts, overlaps and gaps; and identifies opportunities for intra-HHC collaborations, cost or risk mitigations, and other strategies to improve performance and HHC success.

The Portfolio management teams provide oversight to tasks assigned to their portfolio.

The roles and responsibilities for the HHC management team and key Program Element organizational interfaces are summarized below.

1.6.2.1 HHC Element Management Team [top blue box on Figure 1-2]

The HHC structure relies on a management team consisting of the EM, Deputy EM, ES and Deputy ES. The HHC management team ensures all technical requirements are met as well as all JSC Division, Directorate, and Center management requirements. The HHC uses common approaches, tools, and procedures for managing the Program Element.

1.6.2.1.1 HHC Element Manager (EM)

The EM is responsible for the day-to-day management of the Program Element, including budget management, reporting, schedules, and logistics.

The EM reports to the HRP Program Manager and ensures that Program Element decisions are made in a timely manner with the consensus of the entire management team. The EM follows established principles, best practices and guidelines in Project Management, and is authorized to work with the ES to:

- Form the Element team
- Plan the Element
- Establish subordinate Element structure and work with line management to provide managers and personnel
- Allocate requirements and resources to projects/portfolios
- Integrate cost and schedule across subordinate organization
- Develop and maintain a comprehensive schedule and a cost estimate
- Follow established change management processes
- Identify, assess, track and mitigate risks

- Implement/execute the Element per approved Element Plan
- Serve as the Element's official interface with the HRP
- Report Element progress and status to the HRP, HACD, and branch management
- Develop Customer-Supplier Agreements (CSAs)

The Deputy EM supports the EM and represents the Element in the event the EM is not available. The EM relies heavily on the expertise of the rest of the Element management team, consisting of the ES and Deputy ES.

1.6.2.1.2 HHC Element Scientist (ES)

The ES reports to the HRP Chief Scientist. The ES is a key member of the Element leadership and management team, and is responsible for the technical content and direction of the HHC. The ES ensures that decisions of the Element Management team and staff are scientifically well informed. The ES is responsible for ensuring that the scientific requirements are met with results reported in a timely manner. If sufficient budget is not available to implement all requirements, the ES will coordinate with the HHC management team to prioritize the research. The ES will follow the established principles, best practices and guidelines in scientific research, and is authorized to work with the EM to:

- Provide the strategic direction for Element and support Element planning
- Develop a comprehensive research plan and schedule of planned science to meet exploration milestones
- Allocate requirements and research plans to subordinate portfolios
- Integrate technical plans and progress across subordinate portfolios
- Follow established scientific research processes
- Facilitate clear and accurate communications on matters related to the science objectives of the Element, and lead analysis of scientific and developmental requirements, priorities, impacts and tradeoffs
- Provide technical direction to the HHC Lead scientists
- Facilitate technical discussions with the NSBRI, external principal investigators, and Lead scientists to address the HHC actions, objectives, and deliverables
- Serve as a liaison to concurrent Element teams
- Act as point of contact for technical information about the HHC
- Coordinate HHC inputs to and selection recommendations for the annual NRA
- Report Element science progress and status to the HACD and branch management as appropriate

There may be more than one Deputy ES assigned to this Element; the Deputy ES supports the ES, and represents the Element in the event the ES is not available.

1.6.2.1.3 HHC Portfolio Managers (PM) [2nd level blue boxes on Figure 1-2]

The Portfolio Managers (PM) report to the HHC Element Manager and ensures that portfolio decisions are made in a timely manner with the consensus of the relevant Lead Scientist(s). The PM follows established principles, best practices, and guidelines in Project Management, and is authorized to work with the Lead Scientists to:

- Manage each risk or group of risks as a project

- Provide project management support to the Element (e.g., integrated master schedule [IMS] updates, technical cost and schedule reviews [TCSRs], planning, programming, budgeting, and execution [PPBE] packages)
- With the HHC budget analyst team, actively manage grants to reduce cost carryout
- With the HHC budget analyst team, control portfolio budget (identification of threats, liens and opportunities)
- Integrate NSBRI tasks into portfolio for reporting (IMS, Integrated Research Plan [IRP], deliverables)

1.6.2.1.4 HHC Lead Scientists (LS) [Green boxes on Figure 1-2]

The Lead Scientists (LSs) report to the HHC ES. There are a number of LSs in each portfolio and each LS is a key members of the portfolio management team, and is responsible for the technical content and direction of research plans associated with their assigned risks. The LSs ensure that the objectives, requirements, and assumptions for the assigned risks and mitigations are clearly identified, communicated, documented, and controlled, and that the decisions of the Portfolio Manager are scientifically well informed. If sufficient budget is not available to implement all requirements, the LSs will coordinate with the portfolio and HHC management team to prioritize the research. The LSs will follow the established principles, best practices, and guidelines in scientific research, and are authorized to work with the Portfolio Manager to act as Project Scientists for their risks. The LSs responsibilities are:

- Provide horizontal integration across portfolios working with other LSs
- Be responsible for definition and mitigation of assigned risk
- Update research plan with closable gaps
- Be knowledgeable about and advocate for current tasks (including the NSBRI)
- Identify the necessary tasks for closing or reducing gaps
- Lead for the associated Discipline Integrated Product Team
- Develop metrics for tracking gaps
- Provide updates to the Evidence Book and the Risk Management Assessment Tool
- Provide SRP presentations and responses to recommendations
- Integrate accepted SRP recommendations into the IRP
- Prepare content for Program Reviews
- Plan for the yearly HRP's Investigators' Working Group [IWG] meeting
- Identify inter-risk gaps and tasks

1.6.2.1.5 Portfolio Science Coordinators (PSCs) [Maroon boxes on Figure 1-2]

The Portfolio Science Coordinators (PSCs) provide project science support to the portfolios and the Element. They are responsible for understanding the details (content, schedule and risks) of their assigned portfolios. They are also responsible for working with PSCs from other portfolios to identify areas of intra-Element integration. The PSCs responsibilities are the following:

- Provide project science support for risks in assigned portfolio
- Provide gap rewriting support to LSs
- Track gap metrics
- Screen new task synopses
- Coordinate SRPs and track actions

- Assist in evidence documentation (including end of task final reports and gap closure recommendations)
- Update the IRP with content from LSs
- Interface with ISSMP and FAP for experiment integration (e.g., select for flight/bed rest packages)
- Plan interim science reviews
- Complete project level resources and relevancy statements for directed tasks
- Act as liaison to Element Science Management
- PSCs report to the deputy ES

1.6.3 Collaborations

The HHC partners with several internal organizations (e.g., HRP Elements and multiple NASA Centers) for countermeasure and technology development to maximize subject participation and minimize duplication of effort. These partnerships are described in the following paragraphs.

