Fiscal Year:	FY 2010	**Task Last Updated:**	FY 09/14/2010
PI Name:	Small, Ron M.S.		
Project Title:	Modeling and mitigating spatial disorientation in low g environments		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Sensorimotor Adaptation Team		
Joint Agency Name:		**TechPort:**	Yes
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		
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City:	Boulder	**State:**	CO
Zip Code:	80301-2577	**Congressional District:**	2
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2007 NSBRI-RFA-07-01 Human Health in Space
Start Date:	09/01/2007	**End Date:**	08/31/2011
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Young, Laurence (Massachusetts Institute of Technology) Oman, Charles (Massachusetts Institute of Technology) Wickens, Christopher (Alion Science & Technology Corp.)		
Grant/Contract No.:	NCC 9-58-SA01302		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Original Aims: The goal of this industry-university research and development project is to extend Alion's spatial disorientation mitigation software - originally developed for aeronautical use - to NASA's space applications including the Shuttle, CEV, Altair, and Mars exploration missions. Alion's Spatial Disorientation Analysis Tool (SDAT) was designed for post hoc analyses of aircraft trajectory data from U.S. Navy, Air Force and NTSB mishaps to determine the presence or absence of vestibular SD. SOAS (Spatial Orientation Aiding System) is a real-time cockpit aid that has been evaluated in simulators with rated pilots. Both tools incorporate models of the vestibular system and assessor heuristics to predict the epoch and probability of an SD event such as Leans, Coriolis, or Graveyard Spiral illusions, as well as any other significant disparities between actual and perceived pitch attitude (somatogravic), roll rate, or yaw/heading rate. SOAS assesses multi-sensory workload to determine the types of countermeasures to trigger and when to trigger them. This project will: 1) Enhance the utility of SDAT/SOAS by including appropriate mathematical models for vestibular and visual sensory cues, and CNS gravito-inertial force resolution into perceived tilt and translation estimates from MIT's Observer model, and revalidating it using existing aeronautical data sets. 2) Extend the models to describe 0-G, Shuttle, and Altair landing illusions, validating the models using Shuttle and Altair simulator data sets, and current theories (e.g., ROTTR). 3) Extend SDAT/SOAS to consider multiple visual frames of reference, the effects of visual attention and sensory workload, and the cognitive costs of mental rotation and reorientation. The enhanced SDAT/SOAS from Aims 1-3 will be validated via simulator experiments. Key Findings: During the project's third year, we focused on: merging MIT's Observer perception models with Alion's SDAT; enhancing both Observer and SDAT based upon data set analyses, verification tests, and comparisons of analytical results produced by the two models; validation of Observer via comparison to perception data from a NASA-Ames vertical motion simulator (VMS) lunar landing simulator experiment (in collaboration with Dr. Young's NSBRI-funded lunar landing project at MIT), and a dynamic swinging experiment (in collaboration with Drs. Rader and Merfeld at the Massachusetts Eye and Ear Infirmary); obtaining helicopter spatial disorientation event data sets for verification and validation tests; validating and enhancing our visual frame of reference transformation (FORT) tool; and, creating a Space Shuttle orientation survey for commanders and pilots. Due to Constellation program changes, we broadened our focus to include helicopter and fixed-wing aircraft disorientation scenarios and Space Shuttle orientation issues. MIT's Observer has been enhanced with visual inputs and calculations to account for the impact of visual cues on a human's perception of attitude, velocity and displacement. Validations of Observer included: linear and angular acceleration steps; post-rotation tilt; vertical yaw rotations (with and without vision cues); somatogravic illusions (linear acceleration with and without vision cues, and fixed and variable radius centrifugation); static and dynamic roll tilt; off vertical axis rotation; large amplitude horizontal and vertical sinusoidal displacements; circular vection ; linear vection; Coriolis and pseudo-Coriolis illusions; and, astronaut post-flight tilt-gain and tilt-translation illusions. To facilitate integration with SDAT, eObserver, a stand-alone version of Observer was developed; eObserver does not require a MatLab license to run. It includes a GUI (developed by Alion) to ease data file selection and processing step selections. Vestibular threshold literature was studied to determine the best way to represent SCC and otolith thresholds within Observer as a prerequisite for replacing SDAT's vestibular attitude calculator