Fiscal Year:	FY 2018	**Task Last Updated:**	FY 11/28/2018
PI Name:	Holden, Kritina Ph.D.		
Project Title:	Electronic Procedures for Crewed Missions Beyond Low Earth Orbit (LEO)		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture (2) **Medical Conditions**:Risk of Adverse Health Outcomes and Decrements in Performance Due to Medical Conditions that occur in Mission, as well as Long Term Health Outcomes Due to Mission Exposures		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	kritina.l.holden@nasa.gov	**Fax:**	FY
PI Organization Type:	NASA CENTER	**Phone:**	281-483-8829
Organization Name:	Leidos Corporation at NASA Johnson Space Center		
PI Address 1:	2101 NASA Pkwy/SF3		
PI Address 2:	Mail Code: C46		
PI Web Page:			
City:	Houston	**State:**	TX
Zip Code:	77058-3607	**Congressional District:**	22
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2014-15 HERO NNJ14ZSA001N-Crew Health (FLAGSHIP & NSBRI)
Start Date:	10/01/2015	**End Date:**	09/30/2018
No. of Post Docs:	0	**No. of PhD Degrees:**	1
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
Contact Email:	thomas.j.will1@nasa.gov		
Flight Program:			
Flight Assignment:	NOTE: End date changed to 9/30/2018 per E. Connell (JSC HRP)--Ed., 6/25/18 NOTE: End date changed to 2/1/2018 per PI (Ed., 7/13/17) NOTE: Element change to Human Factors & Behavioral Performance; previously Space Human Factors & Habitability (Ed., 1/18/17)		
Key Personnel Changes/Previous PI:	December 2018 report: Jerri Stephenson joined the project in 2018 as Co-investigator in charge of eye tracker data collection and analysis. August 2017: Dr. Jeff Lancaster replaced Dr. Chris Hamblin as the Honeywell co-investigator. and E. Vincent Cross (Leidos) joined as a co-investigator. February 2017 report: Dr. Maya Greene, KBRwyle at NASA Johnson Space Center, joined the project as CoInvestigator with statistics expertise.		

COI Name (Institution):	Morin, Lee M.D., Ph.D. (NASA Johnson Space Center) Schreckenghost, Debra M.E.E. (TRACLabs, Inc.) Greene, Maya Ph.D. (KBRwyle at NASA Johnson Space Center) Lancaster, Jeff Ph.D. (Honeywell) Cross, E. Vincent Ph.D. (Leidos at NASA Johnson Space Center) Stephenson, Jerri M.S. (NASA Johnson Space Center)
Grant/Contract No.:	Internal Project
Performance Goal No.:	
Performance Goal Text:	
Task Description:	The concept of operations in today’s spacecraft cockpit is one in which virtually all tasks are driven by procedures. In addition, crewmembers have near constant access to ground resources and information in the performance of their tasks. As NASA once again prepares for crewed spaceflight beyond low Earth orbit (LEO), future spacecraft will require automated systems that will allow the crew to perform procedures without assistance from the ground. This change threatens to increase astronaut workload, decrease efficiency, and increase the risk of inadequate task execution if electronic procedures are not designed with proper research-based guidance. Two ground-based investigations will be completed, leading to guidelines for designing and using electronic procedures. We will leverage and extend existing electronic procedure software and spacecraft simulations for these studies, to include the PRocedure Integrated Development Environment-PRIDE procedure authoring and execution software developed to model International Space Station (ISS) procedures, and an Orion-like electronic procedures prototype system. The proposed work will provide electronic procedures guidelines to contribute to the Space Human Factors Engineering (SHFE) gap SHFE-HCI-06 closure via the following specific aims: Aim 1: Determine the effect of level of automation of procedure step execution on Situation Awareness, and other human-system performance metrics. Aim 2: In a complex, multiple-procedure scenario, determine the effect of procedure management aids (e.g., availability of task allocation information) on Situation Awareness and other human-system performance metrics. Aim 3: Determine the effect of the level of integration of system and procedural information on Situation Awareness and other human-system performance metrics. In study 1, we will implement and evaluate electronic procedures with three levels of automation: 1) no automation, 2) mixed automation, and 3) high automation. Subjects will perform representative system tasks using prototype displays and the electronic procedures prototype systems. Particular attention will be given to critical measures of human-automation interaction including: Situation Awareness, Usability, Workload, and Trust. The procedures will be performed using two different management aid designs. In Study 2, levels of integration between the procedures and systems displays will be manipulated and compared experimentally; levels will range from no integration (procedures-only), to some integration (procedures and relevant system displays available only under certain conditions), to high integration (procedures and relevant systems displays always visible on the same monitor). Key metrics in this study will include Situation Awareness, Usability, Workload, and Trust. Eye-tracking data and data from a prototype functional Near-Infrared Spectroscopy sensor will also be used to assess performance. Results from these studies will be applicable to a variety of domains that use electronic procedures, including space vehicles, habitats, oil and gas refineries, and power plants. Candidate guidelines will also be submitted to appropriate NASA documents; for example, the Orion Display Format Standards document, NASA Human Integration Design Handbook (HIDH), and NASA-STD-3001, as applicable.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Results from these studies will be applicable to a variety of domains that use electronic procedures, including space vehicles, aircraft, habitats, oil and gas refineries, and power plants. The project includes a university collaborator who will serve as liaison to an industry consortium focused on studying and improving procedure design.
	In future missions, NASA plans to venture beyond Low Earth Orbit (LEO). Communication between the spacecraft and Earth will be subject to longer delays, and in some cases, will be unavailable. These spacecraft will require systems that will allow the crew to perform procedures without assistance from Mission Control. Crewmembers will rely much more heavily on the automated, computer-based tools available within their vehicle or habitat. Given the increased autonomy from the ground, missions will likely be even more dependent on procedures for day-to-day operations and survival. Crewmembers will need to be able to independently operate procedures without missing important steps, keep track of who is working each procedure (i.e., their crewmate, or the system automation), and maintain a view into the vehicle or habitat system’s health and status, along with the effects of their actions on those systems. Current state-of-the-art electronic procedures, such as those used in the aviation domain, can potentially offer some of the support previously provided by Mission Control. This includes assisting the crew in keeping track of the current step, allowing for some automated execution of steps, providing reminder features when multiple procedures are being worked, and providing some level of integration with system telemetry to assist the crewmember in monitoring and timely decision making. Automating functions within these systems has the potential to make crew more autonomous from Mission Control. If not implemented carefully, however, this change could increase astronaut workload, decrease efficiency and situation awareness (SA), and increase the risk of suboptimal task execution (Parasuraman & Manzey, 2010; Parasuraman, Malloy, & Singh, 1993; Metzger & Parasuraman, 2005; Singh, Sharma, Parasuraman, 2001). Two key questions addressed in the present research are: 1) When incorporating automation into electronic procedures, how much automation should be provided? 2) What is the importance of a relevant graphical system display in the execution of electronic procedures, and how important is the visual integration of that display with electronic