1.6.3.1 Other Elements

Within the HRP, other Elements may partner with the HHC to collect evidence and develop countermeasures for exploration mission scenarios.

1.6.3.2 NASA Centers

The JSC will have technical lead for the coordination of all human-based studies within the Element. Support for subordinate project technical studies is provided by other NASA Centers as needed for implementation of ground and flight studies (pre and postflight operations). Specific NASA Center contributions are documented in Inter-Agency Task Agreements (ITAs).

1.6.3.3 Discipline Integrated Product Teams (DIPTs)

A DIPT exists for each discipline associated with the HHC research (i.e., each green box on Figure 1-2). These teams are established as internal groups to provide guidance to the Element on research priorities. Per appointment by the HRP Chief Scientist and concurrence of the HRP Program Manager, each team is led by the HHC LS and is assigned a flight surgeon and the corresponding NSBRI team leader, if a corresponding NSBRI team exists. These three individuals constitute the points of contact for the team. Additional composition of each DIPT is at the discretion of the LS and is expected to include both intramural and extramural discipline experts. To prevent real or perceived conflicts of interest, members of the DIPTs may not serve on the HHC SRP. The DIPTs provide recommendations to the Element to aid in the development of the PPBE packages, solicitations, and research plans.

1.6.3.4 National Space Biomedical Research Institute (NSBRI)

The NSBRI research is organized into the following teams that map to the needs of the HHC: Cardiovascular Alterations, Smart Medical Systems, Musculoskeletal Alterations, and Sensorimotor Adaptation. Interactions between the NSBRI team leaders and the HHC ESs facilitate the exchange of scientific information and foster collaborations to avoid duplication of efforts and optimize the fiscal resources of both parties. The NSBRI personnel will be members

of the DIPTs. Other points-of-contact and interfaces are established between the two entities as required.

To properly focus the areas of research activity, NASA and the NSBRI discuss programmatic needs before announcing forward research solicitations.

1.6.3.5 International Partners (IPs)

The HHC will collaborate with the International Partners (IPs) in both ground and flight investigations to maximize subject participation, share limited resources, share data when possible, and minimize duplication of effort.

1.6.4 Standing Review Panels (SRPs)

The HRP Science Management Office (SMO) is responsible for establishing and coordinating program-level working groups, advisory committees and SRP. Each panel will typically be comprised of approximately five to ten individuals with the appropriate scientific and technical expertise to evaluate the primary discipline area. The HHC SRP candidate participants are recommended to the HRP SMO by the HHC Element management team. The panel will evaluate the appropriateness and feasibility of the proposed research for the stated goals, and serve as a steering committee to evaluate progress of the Element to help optimize the research effort. The HHC participates in meetings when content being reviewed is that implemented by the HHC.

1.6.5 Element Reporting

The HHC EM reports Element performance for the preceding quarter to the HRP Program Manager at the HRP Quarterly Reviews and reports the status of any controlled milestones upon projected completion date. Research results will be documented in peer-reviewed publications as well as appropriate scientific meetings. Recommendations to the HRP will be documented in the NASA publication system. The HHC EM also reports monthly to the HRP Program Manager resource and budget status. Annually, the EM reports on PPBE and on the IRP to the HRP. Every other year, evidence reports are updated as needed based on current findings. Recommendations for countermeasures and standards are also reported to the Human Systems Risk Board (HSRB).

Reporting to the HEOMD is through the HRP in accordance with the HRP Program Plan. The HHC coordinates inputs from the HHC Portfolios and will provide those inputs for the HRP Annual Report.

1.7 Governance Structure

This Element is classified as an Agency Research and Technology Portfolio Project as defined in NPR 7120.8, NASA Research and Technology Program and Project Management Requirements (b) in Section 2.2.1.1. The governing Center organization that provides oversight for this Element is the JSC HRP Office.

1.8 Element Requirements

Element requirements are allocated from the HRP as documented in the HRP PRD. Element requirements involve development and validation of medical standards (PRD Section 4.1),

quantification of physiologic risks (Section 5.1), mitigation of physiologic risks (PRD Section 5.2), treatment and monitoring of unmitigated physiologic risks (PRD Section 5.3), compliance with Agency policy and procedure (PRD Section 6.3) and reduction of required resources (PRD Section 6.4). The physiologic risks allocated by HRP to its Elements are listed in HRP PRD Section 5 in Table 3 – Exploration Missions Human Health and Performance Risks, Evidence Verification, and Mission Criticality.

The HHC is allocated 15 of the HRP risks identified in the PRD. The gaps decomposed from each of these risks serves as the requirements for this Element. These requirements are documented in Appendix D. The EVA risks (DCS, EVA Health, and EVA Performance) are currently being defined and baselined by the HSRB. Currently, Oxidative Damage is not a risk as defined by the HSRB, but HHC plans to present it as a risk to the HSRB in FY12.

1.9 Technical Summary

Spaceflight-induced changes affect in-flight health and performance, as well as long-term health. To understand the extent of the health and performance decrements, the HHC must understand the risks and then develop countermeasures to the highest risks from spaceflight. The HHC is responsible for coordinating research activities across its portfolios and assigned risks. These research activities aim to understand human health and performance issues and determine if these can or should be mitigated. The HHC provides the biomedical expertise for the development and assessment of medical standards; provides vehicle and spacesuit requirements as dictated by human physiologic needs; and will develop a validated and integrated suite of countermeasures for exploration missions that ensure the maintenance of crew health during all phases of the mission, including following return to Earth. Countermeasures target human physiology and performance capabilities at risk from spaceflight missions at each stage of mission performance. Preflight countermeasures involve crew selection, physical fitness and exercise prescription, physiologic adaptation training, and health stabilization. In-flight countermeasures cover physiologic and nutritional health, physical fitness, and mission performance. Postflight countermeasures target rehabilitation strategies. The major deliverables for the HHC are input for the refinement of health and medical standards, validated human health prescriptions, validated exercise system requirements, extravehicular activity (EVA) suit and decompression requirements, integrated physiologic countermeasures, partial gravity human performance predictions and requirements, and criteria for the agency fitness for duty and crew selection/retention standards.

