Fiscal Year:	FY 2012	**Task Last Updated:**	FY 07/12/2012
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		
PI Email:	kduda@draper.com	**Fax:**	FY 617-258-2772
PI Organization Type:	NON-PROFIT	**Phone:**	617-258-4385
Organization Name:	The Charles Stark Draper Laboratory, Inc.		
PI Address 1:	555 Technology Sq		
PI Address 2:	MS 27		
PI Web Page:			
City:	Cambridge	**State:**	MA
Zip Code:	02139-3539	**Congressional District:**	7
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2008 Crew Health NNJ08ZSA002N
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No. of PhD Candidates:	2	**No. of Master' Degrees:**	2
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
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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.)		
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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 Vertical Motion Simulator to investigate the effects of motion cues on pilot		

Task Description:

performance.
2. Key Findings: In project year 3, we completed our investigation of human decision making and risk-taking during simulated lunar landing and further developed the human performance model library. In the experimentation, subjects were asked to select a landing aimpoint within a pre-determined region, and the probability of a human-piloted vs. automatic landing was varied. We hypothesized that the placement of the landing aimpoint would vary with the probability of human-piloted versus automatic flight and whether estimated touchdown errors were remembered by the subjects from earlier in the experiment or presented graphically on scatter plots. Results showed that subjects designated landing points that compensated for estimated touchdown dispersions and knowledge of the probabilities of manual versus automated flight. Subjects made more complete landing selection compensations when estimating touchdown dispersion from graphical plots rather than from memories of previous simulated landings. Parameterized human performance models were integrated in MATLAB/Simulink as a library that can be used by system designers to represent the human in a common modeling framework. In project year 3, three models of human performance -- Action, Attention, and Perception – have been implemented. Future implementations will include blocks of the detection and response to failures, spatial orientation, and variants on decision making. In preparation for the Aim 4 experiments at NASA ARC, significant modifications have been made to the VMS lunar landing cab and simulation. These include 1) a landing point designation phase in the trajectory, 2) the transition to manual control from automatic flight, and 3) the implementation of system failures that the experimental subject will be tasked with detecting and identifying.

