Fiscal Year:	FY 2009	**Task Last Updated:**	FY 09/15/2009
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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Zip Code:	80301-2577	**Congressional District:**	2
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2007 NSBRI-RFA-07-01 Human Health in Space
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No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
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COI Name (Institution):	Young, Laurence (Massachusetts Institute of Technology) Oman, Charles (Massachusetts Institute of Technology) Wickens, Christopher (Alion Science & Technology Corp.)		
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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) is 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, current theories (e.g., ROTTR observer or Bayesian particle filter), as well as archived Apollo LM data, if available. 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 and/or flight experiments. 4) SOAS will be tailored for a lunar landing, using multi-sensory workload to choose appropriate countermeasures and their timing. Countermeasures will include one or more of the following, as conditions warrant: control command displays; 2D and perspective synthetic/enhanced vision displays; attitude indicator formats tailored for physically redirected, off velocity vector viewing; and, auditory cues and commands.

SDAT will also help human factors engineers analyze the following: past Shuttle landing incidents; Orion/CEV/Altair landing and ascent trajectory planning; Altair cockpit displays, and caution and warning system design; workload evaluation; and, crew training and mission simulation. SDAT could assist flight surgeons with post-flight medical debriefings.

Key Findings

During the project's second year, we focused on: understanding the separate Alion & MIT perception models; assessing how to combine them; obtaining vehicle data sets for verification and validation tests; and, prototyping a visual frame of reference transformation (FORT) tool.

We have access to Shuttle, VMS (vertical motion simulator), Altair simulator data sets, and helicopter simulator data sets. Apollo data sets are unavailable.

We also began to understand VMS washout algorithms with the goal to assist the VMS engineers fine-tune those algorithms to better account for lunar gravity.

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.

SDAT/SOAS is being enhanced with micro-gravity illusions heuristics.

Impact of Key Findings on Original Aims

The most important impacts from Year 2 is that we now have a prototype FORT tool to help designers calculate the costs of various cognitive display-control transformations, and Observer has been enhanced with visual cues.

Proposed Research Plan for Year 3

In the third year of this NSBRI sensorimotor adaptation project, the Alion-MIT team will: 1) Continue enhancing and merging SDAT and Observer, and continue comparing analytical results of common data sets.

2) Validate enhancements with previous flight data sets and new data sets (from actual vehicles and simulators). Included may be Shuttle landing data outlier analyses (compared to non-outliers), and data sets from Altair simulators.

3) Further develop the FORT tool from a prototype into a usable tool.

4) Help VMS engineers tune their washout algorithms to better account for lunar gravity.

5) Plan in detail for simulator and possible flight validation experiments in the second half of Year 3 and in Year 4.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Over 15 % of all aircraft accidents are attributable to spatial disorientation, with particularly high prevalence in night military and general aviation operations. Better understanding of the motion patterns leading to SD and potential in-flight warnings and improved displays could reduce this danger. All lessons learned and enhancements to SDAT and SOAS from this NSBRI project will be applied to aviation. In particular, the addition of otolith models to SDAT and SOAS will be useful in analyzing rotary wing SD events and devising appropriate countermeasure strategies within SOAS for this class of vehicles.
MIT's Observer model has aided investigators of aircraft accidents (e.g., 2004 Flash Air 737 fatal crash).

The new FORT tool is intended as a design aid for all vehicle control-display engineers. The tool will help designers objectively assess the costs of frame-of-reference transformations in terms of increased workload, slower response times, and more control reversal errors.

Task Progress:	Our four specific aims are to: 1) Extend SDAT by incorporating MIT's Observer models. Enhance SDAT with pilot head movement data, and visual attention cues. Validate enhancements with existing and new flight data sets. _Progress: SDAT is ready to incorporate MIT's Observer algorithms. SDAT can also accept head movement data, and Observer includes visual orientation cues for perception calculations. We have obtained new data sets (Shuttle, Altair simulator, helicopter simulator, VMS), but were unable to obtain Apollo data, as those data sets were apparently not archived, according to our sources. 2) Extend SDAT assessments to include typical space vehicle illusions: Inversion, Visual Reorientation, Tilt Gain, and Otolith Tilt-Translation Reinterpretation. Validation will include assessment of Shuttle landing data, and Altair simulator data. _Progress: See above. When Observer is incorporated into SDAT, SDAT will be able to assess all the illusions listed above. 3) Further extend SDAT by examining alternative visual reference frames. The FORT model is used to predict the cognitive cost of transitioning between reference frames. Validation of Aims 1-3 for SDAT will include parabolic flight experiments. _Progress: We designed and prototyped a FORT tool to help designers calculate the cognitive costs of FORT. It is a stand-alone tool, not included in either SDAT or Observer. FORT costs include the increased potential for control errors, response time delays, and increased cognitive workload. We analyzed and applied the tool to Shuttle-ISS docking, and to Shuttle-Hubble rendezvous and robotic arm tasks. We have begun to plan flight and simulator experiments to validate all enhancements to SDAT, although parabolic flight experiments may not be included. 4) To further enhance SDAT/SOAS assessor performance, pilot multi-sensory workload is considered in countermeasure selection. Validation experiments are not detailed, but will involve evaluations in ground-based simulators. _Progress: Once we have verified and validated our models, we will assess the efficacy of various countermeasures triggered by SOAS during years three or four.
Bibliography Type:	Description: (Last Updated: 09/08/2020)
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