1.10 Implementation Approach

The HHC is assigned risks from the HRP PRD. From these risks, the HHC assigns gaps to the four HHC research portfolios. Some risks and gaps cross multiple portfolios and/or DIPTs, these are assigned by the Element to a primary portfolio. The Element holds interportfolio meetings to ensure integration of all activities within the Element.

The success criteria include the delivery of operational requirements for each exploration mission as well as validated and optimized countermeasures that allow crew to meet criteria established in the NASA Spaceflight Human System Standard Volume 1: Crew Health document

(NASA-STD-3001). The process to establish these deliverables is iterative. As validation tests are completed and vehicle and habitat designs mature, deliverables will be refined as appropriate.

The HRP performed an analysis to determine program risks with supporting gaps in the knowledge base. The HHC coordinates with its subordinate portfolios to establish recommended areas of research and implement research awards using research calls. These awards have defined schedules and deliverables. Research activities focus on ground-based problem definition and countermeasure development, countermeasure testing in microgravity analogs, and validation in spaceflight studies.

The first step in implementation is a detailed understanding of Program-identified risks set forth in the PRD, standards and research requirements, and existing capabilities and operational requirements to determine performance and knowledge gaps. Research will be solicited or directed to fill these gaps. The FAP ground capabilities/facilities will be used to test the validity of the proposed countermeasure. Validation of countermeasures with human subjects in actual spaceflight requires the involvement of ISSMP personnel to schedule and integrate on-orbit testing using ISS and/or exploration-class missions where appropriate. Results may dictate fundamental changes in protocol, abandonment of the concept and cancellation of further work, or progression to the next phase. Upon validation of the proposed countermeasure, the countermeasure will be delivered to the appropriate customer for operational implementation.

1.11 Element Dependencies

Successful implementation of the HHC depends on:

- Continued JSC SMD involvement for certification and configuration management of medical standards and requirements for assuring astronaut health and safety
- Intra- and extramural discipline experts to act in the capacity of an advisory council for program Element reviews, shared expertise and general consulting
- Astronaut Office support for insight, participation and feedback on Element goals, technology selection reviews, countermeasure validation, as well as analog and flight testing
- HRP support in assembling effective, rapid Non-Advocate Review (NAR) panels for review of directed research relative to candidate scientific proposals
- HRP facilitation of calls for HHC proposal solicitations via the NRA
- Partnering with other HRP Elements for effective use of resources, data-sharing, and facilities
- ISS, or other vehicle programs, to assign a high priority to selected modalities in support of flight validation studies by making available manifest opportunities and in-flight resources (time, stowage, etc.)
- Partnering with the NSBRI for effective use of resources and facilities
- Effective use of data mining techniques to use previously collected data archived in JSC flight and ground databases
- A pool of highly qualified principal investigators to help address the HHC gaps
- SMD for support in risk definition/clarification and advocacy. The SMD also provides a test subject facility and Lifetime Surveillance of Astronaut Health (LSAH) infrastructure

1.11.1 Agreements

Several cooperative, Inter-Agency, Intra-Agency, and International Agreements are established to support the HHC. The agreements listed in Table 1-1 form an integral part of this Element Plan.

Table 1-1: Agreements

Nature of entity	Entity	Description
Within JSC	Bioastronautics Contract (NAS 9-02078)	Personnel, expertise, facilities
	Universities Space Research Association (USRA) Contract (NNJ11HE31A)	
U.S. Non-Government Entities	NSBRI	Research facilitation, award, and management (cooperative agreement)
	Extramural researchers	Via research award
U.S. Government Entities	National Institutes of Health	Access to bed rest capabilities within their specialized clinical research facilities
International Entities	International Partners	Participates in flight/ground studies
Customers	Space Medicine Division, Office of the Chief Health and Medical Officer, Multi-purpose Crew Vehicle, Commercial Crew Program, Other exploration development projects (e.g., Advanced Exploration Systems)	Customer Supplier Agreements will be signed between the Element and the customers for countermeasures, standards and all other HHC deliverables

1.12 Logistics

All HHC logistical needs are anticipated to be identified and met by individual PIs. The PSCs and Portfolio Managers will aid the PIs when necessary.

Non-PI related logistics are handled by the Bioastronautics Contract on a case-by-case basis.

PART II: ELEMENT BASELINE

2.0 Schedules

The HHC milestones and deliverables support Agency exploration timelines. The HRP maintains an IMS of all Element visibility and control milestones that is approved through the HRPCB. Figure 2-1 illustrates the HHC schedule of key milestones and deliverables as agreed to by HRP and documented in the IMS. Key tasks, decision points, and strategies in meeting these

milestones are documented in the IRP. Any changes in Element content or strategy that affect controlled milestones require approval by the HRPCB.

The HHC key target milestones are indicated in Table 2-1.

Table 2-1. Excerpt of HHC Schedule Showing Key Controlled Milestones

HHC Key Controlled MILESTONES	FINISH DATE
Preliminary recommendation for use of bisphosphonates to reduce bone loss	January 2012
Baseline rVIIP Research Plan	August 2012
Preliminary recommendation for update to Immune Standard based on outcome from Integrated Immune flight study	July 2013

2.1 Resources

The resources necessary to successfully complete the tasks and objectives are defined in this Plan over the specified time period per the PPBE process.

2.1.1 Funding Requirements

Funding requirements will be reviewed on an annual basis through the PPBE process. Element content and scope will be reviewed on an annual basis reflecting actual funding allocations. In addition to the identified funding requirements, the HHC requires application of the NSBRI resources to address the HHC gaps. NSBRI application of resources is negotiated with the HRP Program Office and NSBRI management. The most recently approved HHC procurement budget (including civil service travel) and number of HHC civil servant full-time equivalents (FTEs) for fiscal years (FYs) 12–17 is provided in Table 2-2 below:

Table 2-2: Funding Requirements for HHC

HHC SUMMARY	FY12	FY13	FY14	FY15	FY16	FY17
HHC Procurements $M	31.561	31.507	31.529	31.551	31.573	31.597
HHC FTE	29.8	29.8	29.8	29.8	29.8	29.8

2.1.2 Institutional Requirements

Inter-Center and institutional facilities required to support the HHC are identified in Table 2-3.