3: Impact of Key Findings on hypotheses, technology requirements, objectives and specific aims of the original proposal: The results of the fixed-base lunar landing experiment (Aim 3) are important for quantifying flight performance under varying task allocation (probability of human piloted vs. automatic flight), and the influence of prior landing accuracy on the selection of landing aimpoints. This work leverages the hierarchical task analysis performed in Aim 1, and provides key data for the development of representative models of human performance for Aim 2. The experimentation represents typical spacecraft command and control tasks where the flying pilot was responsible for selecting a landing aimpoint from using information from an on-board hazard detection system, and then either supervising the autoflight system or manually commanding the flight path and attitude of a representative lunar landing vehicle. The human performance modeling work addresses the NASA HRP Risk of Poor Critical Task Design, specifically the Gap associated with model-based tools that can assist in the design and evaluation of spacecraft systems and task procedures. The model-based simulation approach enables a systematic evaluation of task allocation, task parameters, and human parameters on system performance. The partnership with NASA ARC and the use of the VMS for Aim 4 experimentation 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: In project year 4, there are four elements of our research plan that we aim to advance: 1) Implementation of models of human failure detection and response to off-nominal scenarios in the human performance model library. 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) Conduct fixed-base and motion-base experimentation using the Draper Laboratory simulator and NASA Ames VMS to examine the effects of simulator motion on failure detection and identification, workload, situation awareness, and flying performance. 3) Complete the packaging of human performance models within MATLAB/Simulink so that they are a stand-alone library. This will include parameterized models for simulation and analysis scripts for model performance and parameter sensitivity analysis. 4) Further the analysis of dynamic task allocation through investigation of pilot performance during adaptive and adaptable automation. Develop an adaptive automation taxonomy and model for evaluating human performance in complex systems. 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 simulation capability and 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 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 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 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. 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 a 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 project year 3, we completed a human subject experiment to test hypotheses and validate model parameters related to decision making in the landing point designation as well as the manual flying associated with piloted lunar landing. The experiment leverages the hierarchical task analysis work that was done in Aim 1 and provided data to be included in representing human performance in the Aim 2 model development. Subjects (n = 11) were tasked with selecting a landing aimpoint, and then flying to that point where the probability of a human-piloted vs. automatic landing was varied. It was expected that the placement of the landing aimpoint would vary with the probability of human-piloted versus automatic flight and whether estimated touchdown errors were remembered by the subjects from earlier in the experiment or presented graphically on scatter plots. We found that subjects did systematically modify the placement of landing aim points based on the likelihood of automatic vs. manual flight, and presenting landing errors graphically allowed subjects to compensate for errors in both risk-critical and non-risk critical landing directions. Parameterized human performance models were integrated in MATLAB/Simulink as a library that can be used by system designers to represent the human in a common modeling framework. The Human Performance Library (HPL) is a collection of human performance models that enables the user to model the human within an existing system model. The HPL integrates with the user's Simulink Library Browser. Three models of human performance -- Action, Attention, and Perception – have been implemented. The Attention block includes three separate attention models (selected signals, fixed-interval scan, and maximum error) which drive the simulated spotlight of attention. The Perception block simulates the perception of an input by allowing a user to specify bias, gain, and noise. The Action block allows a user to input a bias, gain, and time delay to simulate response to an input. Future implementations of the HPL will include blocks of the detection and response to failures, spatial orientation, and variants on decision making. All will include user-configurable parameters to allow for the specification of a number of different scenarios and models of human response. In preparation for the Aim 4 experiments at NASA ARC, significant modifications have been made to the VMS lunar landing cab and simulation. These include the 1) implementation of a landing point designation phase in the trajectory, 2) the transition to manual control modes from automatic flight, and 3) the implementation of system failures (attitude control thruster stuck on, landing radar failure, and fuel leak) that the experimental subject will be tasked with detecting and identifying. Companion pilot experiments have been started in the Draper Laboratory fixed-base simulator.
Bibliography Type:	Description: (Last Updated: 09/04/2023)
Abstracts for Journals and Proceedings	Duda KR, Kaderka JD, Johnson AW, Wen HY, Hainley CJ, Oman CM, Natapoff A, Marquez JJ. "Human-Automation Interactions and Performance Analysis of Lunar Lander Supervisory Control." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Abstracts for Journals and Proceedings	Kaderka JD, Duda KR, Oman CM. "Development and Simulation of a Pilot Failure Detection Model within a Closed-Loop Human-System Model." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Abstracts for Journals and Proceedings	Wen HY, Johnson AW, Duda KR, Oman CM, Natapoff A. "Investigating Human-Automation Task Allocation in Lunar Landing Through Simulation and Human Subject Experiments." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Awards	Duda KR. "Co-chair of Human Factors and Performance session in the Spacecraft, Launch Vehicle Systems, and Technologies track at the IEEE Aerospace Conference, March 2012." Mar-2012
Awards	Oman CM. "Reappointed NSBRI Sensorimotor Team Leader, May 2012." May-2012
Dissertations and Theses	Wen HY. "Human-Automation Task Allocation in Lunar Landing: Simulation and Experiments." S.M. Thesis, Massachusetts Institute of Technology, September 2011. , Sep-2011
Papers from Meeting Proceedings	Wen HY, Johnson AW, Duda KR, Oman CM, Natapoff A. "Decision-Making and Risk-Taking Behavior in Lunar Landing." 56th Annual Meeting of the Human Factors and Ergonomics Society, Boston, MA, October 22-26, 2012. 56th Annual Meeting of the Human Factors and Ergonomics Society, Boston, MA, October 22-26, 2012. In press as of July 2012. , Jul-2012