Fiscal Year:	FY 2011	**Task Last Updated:**	FY 07/05/2011
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Project Title:	Human-Automation Interactions and Performance Analysis of Lunar Lander Supervisory Control		
Division Name:	Human Research		
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Program/Discipline--Element/Subdiscipline:	NSBRI--Human Factors and Performance Team		
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Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
Space Biology Element:	None		
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Space Biology Special Category:	None		
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Zip Code:	02139-3539	**Congressional District:**	7
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Contact Monitor:		**Contact Phone:**	
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COI Name (Institution):	Oman, Charles (Massachusetts Institute of Technology) Marquez, Jessica (NASA Ames Research Center) Bortolami, Simone (The Charles Stark Draper Laboratory, Inc.)		
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	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 for human-system integration in complex systems. Our case study is piloted lunar landing. We aim to quantify human supervisory control performance in a complex system using 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 and human performance models, and analyzed using reliability analysis techniques in MATLAB/Simulink to 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		

Task Description:	model to include the effect of spatial orientation and conduct experiments on the NASA Ames Vertical Motion Simulator to investigate the effects of motion cues on pilot performance. 2. Key Findings: In project year 2, we completed our initial human-system model development. Our simulation varied the human performance model parameters, and recorded system performance to determine the sensitivity to variations in human activity. Landing accuracy and fuel usage were two system-level parameters to score performance against. Two key findings include: 1) the best combined fuel and landing accuracy was found when the human does the decision making, but aided by automated flight, and 2) variability in fuel savings when the human is flying is greater than automated flying, but the average is not always greater. This supports the human-system collaboration hypothesis that the combined human-automation performance is better than either the human or the automation alone. We also completed an experiment investigating "graceful" mode transitions within complex systems. Subjects flew trajectories that transitioned from a fully automatic flight control mode to one of three manual flight control modes. Workload was measured using the Modified Bedford Scale and secondary task response time. Verbal callouts of altitude, fuel, and location - provided a measure of situation awareness (SA). Flight performance was evaluated using the pitch axis tracking error. The key findings include: 1) secondary task response time and subjective workload all significantly increased following the mode transition, 2) the subjects' Modified Bedford reports, when ranked, showed unanimous agreement that workload was lowest prior to the transition, and highest during it, and 3) SA callout accuracy decreased significantly after the transition. With the new SA metric, we were able to demonstrate for the first time a short term decrease in SA during difficult mode transitions. We also found that workload depended on the number of control loops the subject was required to close. 3: Impact of Key Findings on hypotheses, technology requirements, objectives and specific aims of the original proposal: The results of the human-automation task allocation modeling and simulation supports the human-system collaboration hypothesis that the combined human-automation performance is better than either the human or the automation alone. This work leverages the hierarchical task analysis performed in Aim 1, and expands on Aim 2. In addition to the implementation of human performance models, we developed analogous automation performance models - allowing us to simulate performance under varying task allocations. The results of the simulation informed the landing point designation and human decision making hypotheses for Aim 3 experimentation. Several of these tasks models will be implemented as "typical spacecraft command and control tasks." The objective of research Aim 1 was expanded to investigate "graceful" transitions between automation modes. Accidents and incidents in aviation, maritime, and space were analyzed to produce a generalized set of design guidelines and metrics to quantify the workload, situation awareness, and system performance changes during mode changes. An experiment in the context of piloted lunar landing was performed to quantify the "gracefulness" of transitions between automation modes. This investigation filled a void in the task allocation analysis literature by considering dynamic task allocation, as well as utilizing a novel method for assessing situation awareness in near-real-time using verbal callout accuracy. The results of this experimentation contribute to Aims 1 and 3, and the system performance, workload, and situation awareness metrics will be used to inform the modeling effort in Aim 2. 4. Proposed research plan for the coming year In project year 3, there are four elements of our research plan that we plan to advance: 1) Expand on the model development in Aim 2 to include human failure detection and response to off-nominal scenarios. This will allow us to analyze the system response to degraded states, and analyze the human-automation task allocation and system performance using Draper Laboratory's performance and reliability analysis techniques. 2) Complete the human decision making and action experiment during landing point designation and approach-to-landing tasks. This experiment was started in year 2, and the results will be used to validate the Aim 2 models. 3) Initiate the packaging of the human performance models within MATLAB/Simulink to be a stand-alone library. 4) Coordinate the Aim 4 research plan using the NASA Ames VMS. In addition, we will continue to work with other NSBRI HFP Team investigators to identify potential future collaborations that leverage the Team's expertise and integrate this model-based human-system design work.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The integrated human-system modeling and human-automation interaction analyses developed by this project is 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 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 will produce 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 remotely operated vehicle interactions. It may also suggest new methods to assess operator performance and determine training curriculums. The research has also developed a new situation awareness metric - one that allows for continuous measurement without interrupting the reporter or simulation. 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. Specific examples for space operations and exploration may include teleoperation/remote manipulator operation and near-earth object/asteroid rendezvous and proximity operations.

Task Progress:	In year project year 2, we completed our initial human-system model development focusing on the landing-point designation (LPD) through touchdown tasks within a representative lunar landing mission. This was based on the task analysis performed in year 1. We identified eight potential task allocations within the model (i.e., tasks that could be either completed by the human or the automation). The simulation runs varied the human performance model parameters to determine the sensitivity of system performance to variations in human activity. Landing accuracy and fuel usage were two system-level parameters to score performance against. Two key findings that came out of this modeling effort, which are being further explored in a human subject experiment (will be completed in project year 3) include, 1) the best performance (combined fuel and landing accuracy) was found when the human does the decision making, but aided by automated flight, and 2) the variability in fuel savings when the human model is flying is greater than during automated flying, but the average is not always greater. This supports the human-system collaboration hypothesis that the combined human-automation performance is better than either the human or the automation alone. Case studies of accidents and incidents in aviation, maritime, and space were analyzed to produce a generalized set of automation design guidelines and metrics to quantify the workload, situation awareness, and system performance changes during automation mode transitions. We completed an experiment in year 2 investigating mode transitions within complex systems - to determine system attributes which allow the transitions to occur "gracefully." We used piloted lunar landing was our scenario. Subjects flew approach trajectories that transitioned from a fully automatic flight control mode to one of three manual flight control modes. Workload was measured using the Modified Bedford Scale and secondary task response time. A tertiary task - verbal callouts of altitude, fuel, and location - provided a measure of situation awareness. Flight performance was evaluated using the pitch axis tracking error. The key findings include: 1) Secondary task response time and subjective workload all significantly increased following the mode transition, 2) the subjects' Modified Bedford reports, when ranked, showed unanimous agreement that workload was lowest prior to the transition, and highest during it, 3) situation awareness verbal callout accuracy decreased significantly after the transition, and 4) pitch axis tracking mean square error following the transition was significantly greater in re-designation trials. A manuscript is in preparation. Since this experiment utilized a new SA metric, we were able to demonstrate for the first time a short term decrease in SA during difficult mode transitions. We also found that workload depended on the number of control loops the subject was required to close.
Bibliography Type:	Description: (Last Updated: 09/04/2023)
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