Table 2-3: Inter-Center and Institutional Facilities

Organization	Facilities
Johnson Space Center	Human Adaptation & Countermeasures Laboratories Space Medicine Division Habitability & Environmental Factors Laboratories
Glenn Research Center	Engineering Facilities Human Research Program Facilities • Exercise Countermeasures Laboratory • Space Experiments Laboratory

Organization	Facilities
Ames Research Center	Space Biosciences Research Laboratories Human Performance Centrifuge
Landing Sites	Gagarin Cosmonaut Training Center Baikonur Astronaut Rehabilitation Center Baseline Data Collection Facility
Ground Analog Facilities	General Clinical Research Centers (e.g., UTMB) Haughton Mars Devon Island NASA Extreme Environment Mission Operations (NEEMO) Antarctic research centers

2.2 Acquisition Management

The HHC makes use of available NASA and HEOMD acquisition methods, such as NRAs, Requests for Proposals, and Internal Calls for Proposals, to solicit R&T development tasks. Small Business Innovation Research grants (SBIRs) are used to the largest extent possible.

Participating Centers also use competitive contracts for procurement of support to intramural Element tasks. The JSC uses the Bioastronautics Contract that is an Indefinite Deliverables Indefinite Quantity (IDIQ), task-based contract used for laboratory mission operations support and is currently in place. Technical expertise is also contracted at JSC via the Universities Space Research Association (USRA) for personnel to support the HHC research activities.

A new contract will replace the Bioastronautics Contract in the March 2013 timeframe.

Solicitation, selection, and management of ground and flight science and research tasks under this Element follow the processes defined in the HRP Science Management Plan (HRP-47053) (SMP).

2.3 Performance

Element performance will be based upon:

- Crew health physiologic parameters improvement
- Compliance to Permissible Exposure or Outcome Limits and Fitness for Duty Standards
- Annual review by the HRP and Element SRPs to examine:
  - Definition and clarity of requirements identified
  - Implementation plan and review process
  - Maturity of deliverables
  - Validation and operational availability of deliverables for implementation
  - Transition of end-item Element deliverables to customer programs
  - Mitigation of risks, retirement of risks/gaps, and possible generation of new risks/gaps

PART III: SUBPLANS

3.0 Communications Plan

Element management and technical issues are communicated informally during daily tag-ups within the Element management team. More formal communications are conducted between the Element and Program Management staff through weekly Program/Element tag-ups, the quarterly TCSR, and annual progress reports. Element team issues are communicated through bi-weekly Element meetings. Communication with external principal investigators will occur formally at the annual HRP Investigators' Workshop and informally through phone and email contact as needed. Communication with the NSBRI is through regular discussions between the ES and/or Project Scientists, and NSBRI Team Leads. Formal communication with the NSBRI is through the Program Scientist who is the Contracting Officer's Technical Representative for the NSBRI Cooperative Agreement. Element progress and status is reported to line organization management as appropriate to ensure proper and adequate resourcing and skilled personnel supply.

3.1 Control Plan

The Element has full authority and responsibility to implement an Element control plan for all requirements, resource allocation, and schedule milestones delegated to it from the HRP. Changes to the Element objectives and requirements, allocated resources, or Level 1 (controlled) schedule milestones and deliverables as detailed in this Plan require negotiation with and approval by the HRP.

The EM has the authority to redistribute funding among work breakdown structure (WBS) areas within the thresholds established by the HRP with the exception of redistribution of funds across Centers. Any changes concerning the participation of NASA field Centers must be presented to the HRP for approval. Use and management of Element reserves within the Element baseline budget are at the discretion of the HHC Manager and do not require prior approval from the HRP management.

The HHC will use the established JSC HRP board structure to control Level 1 milestones and budget. Level 1 (controlled) milestone acceptance is approved by the HRP CB. Element-level deliverables and high-level visibility milestones will be controlled by the HHC CB, as will the DA project plan.

The HRP management has authority to review this Element and provide assessment, direction, continuation, or termination, as appropriate. Products and changes for this Element will be processed through the appropriate HRP CB as determined by the SLSD Configuration Control Management Plan (JSC 28330, Rev. E).

3.1.1 Configuration Control Boards

The HHC relies on the HHC CB as well as the HRPCB to ensure the configuration management of the Element.

The HHC CB maintains configuration control and quality management oversight for activities of the HHC, as needed. The HHC CB holds configuration control maintenance of the HHC-owned gaps and the DAP Plan. Detailed responsibilities and duties are defined in the HHC CB charter.

For HHC-owned gaps, ad hoc members can be added to the HHC CB for decisions related to closure of the gaps. Once the gap has been closed, all downstream documentation will be updated to reflect this change. This includes the Element Plan and the IRP. The ISSMP CCB controls flight implementation aspects for the HHC-selected investigations.

The HRPCB manages HEOMD resources allocated to the HRP by configuration control maintenance of Element Plans and the HRP Program Plan. Detailed responsibilities and duties are defined in the HRPCB charter. The HHC EM is a standing member of the HRPCB.

The HRP requirements (Human Health and Performance Risks) are defined by the HSRB. Data from the HHC research will be used to close the gaps. This data will be brought to the HSRB for recommendation regarding the pertinent risk. The HSRB provides the final decision to mitigate, accept close or further research the risk. All downstream documentation will then be updated to reflect any risk disposition.

3.2 Risk Management Plan

The HHC will follow continuous risk management in accordance with the HRP Program Plan (Appendix E). The HHC Portfolios identify and provide their top priority risks to the HHC. The EM determines which of those risks are top priority for the Element and then forwards those top Element risks up to the Program.

3.3 Technology Assessment

3.3.1 Strategy

The Element continually assesses the state of knowledge in human health and performance risks. The Element team is continuously communicating with the DIPTs who regularly provide new evidence. New scientific findings are presented at weekly science meetings. Newly developed knowledge can be used to address health protection goals by integrating research results into methodologies for risk mitigation strategies and guidance on new research directions.

