SDBI 1904: Human Factors Assessment of Vibration Effects on Visual Performance During Launch

The primary objective of the of Human Factors Short Duration Bioastronautics Investigation (SDBI) 1904 is to determine visual performance limits during operational vibration and g-loads, specifically through the determination of minimal usable font sizes using Orion-type display formats. Currently there is little to no data available to quantify human visual performance under these extreme conditions. Existing data on shuttle vibration magnitude and frequency is incomplete, does not address seat and crew vibration in the current configuration, and does not address human visual performance. There have been anecdotal reports of performance decrements from shuttle crews, but no structured data has been collected.

The SDBI is a companion effort to the Detailed Test Objective (DTO) 695, which will measure shuttle seat accelerations (vibration) during ascent. Data from the SDBI will serve an important role in interpreting the DTO vibration data. This data will be collected during the ascent phase of three shuttle missions (STS-119, 127, and 128). Both SDBI1904 and DTO 695 are low impact with respect to flight resources, and combined they represent an efficient and focused problem solving approach.

The SDBI and DTO data will be correlated to determine the nature of perceived visual performance under varying vibrations and g-loads. This project will provide:

- Immediate data for developing preliminary human performance vibration requirements
- Flight validated inputs for ongoing and future ground-based research
- Information of functional needs that will drive Orion display format design decisions

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Shelby G. Thompson, Ph.D.[1], Kritina Holden, Ph.D.[1], Douglas Ebert, Ph.D.[2]
Phillip Root[3], Bernard Adelstein, Ph.D.[4], Jeffery Jones, M.D. [3]
[1]Lockheed Martin Mission Operations [3]Wyle Integrated Science and Engineering Group
[3]NASA, Johnson Space Center [4]NASA, Ames Research Center

ABSTRACT

The primary objective of the of Human Factors Short Duration Bioastronautics Investigation (SDBI) 1904 is to determine visual performance limits during operational vibration and g-loads, specifically through the determination of minimal usable font sizes using Orion-type display formats. Currently there is little to no data available to quantify human visual performance under these extreme conditions. Existing data on shuttle vibration magnitude and frequency is incomplete, does not address seat and crew vibration in the current configuration, and does not address human visual performance. There have been anecdotal reports of performance decrements from shuttle crews, but no structured data has been collected.

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INTRODUCTION

The aim of the visual performance SDBI 1904 is to provide supplementary data to that collected by the seat vibration DTO 695. While the DTO data alone are important in terms of providing a measure of vibration and g-loading, human performance data are required to fully interpret the impact of the vibration values collected. The visual performance data collected by the SDBI (i.e., font size for proposed Orion display formats), coupled with subjective comments, will lead to a better understanding of visual performance under the varied vibration and g-loads in an operational setting. These results can be directly applied to future Constellation display format designs in order to mitigate the risks associated with thrust oscillation and human performance.

The SDBI 1904 is an opportunity to address the need for requirements by conducting a highly focused and applied evaluation in a relevant spaceflight environment.

Relevance of Study to Project Risks

The Constellation Program (CxP) plans to take astronauts back to the moon and beyond. The CxP and the Health and Medical Technical Authority (HMTA) are both tracking first stage Ares-I thrust oscillation as one of *the top Program risks*.

SDBI 1904 will address the following program risks currently logged in the Integrated Risk Management Application (IRMA):

- IRMA 2583 – CEV Impacts Due to Thrust Oscillation
  - Given the Ares-I first stage solid rocket will have a thrust oscillation associated with the 1st acoustical resonance occurring during first stage flight and a resonance excitation of the stack axial modes, there is a possibility that the primary and secondary structure of the CEV will be overloaded and the crew's ability to execute normal functions will be impaired.
- IRMA 3397 – Vibration Effects of Crew Performance
  - Given the significant vibrations generated by Ares-I first stage thrust oscillation, there is a possibility that vibrations at the crew seats will cause significant manual and visual task performance degradation and potential after effects.

