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## 2015 Sensorimotor Risk Standing Review Panel

Evidence and Status Review for:

*The Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight*

### Final Report

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#### I. Executive Summary and Overall Evaluation

The 2015 Sensorimotor Risk Standing Review Panel (from here on referred to as the SRP) participated in a WebEx/teleconference with members of the Human Health Countermeasures (HHC) Element, representatives from the Human Research Program (HRP), NASA Headquarters, and NASA Research and Education Support Services (NRESS) on December 17, 2015 (list of participants is in Section VI of this report). The SRP reviewed the new Evidence Report for the Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight (from here on referred to as the 2015 Sensorimotor Evidence Report), and also received a status review of the Risk.

The opening section of the 2015 Sensorimotor Evidence Report provides written descriptions of various incidents that have occurred during space missions. In most of these incidents, the main underlying contributing factors are not easy to identify unambiguously. For example, in section 1.9, a number of falls occurred while astronauts were walking on the moon. It is not clear to the SRP, however, why they fell. It is only possible to extrapolate from likely specific psychophysical or physiological abnormalities, but how these abnormalities were determined, and how they were directly responsible for the falls is unclear to the SRP.

Section 2.1.2 on proprioception is very interesting, but the functional significance of the abnormalities detected is not clear. The SRP sees this as a problem throughout the report: a mapping between the component abnormalities identified and the holistic behaviors that are most relevant, for example, controlling the vehicle, and locomotion during egress, is generally lacking.

The SRP thinks the cognitive section is too strongly focused on vestibular functioning. The SRP questions the notion that the main cognitive effects are mainly attributable to reversible vestibular changes induced by spaceflight. The SRP thinks that there can also be independent cognitive effects.

The Functional Task Test (FTT) protocols and the Field Test are particularly valuable. The conclusion is that the unloading of major postural muscles experienced during spaceflight plays a central role in the alteration of functional task performance and balance control. This conclusion stands in contrast with the statements in other parts of the document that emphasize the role of vestibular changes on these functions. It would help to more fully integrate these two views on the predominant effects of spaceflight.

Although the SRP thinks the countermeasures section is interesting, the proposed countermeasures are not well integrated with the abnormalities described in previous sections. The SRP thinks it would help enormously to have explicit links among each abnormality, its

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overall importance/impact on function, and the appropriate countermeasure that can be implemented to maintain adequate functioning.

The SRP found section 2.3 difficult to understand. The SRP interpreted this section to assert that adaptation to altered gravitational conditions shares mechanisms that also allow adaptation to perturbations in performance on treadmills in 1G. The SRP would like to know the basis for this claim. There is not a great deal known about meta-learning, so is structural learning being posited here? The references here were not convincing to the SRP, and the SRP would like to know if there have been other studies that show the generalization suggested here, and what they are.

The SRP thinks that a more systematic approach would help improve the document. At the moment it appears to provide a very well written and articulate list, but synthesis is largely lacking. Perhaps it would be useful to create a mock scenario from launch to landing, with all the activities in between, and then, to provide a weighting of all the components needed per activity and what parameters would need to be recorded/tested per activity.

## **II. Review of the Evidence for the Risk of Impaired Control of Spacecraft/ Associated Systems and Decreased Mobility Due to Vestibular/ Sensorimotor Alterations Associated with Spaceflight (Sensorimotor Risk)**

### *1. Evaluate the 2015 Sensorimotor Evidence Report using the following criteria:*

#### *A. Does the 2015 Evidence Report provide sufficient evidence that the Risk is relevant to long-term space missions?*

The SRP thinks that the 2015 Sensorimotor Evidence Report provides sufficient evidence that the Sensorimotor Risk is relevant to long-term space missions.

#### *B. Are the Risk Title and Statement properly stated in the current version of the HRP Integrated Research Plan (IRP)?*

The SRP thinks the Risk Title is properly stated in the current version of the HRP IRP.

The SRP suggests rewording the Risk Statement to (edits in bold and italics): “Given that there is an alteration in vestibular/sensorimotor function during and immediately following gravitational transitions manifested as changes in eye-head-hand control, postural and/or locomotor ability, gaze function, and perception, there is a possibility that crew will experience impaired control of the spacecraft during ***gravity transitions and during*** landing or decreased mobility ***during gravity transitions and*** following a landing on a planetary surface (Earth or other) after long-duration spaceflight.”