New technology that is identified and required for the Element shall undergo annual assessment before the solicitation review and selection process. New technology will be assessed for feasibility, readiness, cost, risk and benefit to the Element.

3.3.2 Insertion

The Element along with the HHC LSs integrates scientific research results, including ongoing assessments of progress in the eight science disciplines specified in Section 1.6.1. Transition of research results into requirements, standards, or recommendations for operational procedures will begin only after successful completion of planned ground assessments and analog validations. Recommended changes to human system requirements, standards, guidelines, and practices will be processed through the HRP. These updates will then flow to the HEOMD, as needed, for insertion into the requirements for flight vehicles, habitats, operations, mission planning and other systems.

If HHC requires new technology to be developed to update standards or countermeasures, that technology will be developed within the Element. If this new technology is required by outside

entities; the technology recommendations will be submitted to HRP after the research results have been reviewed and approved, consistent with the Technology Transition process defined in the HRP Science Management Plan.

3.4 Cooperation and Commercialization

The JSC Technology Transfer and Commercialization Office (TTCO) will support the Element to identify and evaluate commercial opportunity options. As applicable, the JSC TTCO will support the Element to develop specific commercialization partnership and/or tech transfer opportunities. The JSC Small Business Innovation Research/Small Business Technology Transfer (SBIR/SBTTR) Program Office will support the Element to identify and evaluate commercial opportunity options. As applicable, the JSC SBIR/SBTTR will support the Element to develop specific commercialization partnerships and/or tech transfer opportunities.

3.5 Safety and Mission Success Plan

3.5.1 Human Test Subjects

For projects involving human subjects, the Element will ensure all HHC investigators follow the JSC's Committee for the Protection of Human Subjects guidelines found at http://irb.nasa.gov/ and SMP to ensure the health, safety and privacy of the subjects are protected.

3.5.2 Animal Test Subjects

For ground-based projects involving animal subjects, the element will ensure all HHC investigators obtain prior approval from the Institutional Animal Care and Use Committee (IACUC) for the appropriate testing location and will also comply with the NRC guide for the care and use of laboratory animals and the animal welfare act (9 CFR - Code of Federal Regulations - Title 9: Animals and Animal Products).

3.5.3 Ground Research

For ground-based research, the Element will comply with the approved Center and Facility safety and quality standards.

3.5.4 Flight Research

For flight research, the Element will comply with the applicable standards and procedures governing ISS flight payloads. Because all HHC-funded flight research flows through the ISSMP for flight integration, the Element will follow ISSMP safety and assurance plans.

3.6 Environment Management Plan

The Element complies with NPD 8500.1 – NASA's Environmental Management Policy. The participating Centers and institutions are required to comply with their Center or institution policies and procedures related to environmental management.

3.7 Systems Engineering Plan

The Element does not have a designated system engineering organization, but system engineering functions are performed by the Element management team.

The HHC will ensure that the Element's goals, objectives and requirements are integrated among the various HHC portfolios. Science portfolios are integrated among the HHC portfolios and discipline teams to ensure synergy while minimizing overlaps. Overall research oversight will be implemented via the ES in conjunction with the EM. Element implementation approaches, reporting, management, and infrastructure will be coordinated across portfolios to minimize overhead and costs. This coordination will be the responsibility of the Element management team, and delegated to the respective participating organizations.

3.8 Verification and Validation

Acceptance in peer-reviewed publications serves as the standard for validation of scientific results from the HHC-funded studies. Validation of operational conclusions from these scientific results will be shown by acceptance in NASA Technical Publications or successful insertion into mission requirements documentation. Countermeasures developed will be evaluated using the appropriate analog environment; then the countermeasure will be validated using flight resources. The verification and validation for the HHC deliverables are unique to each task. The verification and validation will also be driven by exploration mission requirements. The HHC shall subject hardware and software used in flight experiments and tests to functional verification and safety reviews as required by the vehicle program requirements. The HHC shall document these activities in Project Verification and Validation Plans as required by the appropriate ISS requirements.

3.9 Reviews

The HHC participates in reviews agreed to by the HRP. These reviews are identified in the Element schedule.

3.9.1 Reviews within the HRP

The Element participates in quarterly TCSRs with the HRP Office. The critical reporting requirements for the quarterly reviews include assessments of technical (scientific), cost and schedule at the Element level. The Element will conduct detailed reviews of its subordinate portfolios before each TCSR and before the yearly PPBE cycle.

3.9.2 Peer Reviews

There are three types of peer review that can occur for the HHC content: NRA reviews, merit reviews of directed studies, and standing reviews for the scientific content of the Element. These peer review panels are ad hoc review committees called upon to review solicited proposals, directed task research proposals, various existing projects, and approaches to specific technical issues. Panels usually will be chaired by an individual selected from a standing roster having the appropriate expertise for the primary discipline area requiring peer review. Details for the merit reviews and NRA review processes can be found in the HRP Unique Processes, Criteria, and Guidelines (HRP-47069). Details of the standing reviews of the Element can be found in the HRP SMP. The HRP SMO has the responsibility to ensure the panelists do not have conflicts of interest.

3.10 Configuration Management Plan

Configuration management of this document and all Level 1 milestones will be in accordance with the SLSD Configuration Management Plan. Configuration of Level 1 milestones will be controlled through the HRPCB. Configuration of this document will be controlled through the HRPCB. Configuration control of all lower level Element documents, schedules and products will be delegated to the portfolios as deemed appropriate by the HHC CB.

3.11 Education and Public Outreach Plan

Education and public outreach is coordinated and conducted by the HRP Education and Outreach Office. Efforts may include activities such as maintaining an Element website, participating in HRP and HACD outreach, supporting scientific meetings, and providing input to formal K-12 education initiatives. The HHC supports these activities as needed.