with Observer. The FORT tool was validated and modified using the available literature to adjust FORT costs and achieve higher correlations with previous experimental data. SDAT/SOAS is being enhanced with illusions heuristics for pilots of vertical landing vehicles. The IRB-approved survey of Shuttle commanders and pilots seeks to capture the experiences of these crew members before the Shuttle is retired. It asks questions about illusory sensations and how each respondent coped with those sensations, if he/she experienced any. The survey was peer reviewed and will be revised to accommodate peer comments as well as suggestions from the first two respondents. Impact of Key Findings on Original Aims: The most important impacts from Year 3 are: we now have a method for integrating Observer into SDAT, a plan for integrating FORT costs into SDAT, new illusion heuristics for vertical landing vehicles (e.g., helicopters and lunar landers), helicopter SD event data sets for verifying and validating perception models and enhancements, and a survey with which to capture the prevalence and severity of Space Shuttle orientation issues. Proposed Research Plan for Year 4: In the fourth year of this project, the Alion-MIT team will: (1) Complete enhancements to, and the merging of, SDAT and Observer, and continue comparing analytical results of common data sets. (2) Validate enhancements with previous aircraft flight data sets and new data sets (from actual vehicles and simulators). Included will be helicopter SD event data sets and data sets from space vehicle simulators (e.g. NASA-Ames' VMS). (3) Incorporate FORT tool scores into SDAT calculations of SD probability. (4) Characterize the prevalence and severity of Space Shuttle re-entry and landing orientation issues. (5) Plan and conduct experiments to generate validation data (e.g., vertical motion threshold data) and/or to demonstrate the value of SD countermeasures.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	An important goal of this research and development project is to enhance Alion's spatial disorientation analysis tool (SDAT) and spatial orientation aiding system (SOAS), and MIT's Observer human perception model, so that the combined system accurately detects and classifies spatial disorientation events, and triggers the appropriate countermeasures for the situation. The combined system will be useful for aircraft pilots, space travelers, accident investigators, flying safety offices, and physiologists. This wide range of applicability is due to the intentional design of the system's components (i.e., SDAT, SOAS, & Observer) to be useful for post hoc analyses and for in-cockpit pilot aiding.
Task Progress:	During the project's third year, we accomplished the following: • Merged a compiled version of Observer (eObserver) with SDAT; • Investigated how to incorporate thresholds into Observer; • Submitted a manuscript to Biological Cybernetics comparing Observer and Kalman filter models of human orientation perception; • Obtained actual helicopter spatial disorientation event data sets for verification and validation tests; • Gathered perception data from a lunar landing simulator experiment (in collaboration with Dr. Young's NSBRI lunar landing project at MIT); • Validated and enhanced our visual frame of reference transformation (FORT) tool;

Task Progress:	• Submitted a FORT tool paper for the annual Human Factors and Ergonomics Society (HFES) meeting in San Francisco in October 2010 that was accepted; • Created a Space Shuttle orientation survey, for past and present commanders and pilots, that was approved by the MIT and JSC IRBs; and, • Updated the SDAT user guide. Previous technical reports from this project were also published at the FAA's Civil Aero Medical Institute (CAMI) spatial disorientation web site: http://www.faa.gov/
Bibliography Type:	Description: (Last Updated: 09/08/2020)
Articles in Other Journals or Periodicals	Selva P, Oman CM. "Relationships between observer and kalman filter models for human dynamic spatial orientation." Biological Cybernetics. In press, 2010. , May-2010
Dissertations and Theses	Venkatesan RH. "Multisensory models for human spatial orientation including threshold effects." Thesis, Massachusetts Institute of Technology, May 2010. , May-2010
NASA Technical Documents	Small RL, Keller JW, Wickens CD, Oman CM, Newman M, Young LR, Jones TD, Brehon M. "Modeling and mitigating spatial disorientation in low g environments: year 2 report." Boulder, CO : Alion Science and Technology Corp., 2010. , Feb-2010
Papers from Meeting Proceedings	Wickens CD, Keller JW, Small RL. "Left. No, right! Development of the frame of reference transformation tool (FORT)." To be presented at Human Factors and Ergonomics Society (HFES) 54th Annual Meeting, San Francisco, CA, September 27-October 1, 2010. Human Factors and Ergonomics Society (HFES) annual meeting, Proceedings. In press, September 2010. , Sep-2010