Fiscal Year:	FY 2011	**Task Last Updated:**	FY 10/12/2011
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:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	1
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:**	
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 (crew exploration vehicle), 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 National Transportation Safety Board (NTSB) mishaps to determine the presence or absence of vestibular spatial disorientation (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 (central nervous system) gravito-inertial force resolution into perceived tilt and translation estimates from Massachusetts Institute of Technology's (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 fourth year, we focused on: merging MIT's Observer model with Alion's SDAT; enhancing SDAT with N-SEEV (noticing-salience, expectancy, effort, and value) and with three new illusion models, verification tests, and comparisons of analytical results produced by SDAT and Observer; validation of SDAT with anonymous data sets of helicopter pilots who experienced SD; and administering an Institutional Review Board (IRB)-approved Space Shuttle spatial orientation survey. Observer was 'packaged' as a DLL (dynamically linked library) within SDAT. SDAT users can select whether they wish to use Observer algorithms for predicted perception, or SDAT's algorithms. While Observer may be more physiologically accurate, Observer requires data sets to be of a fixed rate and fairly high frequency (10-100 Hz). Unfortunately, actual vehicle flight data recordings rarely meet these requirements. In addition, Observer does not account for misperceptions due to sub-threshold motions, which are critical to many SDAT illusion models. Therefore, we give users the option to select Observer or SDAT algorithms for attitude perception predictions. We designed three new illusion models to SDAT based upon vertical landing vehicle scenarios that we observed in data sets provided by an anonymous source of helicopter data -- data sets that included confirmed SD events. The three models are: (1) "Undetected loss of lift," which occurs when the pilot unwittingly flies out of ground effect with insufficient thrust to maintain the new altitude, resulting in a sudden plunge toward the surface; (2) "Inadvertent drift during hover" that could result in the vehicle striking an obstacle; and (3) "Undetected drift during landing" that could cause the vehicle to tip-over. SDAT has also been enhanced with a pilot attention model called N-SEEV. N-SEEV elevates applied countermeasures when SDAT predicts that the pilot is suffering from SD and has not attended to a lower level of countermeasures. We created an updated version of SDAT's user manual and delivered SDAT and its user manual to the National Space Biomedical Research Institute (NSBRI). We did not undertake an experiment to validate the newly enhanced SDAT because we could use existing data sets plus the new ones acquired from our anonymous source of helicopter data sets. We also judged that a simulator validation experiment would use resources needed to do the best possible job of integrating Observer into SDAT. FORT (frame of reference transformation) tool cost scores were not integrated into SDAT. The FORT tool remains a separate stand-alone tool. We performed additional FORT tool validation, and submitted an article for the Human Factors Journal. We received 40 usable survey responses, analyzed the data from the 71 missions in the responses, and submitted an article to Aviation, Space, and Environmental Medicine reporting our method and results. We also sent de-identified data to our customer, NASA-Johnson Space Center (JSC's) Dr. Jacob Bloomberg, and will make the full set of de-identified data available to anyone who wishes it.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	An important goal of this research and development project was 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 could 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:	Observer was 'packaged' as a DLL (dynamically linked library) within SDAT. SDAT users can select whether they wish to use Observer algorithms for predicted perception, or SDAT's algorithms. While Observer may be more physiologically accurate, Observer requires data sets to be of a fixed rate and fairly high frequency (10-100 Hz). Unfortunately, actual vehicle flight data recordings rarely meet these requirements. In addition, Observer does not account for misperceptions due to sub-threshold motions, which are critical to many SDAT illusion models. Therefore, we give users the option to select Observer or SDAT algorithms for attitude perception predictions. We designed three new illusion models to SDAT based upon vertical landing vehicle scenarios that we observed in data sets provided by an anonymous source of helicopter data -- data sets that included confirmed SD events. The three models are: (1) "Undetected loss of lift" which occurs when the pilot unwittingly flies out of ground effect with insufficient thrust to maintain the new altitude, resulting in a sudden plunge toward the surface; (2) "Inadvertent drift during hover" that could result in the vehicle striking an obstacle; and (3) "Undetected drift during landing" that could cause the vehicle to tip-over. SDAT has also been enhanced with a pilot attention model called N-SEEV. N-SEEV elevates applied countermeasures when SDAT predicts that the pilot is suffering from SD and has not attended to a lower level of countermeasures. We

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Bibliography Type:	Description: (Last Updated: 09/08/2020)
Abstracts for Journals and Proceedings	Small RL, Keller JW, Wickens CD, Oman CM, Jones TD. "Modeling and mitigating spatial disorientation in low g environments: A progress report." Presented at Eighth Symposium on the Role of the Vestibular Organs in Space Exploration, Houston, TX, April 8-10, 2011. Eighth Symposium on the Role of the Vestibular Organs in Space Exploration, Abstract Book, April 2011. , Apr-2011
Abstracts for Journals and Proceedings	Wickens CD, Keller JW, Small RL. "FORT: A frame of reference transformation model of 3D control-display relationships." Presented at the Aerospace Medical Association 82nd Annual Meeting, Anchorage, AK, May 8-12, 2011. Aviation, Space, and Environmental Medicine, 2011 Mar; 82(3):371-2. http://www.ingentaconnect.com/content/asma/asem/2011/00000082/00000003 , Mar-2011
Articles in Other Journals or Periodicals	Wickens C, Keller J, Small R. "Development & Validation of the Frame of Reference Transformation (FORT) Tool." Human Factors, Submitted, August 2011. (Ed. note Apr 2019: recategorized as Other Journals since not yet published) , Aug-2011
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