3.12 Termination Review Criteria

As specified in the HRP Program Plan, the HRP will review the status of each Element at least annually and assess the ability of the Element or portfolio to meet its objectives. The HRP Elements and portfolios are subject to termination as authorized by the HRP Program Manager in consultation with HEOMD. Criteria for termination may include:

- Strategic: Inconsistent with the Exploration vision; inconsistent with the program/mission objectives; overlap with another funded activity; or low priority ranking for HRP or Element given funding constraints
- Technical and Scientific: Performance measures indicate that the technology will not achieve the required technical results by the scheduled need date; performance measures indicate degradation in projected performance versus performance commitments; product delivered is of insufficient quality and/or does not meet performance requirements
- Cost: Over budget by 5% per year for a Element; over budget by 15% per year for a portfolio
- Schedule: Missed milestone(s) or key decision points; missed due dates for major activities, projected delay in the operational readiness review greater than 6 months from the committed date
- Noncompliance with Agency or HEOMD policy
- Knowledge sought is obtained through means other than the current HRP-funded activities

3.13 Knowledge Capture Plan

The data and documents developed under this Element will be catalogued and available through controlled access to the HRP websites in accordance with standard JSC, SLSD and HRP Information Technology procedures. These documents may include published journal articles, conference papers, and/or technical presentations generated by extramural and/or intramural researchers, data entry into the Life Sciences Data Archive (LSDA), NASA publication series, and Project summary documentation. In addition, evidence books for each HHC-managed HRP risks will contain an updated evidence base for each risk and can be accessed at http://humanresearchroadmap.nasa.gov/evidence/. Details for research activities funded

through the HHC can be found on the HRP Task Book website: http://peer1.nasaprs.com/Publication/welcome.cfm.

3.14 Waivers/Deviations Log

There are no known deviations or waivers against NASA or the HRP policies, directives or external requirements, either in existence within the HHC or to be obtained by the Element.

3.16 Appendices

Appendix A – Acronyms

Appendix B – Applicable and Reference Documents

Appendix C – Element Research Plan

Appendix D – Requirements (Risks and Gaps)

APPENDIX A: ACRONYMS AND ABBREVIATIONS

BMD	Bone Mineral Density
CB	Control Board
CCB	Configuration Control Board
CHMO	Chief Health and Medical Officer
CPHS	Committee for the Protection of Human Subjects
CSA	Customer Supplier Agreement
DAP	Digital Astronaut Project
DRM	Design Reference Mission
DIPT	Discipline Integrated Product Team
ECP	Exercise Countermeasures Project
EM	Element Manager
ES	Element Scientist
EVA	Extravehicular Activity
FAP	Flight Analogs Project
FTE	Full-Time Equivalent
HACD	Human Adaptation & Countermeasures Division
HACD CCB	HACD Configuration Control Board
HEOMD	Human Exploration and Operations Mission Directorate
HHC	Human Health Countermeasures
HHC CB	Human Health Countermeasures Control Board
HMTA	Health & Medical Technical Authority
HRP	Human Research Program
HRPCB	HRP Control Board
HRR	Human Research Roadmap
HSRB	Human System Risk Board
IDIQ	Indefinite Deliverables Indefinite Quantity
IP	International Partner
IRB	Institutional Review Board
ISS	International Space Station
ISSMP	ISS Medical Project
ITA	Inter-Center Technology Agreement
JSC	Johnson Space Center
LS	Lead Scientist
LSAH	Lifetime Surveillance of Astronaut Health
LSDA	Life Sciences Data Archive
NAR	Non-Advocate Review
NASA	National Aeronautics & Space Administration
NEEMO	NASA Extreme Environment Mission Operations
NRA	NASA Research Announcement
NRC	National Research Council
NSBRI	National Space Biomedical Research Institute
NxPCM	Non-Exercise Physiologic Countermeasures Project

OCHMO	Office of Chief Health and Medical Officer
PPBE	Program Planning & Budget Execution
PRD	Program Requirements Document
PSC	Portfolio Science Coordinator
R&T	Research & Technology
RFP	Request for Proposal
SBIR	Small Business Innovation Research
SBTTR	Small Business Technology Transfer
SLSD	Space Life Sciences Directorate
SMD	Space Medicine Division
SMO	Science Management Office
SOMD	Space Operations Mission Directorate
SRP	Standing Review Panel
STD	Standard
TBD	To Be Determined
TCSR	Technical Cost and Schedule Review
TTCO	Technology Transfer & Commercialization Office
USRA	Universities Space Research Association
UTMB	University of Texas Medical Branch
WBS	Work Breakdown Structure

APPENDIX B: APPLICABLE AND REFERENCE DOCUMENTS

APPLICABLE DOCUMENTS

Document No.	Title
SA-WI-001	SLSD Master Work Instruction
SA-WI-002	SLSD Human Space Life Sciences Programs Office Work Instruction
SK-WI-001, Rev B	HACD Master Work Instruction
JPD 7120.1	JSC Project Management Policy
Revision C (25 Apr 2011)	Human Research Program Control Board Charter
Baseline (26 Apr 2006)	Human Research Program Science Management Panel Charter
Memo – SK-01-173	Small Assessment Team report
LS-73004	International Space Station Medical Project (ISSMP) Launch and Experiment Manifest
LS-73005	International Space Station Medical Project (ISSMP) Flight Queue Master List
LS-71030	International Space Station Medical Project (ISSMP) Quality Assurance Plan Document
SSP 50260B	ISS Medical Operations Requirements Document
JSC29834 Vol. 1B, Rev. C	Astronaut Medical Evaluations and Requirements Document
HRP-47051	HRP Program Plan
HRP-47052	HRP Program Requirements Document
HRP-47053	HRP Science Management Plan
HRP-47065	Human Research Program Integrated Research Plan
HRP-47069	HRP Unique Processes, Criteria, and Guidelines
NASA-STD-7709	Standard for Models and Simulations

REFERENCE DOCUMENTS

Document No.	Title
http://irb.nasa.gov/	JSC CPHS: Guidelines for Investigators Proposing Human Research for Spaceflight and Related Investigations
JSC 28330C	Space Life Sciences Directorate Configuration Control Management Plan
NASA STD-3001, Vol. 1	NASA Space Flight Human System Standard

Document No.	Title
NPR 7120.8	NASA Research and Technology Program and Project Management Requirements
NPD 8500.1	NASA Environmental Management Policy
	NRC Guide for the Care & Use of Laboratory Animals and the Animal Welfare Act (Code Fed. Reg. Title 9)
TBD	Digital Astronaut Project (DAP) Plan

APPENDIX C: HUMAN HEALTH COUNTERMEASURES ELEMENT RESEARCH PLAN

The HHC Element Research Plan is fully embedded within the HRP IRP (HRP-47065) and not a stand-alone document. The IRP can be viewed electronically as part of the web-based HRP Human Research Roadmap (HRR) at http://humanresearchroadmap.nasa.gov/. The HHC inputs to the IRP will be incorporated as required and will be updated yearly and follows the cycle outlined in the HRP SMP (HRP-47053).

