

Fiscal Year:	FY 2010	Task Last Updated:	FY 08/06/2010
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
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Project Type:	GROUND	Solicitation / Funding Source:	2008 Crew Health NNJ08ZSA002N
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No. of PhD Candidates:	0	No. of Master' Degrees:	0
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):	Oman, Charles (Massachusetts Institute of Technology) Marquez, Jessica (Massachusetts Institute of Technology) 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 perception, decision making, and action for use as an early-stage simulation-based design tool. To support this, we will quantify the effects of both human and automation errors as they propagate through a supervisory control system, as well as the effects of functional allocation and information display on mission and pilot-vehicle system performance through dynamic modeling and experimentation. 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, human perception, decision making and action, and analyzed using reliability analysis techniques in MATLAB/Simulink to quantify system performance. (3) Conduct experiments in the Draper Laboratory fixed-base lunar		

Task Description:

landing cockpit simulator to validate critical parameters within the integrated pilot-vehicle model. (4) Extend the dynamic model to include the effect of spatial orientation on system performance and conduct experiments on the NASA Ames Vertical Motion Simulator to investigate the effects of motion cues on pilot performance.

2. Key Findings - During the first year of the project, we created a hierarchical task analysis (HTA) for lunar landing, starting with Apollo and adding Autonomous Landing and Hazard Avoidance Technology (ALHAT) Project functions and capabilities, to generate sufficient detail for model development. Several task themes emerged - decision making, flying, and sub-system supervisory/monitoring tasks - which provide the basis for the development of several classes of "typical space vehicle command and control tasks" for the model library development. Given the ALHAT requirement to support crewed, cargo, and robotic landings, we identified Landing Point Designation (LPD) as an important activity for the case study. A systems-level model architecture was developed that includes a task network (Stateflow), human performance model (HPM) library (attention, perception, decision making, action), and a vehicle dynamics model (ALHAT Entry Descent and Landing Simulation) - all within MATLAB/Simulink. Within the model, each task or function can be assigned to either a human or automation. Also, failure modes, probabilities, and conditions can be specified a various points within the parameterized model.

During the HTA development, we found that previous research had focused on the analysis of a static allocation of functions between humans and automation. However, in most complex systems, operators switch between levels of automation resulting from switching between modes. An important aspect of these transitions is the ease of it, so that there is not a discontinuity between distant levels of automation, or there is not an unknown or ambiguous status of the system when switching into a new mode. We have defined the term "graceful transition" as "the ability of an operator of a complex system to change between levels of automation or levels of supervisory control (including automation modes) while maintaining control and awareness of the system without sacrificing system performance or mission objectives."

3. Impact of Key Findings on hypotheses, technology requirements, objectives and specific aims of the original proposal - The identification of decision making, flying, and supervisory/monitoring task classes during the HTA development provided a structure for the model library development. In addition to the types of "typical space vehicle command and control tasks," we were able to identify the key elements within those tasks to develop the human and automation blocks that could be parameterized within the overall model. The implementation of the human-system model within the MATLAB/Simulink environment has eased the development due to the mix of existing and customizable blocks, and eliminates the need for communication protocols between software modules.

We expanded the objective of the first aim to include the kinds of interfaces that facilitate graceful transitions in automation modes and in levels of supervisory control. During our HTA, we recognized that previous research had focused on the analysis of only static allocation of functions between humans and automation which represents a gap in the research and analysis methods of complex systems. To support this aim, we are analyzing multiple complex systems (air, space, sea) to produce a generalized set of automation design guidelines and metrics to quantify these transitions for evaluation of complex systems with multiple modes.

4. Proposed research plan for the coming year - In year 2 of the project, we will expand on the development of the human-system model to include multiple phases within a lunar landing trajectory. We will continue to refine the model for landing point designation, developing the ALHAT-based representation, as well as that used during Apollo. Simulation and analyses will be conducted to quantitatively analyze the performance differences between the Apollo and ALHAT function allocations as well as to determine sensitivities to critical parameters within the model. A human subject experiment is planned to validate the model and key findings. In addition, we plan to deliver a comprehensive review of interactions with multiple automation modes and mode transitions within complex systems - maritime, aircraft, and spacecraft. This review will also include proposed methodologies for analyzing the transitions between modes ("graceful transition"), including metrics for quantifying the gracefulness of a system as well as design rules to assist in the development of a system to ensure the ease of transition.

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 the early-stage model-based design approach that utilizes Simulink to represent the system dynamics and capabilities. The formulation of the human as a component in the system under development is critical for the analysis and design of the role of the human in complex systems, where there are interactions with the automated systems and control modes, and while performing critical functions at various levels of supervisory control. This research project will produce both abstract 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 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. This modeling and analysis work can be applied to multiple supervisory control applications, such as aircraft, helicopters, and UAV interactions or explaining the causes of accidents. It may also suggest new methods to assess pilot performance and determine training curricula.

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The systems-level model architecture includes a task network, human performance model (HPM) library, and a vehicle dynamics model - all within MATLAB/Simulink. The LPD task network is implemented using Stateflow, which allows

Task Progress:	<p>task completion and transition conditions. The vehicle dynamics builds on the ALHAT Entry Descent and Landing Simulation which is a representation of the vehicle dynamics and guidance, navigation, and control algorithms, and the HPM library includes functions that follow the "see-think-decide-do" paradigm, and include abstract representations of attention, perception, decision making, and action. Within the network, functions can be assigned to either the human or the automation so subsequent analyses can inform the relative benefit of one function allocation versus an alternative. Failure modes, associated probabilities and conditions can also be specified and added to the parameterized model.</p> <p>During the development of the HTA, we identified a gap in the analysis of complex system automation mode transitions. Previous research focused on the analysis of static allocation of functions between humans and automation; however, in most complex systems, operators switch between levels of automation as a result from switching between modes. These transitions are usually planned and initiated by the operator, but can also result from unplanned events such as a failure or mode confusion. An important aspect of these transitions is the ease of it, so that there is not an abrupt jump between distant levels of automation, or unfamiliarity with the status of the system when operating in the new mode. We have defined the term "graceful transition" as "the ability of an operator of a complex system to change between levels of automation / levels of supervisory control (including automation modes) while maintaining control and awareness of the system without sacrificing system performance or mission objectives." We are analyzing complex systems to produce a generalized set of design guidelines and metrics to quantify these transitions and evaluate systems with multiple modes.</p>
Bibliography Type:	Description: (Last Updated: 09/04/2023)
Abstracts for Journals and Proceedings	<p>Duda KR, Hainley CJ, Wen HY, Oman CM. "Human-automation interactions and performance analysis of lunar lander supervisory control." 2010 NASA Human Research Program Investigators' Workshop, Houston, TX, February 3-5, 2010.</p> <p>2010 NASA Human Research Program Investigators' Workshop. Abstract Book, February 2010. , Feb-2010</p>
Abstracts for Journals and Proceedings	<p>Duda KR, Wen HY, Hainley CJ, Oman CM. "Modeling human-automation interactions during lunar landing supervisory control." 81st Annual Scientific Meeting of the Aerospace Medical Association, Phoenix, AZ, May 10-11, 2010. Aviation, Space, and Environmental Medicine 2010 Mar;81(3):327. , Mar-2010</p>
Awards	<p>Marquez JJ. "NASA Space Flight Awareness Team Award: International Space Station PART Software Team, April 2010." Apr-2010</p>
Awards	<p>Duda KR. "Member of the AIAA Life Sciences and Systems Technical Committee, March 2010." Mar-2010</p>