#### *C. Is the text of the Risk Context provided in the HRP IRP clear?\**

The SRP believes that the period of time meant by “soon after” (highlighted in yellow below) in the Risk Context should be defined: “more quantitatively”. It is unclear if the

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report is referring to seconds, minutes, or hours. If the duration of the effects depends on the specific systems involved, it should be so stated.

It has been shown that long-duration spaceflight alters sensorimotor function which manifests as changes in eye-head-hand control, postural and/or locomotor ability, gaze function, and perception. These changes have not specifically been correlated with real time performance decrements. The risk of impairment is greatest during and soon after G-transitions when performance decrements may have high operational impact (landing, immediate egress following landing). The possible alterations in sensorimotor performance are of interest for Mars missions due to the prolonged microgravity exposure during transit followed by landing tasks. This risk must be defined more completely and be more fully documented (updated Evidence Report due June 2015), and specific observed vestibular/sensorimotor changes be correlated with specific performance issues.

*D. Does the 2015 Evidence Report make the case for the research gaps presented?*

The SRP thinks that the 2015 Sensorimotor Evidence Report makes the case for the research gaps presented. The gaps described are comprehensive but seem vague as a consequence. Nevertheless, the SRP believes that the case for closing the gaps is sound.

*E. Are there any additional knowledge-type gaps or areas of fundamental research that should be considered to enhance the basic understanding of this specific Risk?*

The SRP does not think any additional knowledge-type gaps need to be considered, but wants to make sure that mental state and cognitive function is being looked at in Gap SM7.1 (SM7.1: Determine if there are decrements in performance on functional tasks after long-duration spaceflight. Determine how changes in physiological function, exercise activity, and/or clinical data account for these decrements).

*F. Does the Evidence Report address relevant interactions between this Risk and others in the HRP IRP?*

The SRP finds this difficult to evaluate due to the organization of the 2015 Sensorimotor Evidence Report. Although bone demineralization, muscle atrophy, muscle weakness, and cardiovascular issues are noted, there is no systematic attempt to address the possible relevant interactions.

*G. Is input from additional disciplines needed?*

The SRP finds this difficult to evaluate due to the organization of the 2015 Sensorimotor Evidence Report.

*H. Is the expertise of the authors sufficient to fully cover the scope of the given risk?*

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The SRP thinks the expertise is at the requisite level and the literature cited seems adequate overall. Nevertheless, recent advances in the use of small n statistics, Bayesian computation, and model-building have been achieved in the behavior and performance arena; these advances have not been incorporated into the 2015 Sensorimotor Evidence Report. (e.g., Albert J. 2014. Introduction to multilevel modeling. <https://cran.r-project.org/web/packages/LearnBayes/index.html>;  
Albert J. 2009. Bayesian computation with R. Springer. ISBN 978-0-387-92298-0 <https://www.infona.pl/resource/bwmeta1.element.springer-a2893eef-8822-3e6c-94f6-68ef2512aab5>;  
Johannes B, Gaillard A. 2014. A methodology to compensate for individual differences in psychophysiological assessment. *Biological Psychology*. 96, 77-85)

I. *Is there information from other HRP disciplines that need to be included in the 2015 Evidence Report?*

Similar to section 1.G. above, the SRP thinks this is difficult to determine because of the overall organization of the 2015 Sensorimotor Evidence Report.

J. *Is the breadth of the cited literature sufficient?*

The breadth appears to be appropriate, however some updating of the report in sections that are essentially “cut and paste” from previous reports should be revised to reflect the passage of time (e.g., a 1993 study was described as “recent”; a book that is referenced in the text that is now in 4<sup>th</sup>, not 1<sup>st</sup> edition and the information contained has changed, etc.). The inclusion of references to recent papers on small-n statistics and model building should be considered.

K. *What is the overall quality and readability of the 2015 Evidence Report?*

Overall the report provided interesting insight into the consequences of prolonged exposure to low-gravity environments and of changes in gravity on vision, eye-head-hand coordination, and static and dynamic postural control. Reorganization of the report that link these consequences to the associated risk statements, current research and the proposed countermeasures would facilitate identifying whether or not any additional knowledge gaps or areas of fundamental research should be considered. The current organization of the report made it difficult to answer some of the questions in the SRP charge in more detail.