The Human Research Program (HRP) bears partial responsibility for the development of appropriate standards for human spaceflight; at this time the Constellation Program is faced with a top Program risk and a paucity of data, and HRP is uniquely equipped to provide critical data toward the solution of this problem at minimal cost.

Currently, no performance limits on vibration exist for the Program

- If overly conservative limits are arbitrarily chosen, there is a high risk of overspending and delay of schedule due to the development of unnecessary vibration mitigation strategies.
- If liberal limits are imposed, a similar risk exists; re-design of display and control systems after implementation for the purpose of solving vibration-related performance issues would incur substantial cost and delay of Orion operations.

The SDBI 1904 is related to all three of the SHFH risks:

- Risk of Error Due to Inadequate Information
- Risk Associated with Poor Task Design
- Risk of Reduced Safety and Efficiency Due to Poor Human Factors Design

If data cannot be found in a display because the or text is not easily readable because of high vibration or g-loading, crewmembers will not be able to perform the task or have reduced productivity, and increased errors.

METHODS

Test Environment and Participants

The SDBI will take place in cooperation with the DTO onboard three shuttle missions:

Mission	Launch Date
STS-119	February 12th
STS-127	March '09
STS-128	August '09

- All data will be collected on the mid-deck of the shuttle (see Figure 1)
- This gives the potential to collect data with up to nine crewmembers (3 per flight)
- Consent protocols have been completed (i.e., CPHS, HRMRB, and international review boards), whereby shuttle, station, and international partners are all eligible to participate

Evaluation Materials

- Three placards (16" wide x 10" tall) will be attached with Velcro to a single locker face, one directly in front of each mid-deck crewmember (see Figure 2).
- Each display format will contain one of four effective font sizes (10, 12, 14, or 17 point) as illustrated in Figure 3

Procedures

Data will be collected by marking a data collection sheet (see Figure 4). There are five vibration phases of interest that data will be collected:

- Pre-launch – no vibration or g-loading (control assessment)
- Launch – highest vibration phase, (~10 seconds post lift-off)
- Pre-max Q – the time from lowest vibration after launch until onset of the highest dynamic pressure (q), (~20 seconds post lift-off)
- Max Q – the time of highest dynamic pressure and second highest vibration during the ascent phase of flight, (~50 seconds post lift-off)
- Post-max Q – the time after max q until SRB separation, (~80 – 125 seconds post lift-off)

Following SRB separation, participants will fill-out a short questionnaire concerning different aspects of the display (see Figure 4). Participants will also be debriefed following their mission or via email if aboard ISS.

CURRENT STATUS

- Placard placement is discussed with crew at first post-insertion training (~L -6 months)
  - This was just completed for STS-128
- In depth training of data collection procedures using a vibrating display placard occurs at last post-insertion training (~L -1 month)
  - This was just completed for STS-119
  - STS-127 training TBD

The number of participants for each mission and study conditions are as follows:

- STS-119: no video, 2 participants sharing a single placard
- STS-127: video, 3 participants and 3 placards
- STS-128: video, 3 participants and 3 placards