APPENDIX D: HUMAN HEALTH COUNTERMEASURES REQUIREMENTS (RISKS AND GAPS)

Risk Title	Gap Title
Risk of Microgravity-Induced Visual Impairment/Intracranial Pressure	VIIP1: What is the etiology of visual acuity and ocular structural and functional changes seen in-flight and postflight?
	VIIP2: Does exposure to spaceflight cause changes in visual acuity, intraocular pressure and/or intracranial pressure? Are the effects related to mission duration?
	VIIP4: Are changes in visual acuity related to changes in chronic choroidal engorgement, elevated intraocular pressure, and/or intracranial pressure?
	VIIP5: Do multiple or cumulative exposures to spaceflight increase the risk of changes in visual acuity, intraocular pressure, or intracranial pressure?
	VIIP8: What is the role of the ISS environment (eg, high salt diet, CO_2 pockets, pharmaceutical use, exercise countermeasures) on ocular structure and function and intracranial pressure?
	VIIP3: What in-flight diagnostic tools are needed to measure changes in intraocular pressure and intracranial pressure?
Risk of Intervertebral Disk Damage	B4: What is the incidence of intervertebral disk damage following spaceflight?
Risk of Cardiac Rhythm Problems	N7: What are the potassium, magnesium, and phosphorus changes in relation to cardiovascular issues and bone loss?
	CV1: What are the in-flight alterations in cardiac structure and function?
	CV8: Can manifestations of subclinical or environmentally induced cardiovascular diseases during spaceflight be predicted?
	CV7: How are fluids redistributed in flight?
Risk of Renal Stone Formation	B5: What is the current state of knowledge regarding renal stone formation?
	B6: What are the contributing factors other than loss of bone mineral density?

Risk Title	Gap Title
	B7: Is it necessary to increase crew fluid intake and, if possible, to what extent will it mitigate stone formation?
	B8: Do pharmaceuticals work effectively in spaceflight to prevent renal stones?
	B9: What is the frequency of postflight stone formation; the incidence and types of stones; and the time course of stone formation? How does stone formation correlate with food intake and hydration status?
	B16: Can inhibitors of stone formation be sufficiently provided through dietary sources?
	N13: Can renal stone risk be decreased using nutritional countermeasures?
	N14: What integrated nutritional, exercise and/or pharmaceutical countermeasures can be used to mitigate bone loss?
Risk of Therapeutic Failure Due to Ineffectiveness of Medication	PH01: Inadequate tracking of medication use, indication, efficacy, and side effects.
	PH02: What drug interactions may adversely affect clinical care?
	PH04: What diagnostic, therapeutic, and laboratory technologies are necessary to predict and manage medication side effects, interactions, and toxicity during spaceflight?
	PH06: Can a standard procedure for prospective analyses of drugs to be considered for flight and periodic analyses of drugs that are used for flight be developed?
	PH07: What are the effects of spaceflight on pharmacokinetics and pharmacodynamics?
	PH09: What is the stability of drugs during long-duration spaceflight?
	PH10: What are the effects of in-flight drugs on exercise, orthostatic tolerance, motor control, cognitive function, or other performance-determining aspects of physiology? Can novel multidisciplinary therapeutic approaches be used to enhance efficacy and reduce side effects?
	PH13: Which sleep aid is best in flight in terms of efficacy? In terms of limited side effects?

Risk Title	Gap Title
	PH15: Are the antimicrobials carried on board effective against microbes that exhibit spaceflight-related changes?
	M14: What anabolic or anticatabolic drugs can be used to mitigate muscle loss?
Risk of Compromised EVA Performance and Crew Health Due to Inadequate EVA Suit Systems	EVA 6: What physiologic and amp; performance capabilities are required for suited operations?
	EVA 7: How do EVA suit design parameters* affect crew health and performance in exploration gravity environments and how can their effects be predicted?
	EVA 8: What are the metabolic costs of expected nominal and amp; contingency suited tasks in exploration gravity environments and how can heat produced during exploration EVA effectively be removed?
	EVA 9: How do EVA duty day work-rest cycles (eg, long, single vs. short, multiple EVAs/day) impact crew performance and amp; health?
	EVA 10: How can biosensors be integrated with advanced tools, biofeedback and amp; information systems to improve EVA crew performance and autonomy?
	EVA 11: How do suit fit and suit-human biomechanical interactions affect the likelihood of crew injury?
	EVA 12: What is the risk of decompression sickness (DCS) in micro- and partial-gravity environments?
	EVA 13: What is the risk of hypoxia during exploration missions?
Risk of Crew Adverse Health Event Due to Altered Immune Response	B31: Need additional information regarding hard and soft tissue healing in-flight. If impaired healing exists, what countermeasures can enhance healing?
	IM1: Does spaceflight alter immune function?
	IM2: Is an improved immune standard needed?
	IM3: Are there suitable analogs for immune dysregulation?
	IM4: Can in-flight hardware to evaluate hematology/infection/immunity be developed?

Risk Title	Gap Title
	IM5: What is the time course and etiology of immune changes?
	IM6: What are the cumulative effects of chronic immune dysfunction on missions greater than 6 months?
	IM7: What is the correlation of observed laboratory immune changes during spaceflight with known clinical conditions?
	IM8: What is the correlation of immune risks with other risks, particularly psychological stress, physical deconditioning, nutrition, and/or radiation?
	PH15: Are the antimicrobials carried on board effective against microbes that exhibit spaceflight-related changes?
Risk of Orthostatic Intolerance During Re-Exposure to Gravity	PH10: What are the effects of in-flight drugs on exercise, orthostatic tolerance, motor control, cognitive function, or other performance-determining aspects of physiology? Can novel multidisciplinary therapeutic approaches be used to enhance efficacy and reduce side effects?
	CV3: Is orthostatic intolerance a potential hazard?
	CV4: Is 1/6-g exposure protective of 1-g orthostatic tolerance?
Risk of Impaired Control of Spacecraft, Associated Systems and Immediate Vehicle Egress Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight	SM1: What is the relationship between in-flight exercise and postflight sensorimotor performance?
	SM2: What are the effects of long-duration spaceflight on sensorimotor function over a crewmember's lifetime? What are the changes in sensorimotor function over the course of a mission?
	SM4: What is the correlation between previous performance data with clinical observations?
	SM6: Can a seated manual/visual performance assessment after long-duration spaceflight be completed?