2. *Provide comments on any important issues that are not covered by the criteria in #1 above.*

It is not clear to what extent changes in the vestibulo-ocular reflexes, and the functional ramifications of those changes, for *unpredictable* head movements are being examined. However, the work on generalization of adaptability is both exciting and encouraging (Section V. 2.3 of the 2015 Sensorimotor Evidence Report).

The SRP could not find a description of testing to identify adaptive ability of each person and

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designing of personalized adaptation training paradigms or the application of relatively new techniques; for example, stochastic resonance (SR). Page 77 states that “individualized training programs in conjunction with SR designed to promote the use of multiple sensory modalities can enhance the ability to adapt.....in the astronaut population” but does not indicate the status of applying that approach to the NASA programs or even if the approach is being used at all.

### **III. Comments regarding the Sensorimotor Risk Status Review**

Although the teleconference/WebEx format of the review allows an excellent opportunity for the members of the SRP to receive a briefing on the current status of the Sensorimotor Risk, there is no real opportunity for the SRP members to discuss any of the issues among themselves in depth, nor is there an opportunity to interact with the presenters after later deliberations. The in-person meetings of the SRP are far superior, and should be pursued whenever possible.

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#### **IV. 2015 Sensorimotor Risk SRP Evidence Review: Statement of Task for the Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight**

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In 2008, the Institute of Medicine (IOM) reviewed NASA's Human Research Program (HRP) Evidence Books that describe the Risks that were identified in NASA's Human Research Program Requirements Document (PRD). The 2015 Evidence Report for the Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight (Sensorimotor Risk) has not been reviewed since the last IOM review and there have been significant changes to the evidence base for the Risk.

The 2015 Sensorimotor Risk Standing Review Panel (SRP) is chartered by the Human Research Program (HRP) Chief Scientist to review the updated Evidence Report for the Sensorimotor Risk. The 2015 Sensorimotor Risk SRP will evaluate the Evidence Report and generate a final report of your analyses of the evidence base, including any recommendations on how to improve the current Evidence Report, and submit it to the HRP Chief Scientist. Your report will also be made available on the Human Research Roadmap (HRR) website.

##### **The 2015 Sensorimotor Risk SRP is charged to:**

1. Evaluate the 2015 Sensorimotor Risk Evidence Report based on each of the following criteria:
  - A. Does the 2015 Evidence Report provide sufficient evidence that the Risk is relevant to long-term space missions?
  - B. Are the Risk Title and Statement properly stated in the current version of the HRP Integrated Research Plan (IRP)?\*
  - C. Is the text of the Risk Context provided in the HRP IRP clear?\*
  - D. Does the 2015 Evidence Report make the case for the research gaps presented?
  - E. Are there any additional knowledge-type gaps or areas of fundamental research that should be considered to enhance the basic understanding of this specific Risk?
  - F. Does the Evidence Report address relevant interactions between this Risk and others in the HRP IRP?
  - G. Is input from additional disciplines needed?
  - H. Is the expertise of the authors sufficient to fully cover the scope of the given risk?
  - I. Is there information from other HRP disciplines that need to be included in the 2015 Evidence Report?
  - J. Is the breadth of the cited literature sufficient?
  - K. What is the overall quality and readability of the 2015 Evidence Report?
2. Provide comments on any important issues that are not covered by the criteria in #1 above.

*\* Please be aware that any suggested changes to the Risk Title, Statement, and Risk Context by the SRP may need to be approved by the Human Systems Risk Board (HSRB). The HSRB has the overall responsibility to implement and maintain a consistent, integrated process for assessing, documenting, and tracking all risks to the human system associated with spaceflight activities (both in flight and post flight).*

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**Additional information regarding this review:**

