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Zip Code:	80301-2577	**Congressional District:**	2
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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 applications in the Shuttle, CEV, Altair, and Mars exploration mission. Alion's Spatial Disorientation Analysis Tool (SDAT) is 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 first year, we focused on: understanding the domain and astronaut susceptibility to various disorienting situations; understanding each other's perception models; obtaining vehicle data sets for verification and validation tests; and, designing a visual frame of reference transformation (FORT) model.

We have access to Shuttle, VMS (vertical motion simulator), and Altair simulator data sets, and are still pursuing Apollo data sets. To supplement these data, we are also pursuing rotary wing data from Ft. Rucker, as well as other sources. The reason we seek rotary wing data is that they represent the closest analogs to lunar landers on Earth, and they are plentiful. Their lateral and vertical motions are significantly different from fixed-wing aircraft, thus giving us data with which to verify and validate enhancements to SDAT and Observer.

MIT's Observer has been enhanced with a user interface for condition selection (e.g., gravity environment) and results presentation. It now uses improved calculations for perceived "down" and azimuth, as well as perceived linear velocities and displacements.

Impact of Key Findings on Original Aims

The most important impact from Year 1 is that we must re-double our efforts to obtain relevant data sets with which to verify and validate improvements to SDAT and Observer. We also determined that Altair simulators would be suitable platforms for validation experiments, supplementing or replacing parabolic flight experiments, based on cost considerations, and availability.

After designing a FORT model, we decided that it should not be incorporated into SDAT per se. Rather, the FORT cost function should be used to help determine an astronaut's risk of SD in a given situation, yielding design guidelines to help determine the severity of an SD event, and to help select countermeasures when a frame-of-reference transformation SD occurs.

Proposed Research Plan for Year 2

In the second 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 will be Shuttle landing data outlier analyses (compared to non-outliers), and data sets from Altair simulators.

3) Incorporate the FORT model's cost function into SDAT and develop a separate FORT design tool (if schedule and budget conditions permit).

4) Plan in detail for simulator and parabolic flight validation experiments in Years 3 and 4.

We will not pursue applying SDAT or Observer to elderly falls, as stated in our proposal, because that presents a significant distraction to the main focus of our research, which is to understand astronaut SD events and to apply appropriate countermeasures to help astronauts who experience SD. In Year 2 we will focus more attention on designing validation experiments in parabolic flight and in suitable ground-based simulators (e.g., VMS and Desdemona). Parabolic flight experiments will borrow ideas from Borah and Young's TIFS experiments in the 1980s, which measured in-flight perception of vertical and translatory motions.

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. Lastly, MIT's Observer model has aided investigators of aircraft accidents (e.g., 2004 Flash Air 737 fatal crash).
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: We have enhanced SDAT with MIT models and designed a visual frame-of-reference transformation (FORT) model. The MIT Observer model has been modified so that the strength of gravity is variable, an additional parameter has been incorporated to facilitate dynamic modeling of entry and post-landing OTTR and Tilt-Gain illusions, and the model was extended to calculate perceived velocity and displacement in the perceptual horizontal plane. We have obtained new data sets (Shuttle, Altair simulator) and still have more to obtain (e.g., Apollo data) with which we will validate the enhancements. 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. In addition, we devised scenarios to examine predicted perceived orientation via SDAT and Observer analyses, and have begun those analyses of Shuttle and Altair simulator data sets. SDAT has been enhanced with additional illusion sequences, specifically for somatogravic and lateral drift perception illusions. 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: See above. In addition, we designed a FORT model and will incorporate its cost portion into SDAT. We have begun to plan flight and simulator experiments to validate all enhancements to SDAT. 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, based upon the scenarios devised in item 2, above.
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