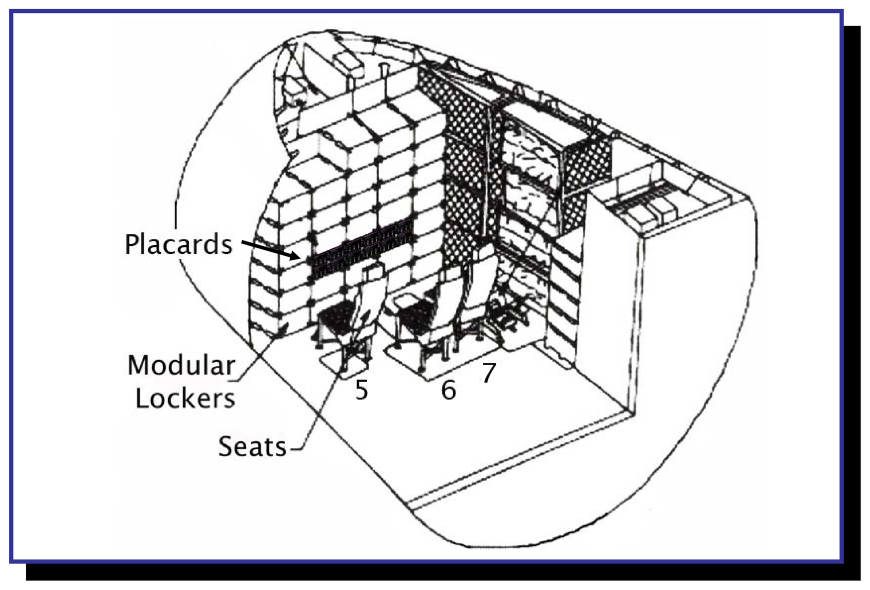
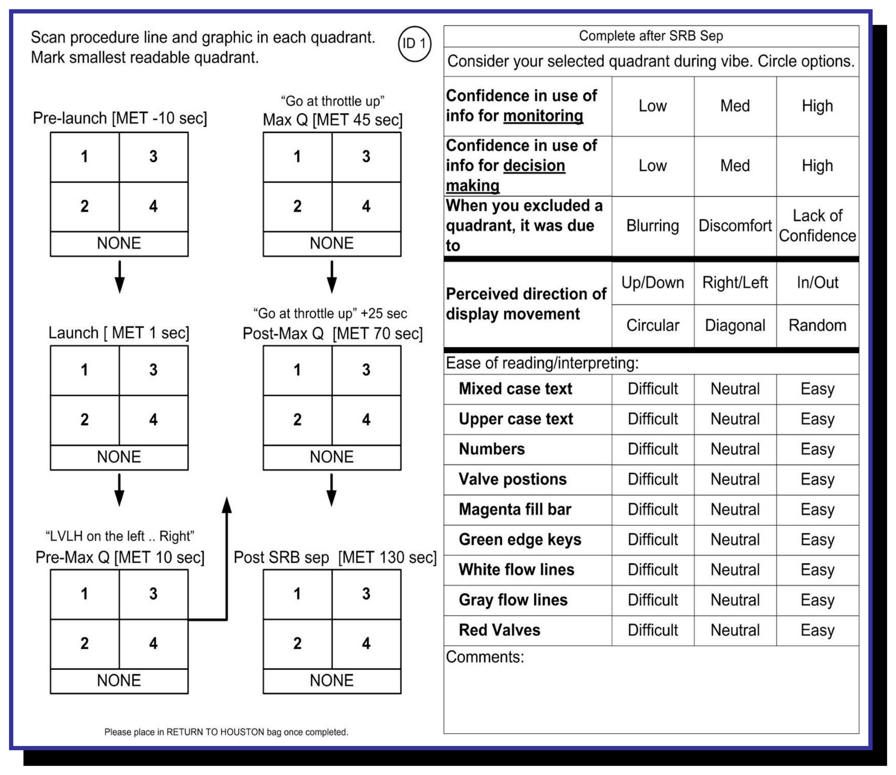


Figure 1. Diagram of the shuttle mid-deck showing the seating arrangement for the three crewmembers and placards on the lockers.

Figure 2. View of the shuttle mid-deck with suggested placard placement for each of the three seats.

Figure 3. Placard that will be used during the shuttle flights to evaluate visual performance.



