Fiscal Year:	FY 2014	**Task Last Updated:**	FY 04/21/2014
PI Name:	Adelstein, Bernard Ph.D.		
Project Title:	Display Reading Performance Under Lateral Whole-Body Vibration Due to 12-Hz Thrust Oscillation		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **SHFH**:Space Human Factors & Habitability (archival in 2017)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	Bernard.D.Adelstein@nasa.gov	**Fax:**	FY
PI Organization Type:	NASA CENTER	**Phone:**	(650) 604-3922
Organization Name:	NASA Ames Research Center		
PI Address 1:	Human Systems Integration Division		
PI Address 2:	MS 262-2		
PI Web Page:			
City:	Moffett Field	**State:**	CA
Zip Code:	94035-1000	**Congressional District:**	18
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	Directed Research
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No. of PhD Candidates:		**No. of Master' Degrees:**	
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No. of Bachelor's Candidates:	2	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmore, Mihriban	**Contact Phone:**	281-244-1004
Contact Email:	mihriban.whitmore-1@nasa.gov		
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Flight Assignment:	NOTE: Extended to 10/30/2013 per E. Connell/HRP (Ed., 10/21/13)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Beutter, Brent (NASA Ames Research Center) Kaiser, Mary (NASA Ames Research Center) Dory, Jonathan (NASA Johnson Space Center)		
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Task Description:

Current analyses for the Orion and Space Launch System (SLS) Programs indicate that the crew will be subject predominantly to lateral (left-right for Orion seat occupant) vibration caused by out-of-phase ~12-Hz thrust oscillation (TO) in the SLS's two side-mounted solid rocket boosters. While these analyses show that the axial (occupant chest-to-spine) component of TO vibration will remain below the 0.21-grms and 0.7-gpeak limits established by the Constellation Program (CxP) for crew performance, the lateral component potentially could exceed the CxP requirement's 0.1-gpeak limit for concurrent off-axis vibration. The 0.1-gpeak lateral component limit has never been verified empirically, and may be overly conservative. The 0.1-gpeak limit is traceable to vibration studies conducted by our lab that enabled CxP's to define axial TO requirements. In those studies, under deliberately controlled axial vibration, we observed that participants exhibited oscillatory lateral head motion up to 0.1 gpeak as a "side effect" of the applied chest-to-spine vibration input, and that this had a negligible impact on their performance. This observation of negligible impact provided the basis of the CxP lateral vibration limit that according to the Orion and SLS Loads Panel was inherited by those programs. In recent months, the Orion and SLS Loads Panel has inquired about the validity of the TO vibration requirements' lateral component, and asked whether it could be relaxed in the presence of negligible axial vibration.
Spaceflight launch environments have several unique aspects including semi-supine (recumbent) seating posture, supported and potentially restrained crew head configuration, and peak vibration being accompanied by concurrent elevated G-load. These factors produce head-neck-torso biodynamic responses that differ significantly from the typical non-NASA configuration of upright, seated individuals without head restraints. Therefore, the existing literature for visual performance under vibration is of marginal applicability to the anticipated lateral SLS-Orion TO vibration. Specifically, human performance data under relevant seating and head-constraint conditions have been collected only to address the axial vehicle vibration concerns that arose for the Gemini and Constellation Programs. The absence of lateral performance data consequently necessitates further human-in-the-loop testing before (a) validated lateral vibration requirement(s) can be written for Orion and SLS. Presently, a new task covering lateral vibration is being planned for Gap SHFE-HAB-03. After completion of the proposed study, we will narrow this gap specifically by having addressed numeric text legibility (visual performance) under controlled single-frequency (12-Hz) lateral vibration, the current Orion/SLS concern.

Specific Aims:

In the proposed work, we will control lateral vibration (while minimizing chest-to-spine input components) at the predicted 12-Hz frequency of TO vibration in the first empirical investigation of the impact of lateral vibration amplitude on semi-supine observers' visual performance. We will measure observer performance in terms of response time and error rate, using the same numeric text legibility procedure that we employed previously to deliver similar data to CxP for axial (chest-to-spine) TO vibration. These new data will provide the SLS and Orion programs with a rational, quantitative basis to update the inherited CxP limit for lateral TO in the presence of minimal axial vibration, thereby allaying a human performance risk as well as potentially offering design relief for SLS and Orion.

In addition, we will also investigate the efficacy of a strobing countermeasure to improve the readability of display panels under lateral TO vibration. In previous work for axial TO, we showed strobing to be an effective mitigation, restoring display reading error rates at 0.7-g, 12-Hzvibration to the error rates measured for zero vibration. Knowledge gained from this work will provide the help augment the HIDH vibration section, which currently lacks information about the impact of lateral vibration on human performance relevant to spaceflight. Requirement(s) resulting from the proposed study may also be added to NASA-STD-3001 Vol. 2. , 12-Hz vibration to the error rates measured for zero vibration.