1. Participate in a WebEx conference call on December 17, 2015 at 1:00 pm ET to discuss the Evidence Report with the Human Health Countermeasures (HHC) Element.
2. Prepare a draft final report within one month of the WebEx conference call that contains a detailed evaluation of the Evidence Report specifically addressing items #1 and #2 of the SRP charge. The draft final report will be sent to the HRP Chief Scientist and he will forward it to the appropriate Element for their review. The HHC Element and the HRP Chief Scientist will review the draft final report and identify any misunderstandings or errors of fact and then provide official feedback to the SRP within two weeks of receipt of the draft report. If any misunderstandings or errors of fact are identified, the SRP will be requested to address them and finalize the 2015 SRP Final Report as quickly as possible. The 2015 SRP Final Report will be submitted to the HRP Chief Scientist and copies will be provided to the HHC Element that sponsors the sensorimotor discipline and also made available to the other HRP Elements. The 2015 SRP Final Report will be made available on the HRR website (<http://humanresearchroadmap.nasa.gov/>).

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**To clarify, the Risk Statement and Risk Context are defined as follows:**

**Risk Statement:**

“Given the CONDITION, there is a possibility that a CONSEQUENCE will occur”.

Condition: a single phrase briefly describing current key circumstances, situations, etc. that are causing concern, doubt, anxiety, or uncertainty – something that keeps you up at night.

Consequence: a single phrase or sentence that describes the key, negative outcome(s) of the current conditions.

Notes:

The condition-consequence format provides a more complete picture of the Risk, which is critical during mitigation planning. The condition component focuses on what is currently causing concern. This is something that is true or widely perceived to be true. This component provides information that is useful when determining how to mitigate a Risk.

The consequence component focuses on the intermediate and long-term impact of the risk. Understanding the depth and breadth of the impact is useful in determining how much time, resources, and effort should be allocated to the mitigation effort.

A well-formed Risk Statement usually has only one condition, and has one or more consequences.

**Risk Context:**

Purpose: provide enough additional information about the Risk to ensure that the original intent of the Risk can be understood by other personnel, particularly after time has passed.

Description: capture additional information regarding the circumstances, events, and interrelationships not described in the Risk Statement.

An effective context captures the what, when, where, how, and why of the Risk by describing the circumstances, contributing factors, and related issues (background and additional information that are NOT in the Risk Statement).

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**V. 2015 Sensorimotor Risk SRP Status Review: Statement of Task for the Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight**

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The 2015 Sensorimotor Risk Standing Review Panel (SRP) will participate in a Status Review that will occur via a WebEx/teleconference with the Human Research Program (HRP) Chief Scientist (or designee) and members of the Human Health Countermeasures (HHC) Element. The purpose of this review is for the SRP to:

1. Receive an update by the HRP Chief Scientist (or designee) on the status of NASA's current and future exploration plans and the impact these will have on the HRP.
2. Receive an update on any changes within the HRP since the 2014 SRP meeting.
3. Receive an update by the Element or Project Scientist(s) since the 2014 SRP meeting.
4. Participate in a discussion with the HRP Chief Scientist (or designee) and the Element regarding possible topics to be addressed at the next SRP meeting

The 2015 Sensorimotor Risk SRP will produce a report/comments from this status review within 30 days of the 2015 update. These comments will be submitted to the HRP Chief Scientist and copies will be provided to the HHC Element that sponsors the muscle discipline and also made available to the other HRP Elements. The 2015 SRP Final Report will be made available on the Human Research Roadmap public website (<http://humanresearchroadmap.nasa.gov/>).

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## **VI. Sensorimotor Risk SRP Evidence Review WebEx/Teleconference Participants**

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### **SRP Members:**

Malcolm Cohen, Ph.D. (chair) – NASA Ames Consultant (retired)

Susan Herdman, Ph.D. – Emory University

John Krakauer, M.D. – The Johns Hopkins Hospital

### **NASA Johnson Space Center (JSC):**

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Mark Shelhamer, Sc.D.

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Susan Steinberg, Ph.D.

Laura Taylor, Ph.D.

Jennifer Villareal, Ph.D.

### **NASA Headquarters (HQ):**

Stephen Davison, Ph.D.

Bruce Hather, Ph.D.

### **NASA Space Biomedical Research Institute (NSBRI)**

Tracy Johnson, Ph.D.

### **NASA Research and Education Support Services (NRESS):**

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## VII. 2015 Sensorimotor Risk SRP Roster

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