Risk Title	Gap Title
	SM7: Can an integrated postflight functional task performance test be used on returning ISS crew members to obtain performance decrements?
	SM12: Develop standards for spaceflight cockpit displays and inputs.
	SM24: Can individual capacity to produce adaptive change in sensorimotor function to transitions in gravitational environments be predicted with preflight tests of sensorimotor adaptability?
	SM26: Does exposure to long-duration spaceflight lead to neural structural alterations and does this remodeling impact cognitive and functional performance?
	PH10: What are the effects of in-flight drugs on exercise, orthostatic tolerance, motor control, cognitive function, or other performance-determining aspects of physiology? Can novel multidisciplinary therapeutic approaches be used to enhance efficacy and reduce side effects?
Risk of Injury from Dynamic Loads	OP1: How do we protect the crew from injury during dynamic phases of flight?
Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity	CV2: What is VO_2max in-flight and immediately postflight?
	M7: Can the current in-flight performance be maintained with reduced exercise volume?
	M8: What is the minimum exercise regimen needed to maintain fitness levels for tasks?
	M9: What is the minimum set of exercise hardware needed to maintain those (M8) fitness levels?

Risk Title	Gap Title
Risk of Bone Fracture	B1: (a) Is there an increased lifetime risk of fragility fractures/osteoporosis in astronauts; (b) is bone strength completely recovered post-flight and does BMD reflect it; and (c) what are the risk factors for poor recovery of BMD/bone strength?
	B2: What new technologies are available for in-flight fracture diagnosis?
	B3: What pharmaceuticals against bone loss are best used and how?
	B10: How can skeletal adaptation be monitored during flight to (a) reflect changes in bone turnover/calcium kinetics, (b) determine whether there is a plateau in bone loss, and (c) evaluate gender effects?
	B15: What exercise protocols are necessary to maintain skeletal health and can exercise hardware be designed to provide these?
	B29: What is the risk of vertebral compression fractures?
	B30: What are the loads applied to bone in-flight and during EVA activities and do they increase fracture risk in light of expected bone loss?
	B31: Need additional information regarding hard and soft tissue healing in flight. If impaired healing exists, what countermeasures can enhance healing?
	N5: Can a single test monitor net bone calcium changes?
	N7: What are the potassium, magnesium, and phosphorus changes in relation to cardiovascular issues and bone loss?
	N14: What integrated nutritional, exercise and/or pharmaceutical countermeasures can be used to mitigate bone loss?
Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance	M1: What is the current state of knowledge regarding exercise performance?
	M2: What is the current status of in-flight and postflight exercise performance capability?
	M3: What tasks will be required for Exploration missions?

Risk Title	Gap Title
	M4: What are the physiologic costs of Exploration mission tasks?
	M6: Can a standardized performance measure of readiness for Exploration mission tasks be developed?
	M7: Can the current in-flight performance be maintained with reduced exercise volume?
	M8: What is the minimum exercise regimen needed to maintain fitness levels for tasks?
	M9: What is the minimum set of exercise hardware needed to maintain those (M8) fitness levels?
	M14: What anabolic or anti-catabolic drugs can be used to mitigate muscle loss?
	M23: Do factors in addition to unloading contribute to muscle atrophy during spaceflight (eg, radiation, inflammation, hydration, redox balance, energy balance)?
	M24: What is the time course of changes in muscle protein turnover, muscle mass and function during long-term spaceflight?
	N9: What are the interactions of exercise and nutrition in altered weight bearing environments that mitigate muscle loss (Muscle)?
	SM7: Can an integrated postflight functional task performance test be used on returning ISS crew members to obtain performance decrements?
Risk Of Early Onset Osteoporosis Due To Spaceflight	B1: (a) Is there an increased lifetime risk of fragility fractures/osteoporosis in astronauts; (b) is bone strength completely recovered postflight and does BMD reflect it; and (c) what are the risk factors for poor recovery of BMD/bone strength?
	B3: What pharmaceuticals against bone loss are best used and how?
	B10: How can skeletal adaptation be monitored during flight to (a) reflect changes in bone turnover/calcium kinetics, (b) determine whether there is a plateau in bone loss, and (c) evaluate gender effects?
	B11: What are the effects of radiation on bone?

Risk Title	Gap Title
	B15: What exercise protocols are necessary to maintain skeletal health and can exercise hardware be designed to provide these?
	B31: Need additional information regarding hard and soft tissue healing in flight. If impaired healing exists, what countermeasures can enhance healing?
	MO5: Determine how can osteoporosis treatments be employed?
	N5: Can a single test monitor net bone calcium changes?
	N7: What are the potassium, magnesium, and phosphorus changes in relation to cardiovascular issues and bone loss?
	N14: What integrated nutritional, exercise and/or pharmaceutical countermeasures can be used to mitigate bone loss?
Risk Factor of Inadequate Nutrition	N1: Are nutrients in food stable during spaceflight?
	N2: What is the adequate dose range of vitamin D supplementation?
	N3: How do nutritional status/nutrition requirements change during spaceflight?
	N4: Do countermeasures impact nutrition?
	N6: What impact does the spaceflight environment have on oxidative damage?
	N9: What are the interactions of exercise and nutrition in altered weight bearing environments that mitigate muscle loss?
	N14: What integrated nutritional, exercise and/or pharmaceutical countermeasures can be used to mitigate bone loss?
	N15: Can nutrition/nutrients mitigate O_2/radiation risks?
	M23: Do factors in addition to unloading contribute to muscle atrophy during spaceflight (eg, radiation, inflammation, hydration, redox balance, energy balance)?