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## 2012 Occupant Protection Risk Standing Review Panel

### Research Plan Review for: *The Risk of Injury from Dynamic Loads*

### Final Report

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## I. Executive Summary and Overall Evaluation

The 2012 Occupant Protection (OP) Risk Standing Review Panel (from here on referred to as the SRP) met for a site visit in Houston, TX on November 8 - 9, 2012. The SRP reviewed the new Evidence Report for the Risk of Injury from Dynamic Loads, as well as the Research Plan for this Risk that is in the Human Research Program's (HRP) Integrated Research Plan (IRP Rev. D)

Overall, the SRP thought that the Research Plan described in the IRP Rev. D was thorough and well organized.

## II. Critique of Gaps and Tasks for the Risk of Injury from Dynamic Loads

### Gaps and Tasks:

#### **OP1: How do we protect the crew from injury during dynamic phases of flight?**

The SRP could not come to agreement on what the term "dynamic phases of flight" was, so this needs to be defined better. If this includes any event that causes transient loads, then perhaps the word "mission" should be used as in "dynamic phases of flight and dynamic events during the mission."

#### Tasks:

- **Occupant Protection Data Mining and Modeling Project** – PI: Michael Gernhardt, Ph.D., NASA Johnson Space Center
    - The SRP thinks that before mining the data, the OP discipline needs to have a better definition of the test conditions that include G-loads and time durations by direction.
    - Instead of basing their analyses only on selected examples, the PI should attempt to establish time-history corridors for accelerations and loads that include worst-case scenarios. The SRP thinks it is necessary to establish acceleration-time or force-time scenarios that are specific to occupant loading directions in nominal and off-nominal (includes worst-case) scenarios. Of course, if NASA knows what the G-time history of the capsule is, that can be translated to the occupants with certain assumptions or modeling techniques. It will be easier to protect the occupant if it is known that in an off-nominal landing, for example, the capsule experiences a certain G-time pulse in each direction. The SRP found it surprising that the current Orion design of a stroking occupant platform was based upon very limited information. The SRP would like to see more specific design criteria based upon a bounding of the problem (corridor) in the form of G-load-time histories in the X-, Y-, and Z-directions.
  - **Comparison of Biodynamics Models Using Automotive Racing Crash Data** – Task completed
    - Although this task is completed, the SRP is unsure of the relevance of this task to the
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gap since the data they are comparing (race car drivers) are in a very different environment than an astronaut (the race car drivers are packaged well, seat, helmet) and the directions of loading seem also quite different to space applications.

- **Deconditioning Summit** – PI: Michael Gernhardt, Ph.D., NASA Johnson Space Center
  - The SRP thinks this task is relevant and appropriate for this particular gap.
- **Deconditioning Summit Follow-On Study** – Planned task
  - The SRP thinks that any of the studies that pertain to bone strength are relevant to OP whereas the studies looking at the mechanism of bone degradation are not relevant to OP. The OP group ideally would need a scaling factor of some kind that provides bone strength loss as a function of anti-gravity exposure. Perhaps also as a function of individual bones.
- **EFT-1 Modeling** – Planned task
  - The SRP recommends measuring linear acceleration and angular velocity in each of the three directions so that the PI will have six degrees of freedom (6DoF) when measuring acceleration. It has been demonstrated that concussion and other diffuse brain injuries are more related to rotational rather than linear acceleration measures.
  - The PI should state where the accelerometers will be positioned in the vehicle and how they plan to use the data to estimate the seat accelerations computationally.
- **EM-1 Data Collection and Modeling** – Planned task
  - The SRP thinks that this study could replace task “EFT-1 Modeling” because this task will provide all the data you received from “EFT-1 Modeling” plus a lot more. The SRP recommends adding high-speed cameras and kinematic markers on the dummies; the manufacturer (Integrated Device Technology (IDT)) makes a small size high-speed, high-resolution camera (Nx Series) that might work well onboard and inside the occupant compartment during flight. The SRP also suggests using this study to help with validation. Therefore, one dummy should wear a suit and helmet and one should be unsuited to examine motion differences.
  - The SRP discussed several options for high-speed cameras including ones that may not require high-wattage lighting to illuminate the dummies. These may be the best option due to space constraints within the vehicle. The PI should provide details as to how and where motion tracking markers will be placed on the dummies.
- **EM-2 Modeling** – Planned task
  - The SRP does not think this task will aid the validation of the model in its current explanation. The SRP recommends collecting acceleration data off the crew not the seats; dummies should be equipped with accelerometers and onboard data acquisition systems. Ideally, the PI should obtain the same measurements on the crew and the volunteers so as to validate the volunteer experiments. The addition of the high-speed cameras would facilitate kinematic analysis.
  - The HRP IRP Rev. D. indicates that this task is planned to occur well in the future, FY 20. The PI should provide a plan that describes steps that would be taken if these data indicate that the earlier computational modeling data were not valid. Would there be sufficient time to improve the seat and restraint systems for occupant protection? What parameters will be used to compare with the previous volunteer experiments and modeling results and what error level is acceptable?
- **Human Volunteer Testing** – Planned task
  - The SRP thinks this task is relevant and appropriate for this particular gap. The SRP

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is unsure of what will be measured in volunteers, but the SRP recommends getting as many measurements as possible from the volunteers (kinematics and accelerations to match back to Test device for Human Occupant Restraint (THOR)). The SRP thinks the experimental design needs to validate the biofidelity of THOR and more tests should be focused on the 50<sup>th</sup> percentile. The SRP thinks the sample size will need to be adjusted accordingly to look at sex differences, anthropometry, and age if those are relevant variables.