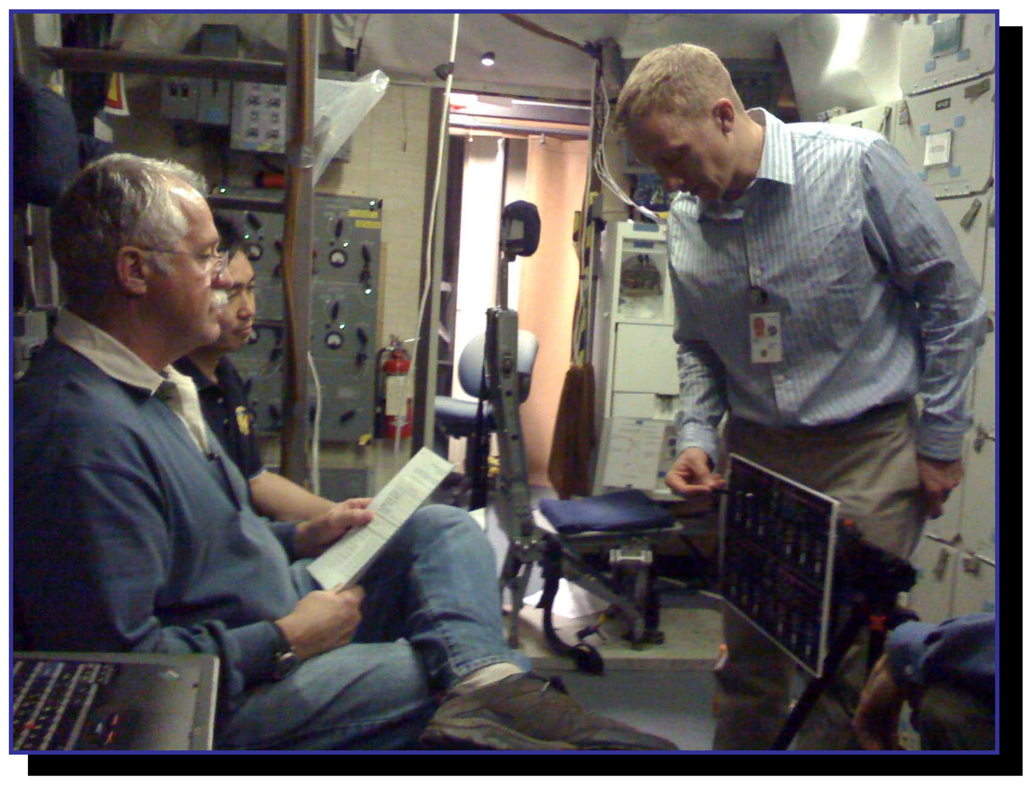
Scan procedure line and graphic in each quadrant.
Mark smallest readable quadrant.
ID 1

Pre-launch [MET -10 sec]: 1 3 / 2 4 / NONE
"Go at throttle up" Max Q [MET 45 sec]: 1 3 / 2 4 / NONE
Launch [MET 1 sec]: 1 3 / 2 4 / NONE
"Go at throttle up" +25 sec Post-Max Q [MET 70 sec]: 1 3 / 2 4 / NONE
"LVLH on the left .. Right" Pre-Max Q [MET 10 sec]: 1 3 / 2 4 / NONE
Post SRB sep [MET 130 sec]: 1 3 / 2 4 / NONE

Please place in RETURN TO HOUSTON bag once completed.

Complete after SRB Sep			
Consider your selected quadrant during vibe. Circle options.			
Confidence in use of info for monitoring	Low	Med	High
Confidence in use of info for decision making	Low	Med	High
When you excluded a quadrant, it was due to	Blurring	Discomfort	Lack of Confidence
Perceived direction of display movement	Up/Down	Right/Left	In/Out
	Circular	Diagonal	Random
Ease of reading/interpreting:			
Mixed case text	Difficult	Neutral	Easy
Upper case text	Difficult	Neutral	Easy
Numbers	Difficult	Neutral	Easy
Valve postions	Difficult	Neutral	Easy
Magenta fill bar	Difficult	Neutral	Easy
Green edge keys	Difficult	Neutral	Easy
White flow lines	Difficult	Neutral	Easy
Gray flow lines	Difficult	Neutral	Easy
Red Valves	Difficult	Neutral	Easy
Comments:			

Figure 4. Data collection sheet and post-evaluation questionnaire used in the current study.



Final training session for the 2 participants of the STS-119 mission.

Placard placement and training session for STS-128 crew participants.