Fiscal Year:	FY 2013	**Task Last Updated:**	FY 09/17/2013
PI Name:	Duda, Kevin R Ph.D.		
Project Title:	Human-Automation Interactions and Performance Analysis of Lunar Lander Supervisory Control		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Human Factors and Performance Team		
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		
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Zip Code:	02139-3539	**Congressional District:**	7
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2008 Crew Health NNJ08ZSA002N
Start Date:	07/01/2009	**End Date:**	06/30/2013
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	2	**No. of Master' Degrees:**	2
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):	Oman, Charles (Massachusetts Institute of Technology) Marquez, Jessica (NASA Ames Research Center) Bortolami, Simone (The Charles Stark Draper Laboratory, Inc.)		
Grant/Contract No.:	NCC 9-58-HFP02001		
Performance Goal No.:			
Performance Goal Text:			
	1. Original Project Aims/Objective: The project objective is to produce an integrated human-system model that includes representations of human attention, perception, decision making, and action for use as an early-stage simulation-based design tool for human-system integration in complex systems. Our case study is piloted lunar landing. There are four integrated specific aims: (1) Perform a critical analysis of human operator-automation interactions and task allocations, considering information requirements, decision making, and the selection of action; (2) Develop a closed-loop pilot-vehicle model, integrating vehicle dynamics and human performance models, and parametrically analyze and quantify system performance; (3) Conduct experiments in the Draper Laboratory fixed-base simulator to validate critical parameters within the integrated pilot-vehicle model; (4) Extend the model to include the effect of spatial orientation and conduct experiments on the NASA Ames Research Center (ARC) Vertical Motion Simulator (VMS) to investigate the		

Task Description:	effects of motion cues on pilot performance. 2. Key Findings: In project year 4, we completed our investigations of flight performance and failure detection in the NASA Ames VMS, quantification of operator visual attention in the Draper Laboratory fixed-base simulator, closed-loop human-system model for representing the human in a complex system, and analyzed dynamic task allocation between the human and the system in operational implementations. In the two VMS experiments, participants with flight experience detected and diagnosed system-level failures with varying levels of control and with and without motion cues. The effect of how often a failure appeared in the test matrix was also evaluated. Results indicated that the pilots had a correct hit rate of 90.7 percent of failure trials and a correct rejection rate of 90.2 percent of no-failure trials. There was no effect of motion cues on flight performance or failure detection. Failures were also more easily detected in the high frequency (75% of trials had a failure) condition than in the low frequency (25%) condition. In all cases, workload and situation awareness decreased following a planned mode transition from automatic flight to manual control. In the Draper Laboratory visual attention experiment, there was an effect of mode transition on the average dwell duration and number of visual fixations, as measured by an eye tracker. These effects were due to the transition's final mode, and not the initial mode or the direction of the mode transition (whether increasing or decreasing level of automation). Average dwell duration prior to the failure detection was found to be higher on the instruments that were used to detect the failure, as compared to the no-failure conditions. Lastly, the results of the experiments have been used to update the integrated human-system model. The modeling effort represents the cognitive processes and action responses of the human, who can act as both a flying pilot as well as a supervisory pilot. 3. Impact of Key Findings on hypotheses, technology requirements, objectives and specific aims of the original proposal: The results of the pilot visual attention experiment (Aim 3) and VMS failure detection experiments (Aim 4) are critical for the understanding of pilot performance in nominal and off-nominal scenarios. The data collected from the experiments provides critical information for parameter justification for the identified operational scenario within the integrated human-system model (Aim 2). The experiments further investigated our previous identification of the effect of flight control mode transitions on workload and situation awareness, by quantifying visual attention on primary and supervisory flight instruments. The experimentation represents typical spacecraft command and control tasks where the flying pilot was responsible for selecting a landing aimpoint using information from an on-board hazard detection system, and then either supervising the autoflight system or manually commanding a representative lunar landing vehicle. The system-level failures that were introduced represent plausible failures that would be detected on either the primary flight displays or secondary displays. By quantifying performance, workload, and situation awareness across these experimental conditions, we've demonstrated a robust set of metrics that can be applied throughout a system's design and verification cycle to benchmark and evaluate the implementation (SHFE-TASK-01: How can workload measures and tools be developed to unobtrusively monitor and trend workload throughout the mission design and verification cycle in a consistent manner?). The integrated human-system performance modeling work and MATLAB/Simulink library (Aim2) addresses the NASA Human Research Program (HRP) Risk of Poor Critical Task Design, specifically the Gap associated with model-based tools that can assist in the early-stage research and drafting of spacecraft systems and task procedures (SHFE-TASK-02: What model-based HF Tools can assist with the design and evaluations of spacecraft systems and task procedures?). The parameterized model-based simulation approach enables a systematic evaluation of task allocation, task parameters, and human parameters on system performance. The partnership with NASA Ames Research Center and the use of the VMS experimentation has both provided us valuable data for the modeling and simulation of typical spacecraft command and control tasks, and has advanced their trajectory simulation capability through the implementation of a landing point designation phase and off-nominal scenarios. 