- The time-history responses for input loads and accelerations should be specified and an explanation provided as to how these chosen responses relate to actual responses that an astronaut will experience during a mission. This relates to the proposed new task below.

**Proposed New Task:** The SRP suggests that a new task be included before any of the listed tasks are done that defines what “spaceflight dynamics” are. It would help the project goals if the group could more specifically define (or at least bound) the acceleration magnitudes and directions associated with the dynamic phases of flight and the mission so that the other tasks can have more specific endpoint goals. As a result, the task should help define what nominal and off-nominal loads are.

### **III. Discussion on the strengths and weaknesses of the IRP and identify remedies for the weaknesses, including answering these questions:**

Is the Risk addressed in a comprehensive manner?

- The SRP thinks the risk is addressed in a comprehensive manner and that the OP discipline is doing everything that should be done (data mining, mission exposure).
- The SRP thinks that the OP group is following the right procedures considering the difficult task they have of identifying nominal and off-nominal conditions.

Are there obvious areas of potential integration across disciplines that are not addressed?

- The SRP thinks that the integration with the bone discipline is very good.
- The SRP suggests more integration with the muscle/exercise discipline, intervertebral disc (IVD) discipline, and osteoporosis discipline because some of their intrinsic factors may affect occupant tolerance to dynamic impacts.

Although the majority of the tasks under this gap were “Planned”, the SRP thinks that tasks still should have had more details about the aims and expected deliverables.

### **IV. Additional Comments**

Research Plan presentation, page 7

- The rationale for injury prevention countermeasures focuses on injuries to the extremities. The SRP suggests broadening this rationale statement to include the importance of preventing injuries to other anatomical regions including head, neck, back, chest, etc.

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Research Plan presentation, page 34

- The list of critical injury definitions is too general.
- The SRP thinks that the list of injuries should be specific to deriving countermeasures.

Research Plan presentation, page 43

- The PIs should explain how these parameters will be computed or measured from the human volunteer tests. Why were these specific parameters chosen and not others that may also be relevant to injury causation (i.e., cervical and lumbar spine shear forces and bending moments)?

## **V. 2012 Occupant Protection Risk SRP Research Plan Review (Site Visit): Statement of Task for the Risk of Injury from Dynamic Loads**

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The 2012 Occupant Protection (OP) Risk Standing Review Panel (SRP) is chartered by the Human Research Program (HRP) Chief Scientist. The purpose of the SRP is to review the Human Health Countermeasures (HHC) Element section of the HRP's Integrated Research Plan, Revision D (IRP Rev. D) which is located on the Human Research Roadmap (HRR) website (<http://humanresearchroadmap.nasa.gov/>). Your report will be provided to the HRP Chief Scientist.

### **The 2012 Occupant Protection Risk SRP is charged (to the fullest extent practicable) to:**

1. Evaluate the ability of the IRP Rev. D to satisfactorily address the Risk by answering the following questions:
  - A. Have the proper Gaps been identified to address the Risk?
    - i) Are all the Gaps relevant?
    - ii) Are any Gaps missing?
  - B. Has the appropriate target for closure for the Gap been identified?
    - i) Are the interim stages appropriate to close the Gap?
  - C. Have the proper Tasks been identified to fill the Gaps?
    - i) Are the Tasks relevant?
    - ii) Are any Tasks missing?
2. Identify the strengths and weaknesses of the IRP Rev. D, *and* identify remedies for the weaknesses, including answering these questions:
  - A. Is the Risk addressed in a comprehensive manner?
  - B. Are there obvious areas of potential integration across disciplines that are not addressed?
3. Please evaluate the progress in the IRP Rev. D since your 2011 SRP meeting.
4. Please comment on any important issues that are not covered in #1, #2, or #3 above. If a charge addendum is provided, please address each of the questions as fully as possible.

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### **Additional Information Regarding This Review:**

1. Expect to receive review materials at least four weeks prior to the meetings.
2. Participate in a 2012 OP Risk SRP conference call to discuss any issues, concerns, and expectations of the review process approximately three weeks prior to the meeting.
  - A. Discuss the 2012 OP Risk SRP Statement of Task and address questions about the SRP process.
  - B. Identify any issues the 2012 OP Risk SRP would like to have answered prior to or during the meeting.
3. Attend the 2012 OP Risk SRP meeting at NASA JSC on November 8 - 9, 2012.
  - A. Attend Element or Project presentations, question and answer session, and briefing.
  - B. Prepare a draft report that addresses each of the evaluation criteria listed in the panel charge. Debrief the HRP Chief Scientist and a representative from the HHC Element on the salient points that will be included in the final report and specifically the items in the panel charge.
4. Prepare a draft final report (within one month of the site visit debrief) that contains a detailed evaluation of the current IRP specifically addressing items #1, #2, #3, and #4 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 have 10 business days to review the draft final report and identify any misunderstandings or errors of fact and then provide official feedback to the SRP. The SRP will have 10 business days to address any issues and finalize the 2012 SRP Final Report. The 2012 SRP Final Report will be submitted to the HRP Chief Scientist and copies will be provided to the HHC Element that sponsors the OP discipline and also made available to the other HRP Elements. The 2012 SRP Final Report will be made available on the Human Research Roadmap public website (<http://humanresearchroadmap.nasa.gov/>).

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## VI. 2012 Occupant Protection Risk Standing Review Panel Roster

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