Rationale for HRP Directed Research:

Insufficient time for solicitation because data for human performance under lateral vibration are needed to support thrust oscillation and seat analyses, respectively, for SLS DAC-3 and MPCV MDAC-2 program milestones. The first milestone is SLS DAC-3 completion in September 2013.

Research Impact/Earth Benefits:

This directed project was conducted specifically to support NASA's Space Launch System (SLS) and Multipurpose Crew Vehicle (MPCV) Programs. The findings from the present project enable human-vibration-based vehicle requirements to be written for these NASA programs.
There are no immediate impacts or benefits for life on Earth beyond applicability of the project results to the aforementioned programs.

Task Progress:

NASA's Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (MPCV) Programs recently revealed that thrust oscillation (TO) from the SLS's side-mounted solid rocket boosters will cause astronauts to experience narrowly focused (~12-Hz) lateral (side-to-side) vibration during launch. This vibration raises a concern because of its potential impact on the crew's ability to visually monitor vehicle systems. Due to the absence of comparable spaceflight experience and relevant data in the literature, we conducted a laboratory investigation to address this concern by examining the effects of lateral vibration on visual performance in order to support the programs' development of new TO requirements.
The investigation comprised two experiments. In the first, we sought to identify the vibration amplitudes that resulted in degraded visual performance. In the second, we examined whether any such decrements could be mitigated by a display strobing countermeasure that we had previously demonstrated to be effective for axial (chest-to-spine) vibration. In each experiment, the same general-population participants (8 male/4 female, ages 23-42 years) performed a number reading task while undergoing lateral, whole-body vibration at 12-Hz that was superimposed on a 1-G (Earth gravity) chest-to-spine bias in a semi-supine space-launch seating configuration. The display was held stationary (i.e., never vibrated) during the study. In addition, a strap snugged across the forehead served as a surrogate for the elevated G-loading that would be encountered during launch, thereby ensuring continuous head contact with the seatback. The task, which was identical to one we employed to inform the Constellation Program's development of similar requirements for axial TO vibration during 2008-2009, involves viewing an Orion-inspired high-density numeric display format on a liquid-crystal display (LCD) panel, locating a specified three-digit string, and determining whether that string comprises a monotonic sequence. Thus the task tested both visual acuity and cognitive processing.

Trials were grouped into 145-s vibration blocks, each delivered at a constant sinusoidal amplitude. For the first experiment, blocks at zero-to-peak vibration levels between zero and 0.7 g (bracketing current estimates for lateral

Task Progress:	TO-driven vibration to crew) were presented under constant LCD backlight illumination. After a rest period, two more 0.7-g blocks were presented, one in which the backlight was strobed in synchrony with chair vibration and another in which the backlight was dimmed to an equivalent constant luminance. Each participant's block order was repeated on a second day, with a 10-pt font-size version of the task presented on one of the days and 14.5-pt on the other. Objective measurements of task error rates and average response times, as well as participants' subjective ratings of workload and the visual and cognitive impact of vibration, were obtained for each block. While some subjective ratings indicated statistically significant differences between the highest level (0.7 g) and the zero-vibration control condition in the first experiment for both font sizes, neither the error rates nor average response times demonstrated a significant impact of vibration at any study level, with median error rates remaining below the task's 5% baseline for all conditions. Moreover, due to the absence of any objective impact for 0.7-g lateral vibration, the strobe countermeasure was not seen to confer a benefit in this case. High-speed (200 frames/s) video recordings of eye-in-space motion analyzed from five of the study participants revealed that the eye was minimally affected by lateral vibration in the 12-Hz band, with resultant gaze deflections rising on average by only ±2 arcmin (±0.28 mm at the display panel). This limited response, when compared with ±1.2 mm of lateral seatback motion adjacent to the head for 0.7-g vibration, suggests that the absence of objectively measured performance effects may be due to the observers' eye-head system being largely decoupled from lateral chair inputs at 12-Hz despite the head restraint strap. With negligible 12-Hz lateral eye-head response, visual blur therefore would be dominated by display panel vibration, with such panel motion either estimated from engineering models or directly measured.
Bibliography Type:	Description: (Last Updated: 04/13/2017)
Abstracts for Journals and Proceedings	Adelstein BD, Beutter BR, Kaiser, MK, Dory JR, Anderson MR, Liston DB. "Display Reading Performance Under Lateral Whole-Body Vibration Due to 12-Hz Thrust Oscillation." 2014 NASA Human Research Program Investigators' Workshop, Galveston, TX, February 12-13, 2014. 2014 NASA Human Research Program Investigators' Workshop, Galveston, TX, February 12-13, 2014. http://www.hou.usra.edu/meetings/hrp2014/pdf/3136.pdf , Feb-2014