4. Proposed research plan for the coming year: This is the final report for this project. Aspects of the project, specifically the flight performance, workload, and situation awareness metrics will be further investigated, developed and evaluated in additional spaceflight operational scenarios through National Space Biomedical Research Institute (NSBRI) Project HFP03401--Metrics and Methods for Real-Time Task Performance Assessment. This newly funded project aims to transition these metrics to other NSBRI Human Factors and Performance (HFP) Team investigators, and make the capability more broadly available to the research community.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The integrated human-system modeling and human-automation interaction analyses developed by this project are generally applicable to any complex system, whether it is land, air, sea, or space-based. The development of the task network and human performance model library in the MATLAB/Simulink environment is an important contribution to model-based research that utilizes Simulink to represent the system dynamics and human performance capabilities. The formulation of the human as a component in the system under development is critical for the analysis and design of complex systems, where there are human interactions with the automated systems and control modes, and while performing critical functions at various levels of supervisory control. This research project produced representations of human performance models to formulate the human as a system component as well as analytic approaches to determine the effect of human and/or automation errors as they propagate through the system and affect mission performance and reliability. Our analyses of adaptive/adaptable automation and automation mode transitions goes beyond the space-rated vehicles and includes aviation and nautical accidents/incidents – documenting and learning from the interactions between the human and the automation to develop a generic set of guidelines for the design of system modes as well as to produce metrics for quantitatively evaluating the ease and safety of transitioning between modes in both nominal and off-nominal scenarios. Dynamic task allocation – in which the allocation of tasks between the human operator and the automation can change in response to the operator, system, or environmental states – exists in all complex systems. The analysis of these systems has motivated both the identification of research gaps between what the literature recommends and the current implementation of dynamic task allocation, and recommendations for the reduction of these gaps – a need for all complex systems. The research has also developed a new situation awareness metric – one that allows for continuous measurement without interrupting the reporter or simulation – and has been used in several experiments. This non-invasive method requires the participant to verbally callout specific vehicle/system states that are pertinent to the task that they are executing, and we record the correctness of the callout. Within a trial this gives an indication of which points they missed callouts, and across trials it provides temporal comparisons of task sequences/events that result in lower situation awareness. This method could be applied to many land, sea, or space-based systems where there is a need to assess operator situation awareness over time without interfering with the activity, or interrupting the simulation. Specific examples for space operations and exploration may include teleoperation/remote manipulator operation and near-Earth object/asteroid rendezvous and proximity operations.

Task Progress:	Two separate piloted lunar landing experiments in the NASA ARC VMS were conducted to investigate 1) the effect of vehicle control mode, motion cues, and failure type on failure detection performance, and 2) the interaction between level of automation and failure frequency on failure detection and diagnosis. In VMS Experiment 1, the pilots performed a landing point designation and then transitioned to one of three manual modes. Three failure types were modeled. Results indicated that the pilots had a correct hit rate of 90.7% of failure trials and a correct rejection rate of 90.2% of no-failure trials. There was no effect of motion cues on flight performance or failure detection. There was a significant effect of control mode and failure type in time to detect failures, although the significance of control mode depended on the failure type. In all cases, quantitatively evaluated workload and situation awareness decreased following a planned mode transition from automatic flight to manual control (as seen in prior work). In VMS Experiment 2, the pilots initially performed a landing aimpoint designation in autopilot, then initiated a transition where the vehicle would maintain in high automation (autopilot) or enter a low automation condition. Their tasks were to fly to the designated landing aimpoint, while making call-outs and detecting and diagnosing a failure. Two failures were modeled, and the failure frequency (25% or 75%) was a between-subjects variable. Failures were more easily detected in the high frequency (75%) condition than in the low frequency condition. Additionally, participants were more hesitant to declare they observed a failure when they occurred more frequently and when participants were manually in control. The Draper Laboratory fixed-base simulator was modified to include an eye tracker for measuring operator visual fixations. Each trial began in one of three vehicle control modes, and then transitioned to one of the other two. The same three failures as VMS Experiment 1 were modeled. Subjects were asked to fly the vehicle, report workload, make verbal callouts, and detect and diagnose a failure. There was an effect of mode transition on both average visual dwell duration and number of fixations for all instruments. These effects were due to the transition's final mode, and not the initial mode or the direction of the mode transition (whether increasing or decreasing level of automation). The results of the VMS and Draper Laboratory experiments have been used to update the integrated human-system model. The model represents the cognitive processes and action responses of the human, who can act as both a flying pilot as well as a supervisory pilot. The model blocks have been updated in the Human Performance Model (HPM) library, and the integrated model has been used to run sensitivity analyses to the effect of parameter variation on simulated system performance.
Bibliography Type:	Description: (Last Updated: 09/04/2023)
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