procedures? Of primary interest is the effect of these different procedure configurations on human performance, namely SA and workload. The three aims of this research are as follows:

Task Progress:

Aim 1: Determine the effect of level of automation of procedure step execution on SA, and other human-system performance metrics.

Aim 2: In a complex, multiple-procedure scenario, determine the effect of procedure management aids (e.g., availability of task allocation information) on SA and other human-system performance metrics.

Aim 3: Determine the effect of the level of integration of system and procedural information on SA and other human-system performance metrics.

Two studies were completed as part of this research project: Study 1 addressing level of automation of electronic procedures (Aims 1 and 2 above), and Study 2 addressing procedure/display integration (Aim 3). One of the key measures of interest in both studies was Situation Awareness, which was measured using the Situation Presence Assessment Method (SPAM; Durso, Hackworth, Truitt, Crutchfield, and Manning, 1998). SPAM uses time to answer a query about the system as a measure of situation awareness. Accuracy, workload, trust, usability and subjective preferences were also measured in both studies.

Study 1 involved twenty-seven crew-like subjects learning and performing tasks with PRocedure Integrated Development Environment (PRIDE) procedures and a habitat simulation system developed by TRACLabs. Subjects completed the scenario-based procedures while seated at a workstation intended to simulate a Habitat Control Station. The station consisted of two computers: the Procedures computer used to complete electronic procedures using PRIDE, and the Mission Control Center (MCC) computer where subjects answered computer-based questions from a mock Mission Control Center throughout the test session. MCC questions were Situation Awareness queries or simple progress questions (distractors). For the within-subjects study, subjects completed the procedures under conditions of: 1) no automation, 2) mixed automation, and 3) high automation. Another experimental factor was the location of a procedure management aid (always visible or on request).

Study 2 involved twenty crew-like subjects learning and performing tasks with an electronic procedures system and a flight control simulation. Subjects completed the scenario-based procedures, which included responding to alarms, performing malfunction procedures, and monitoring spacecraft launches, while seated at a workstation intended to simulate a future space vehicle control station. The station consisted of two computers: the Procedures computer used to complete electronic procedures using Orion-like procedures developed by the Crew Interface Rapid Prototyping Laboratory, and a Mission Control Center (MCC) computer where the subjects answered computer-based questions from a mock Mission Control Center throughout the test session. MCC questions were Situation Awareness queries or Bedford workload rating scales. For the within-subjects study, subjects completed the procedures under one of the following configurations: 1) procedures-only (no system display, telemetry only), 2) serial procedures (procedure was shown with an associated system display in toggle fashion, only for commands or on request), and 3) simultaneous procedures (procedure and related system display were shown on the same monitor). In addition to accuracy, workload, trust, usability and subjective preferences, performance data were collected from an eyetracker and a prototype functional Near Infrared Spectroscopy (fNIRS) sensor.

Results have implications for the design of electronic procedures systems, including use of automation and the role of systems displays. Results from both studies are currently being prepared for submittal to a technical journal.

References

Parasuraman, R., & Manzey, D. H. (2010). Complacency and bias in human use of automation: An attentional integration. Human factors, 52(3), 381-410.

Parasuraman, R., Molloy, R., & Singh, I. L. (1993). Performance consequences of automation-induced 'complacency'. The International Journal of Aviation Psychology, 3(1), 1-23.

Metzger, U., & Parasuraman, R. (2005). Automation in future air traffic management: Effects of decision aid reliability on controller performance and mental workload. Human Factors, 47(1), 35-49.

Singh, I. L., Sharma, H. O., & Parasuraman, R. (2001). Effects of manual training and automation reliability on automation induced complacency in flight simulation task. Psychological Studies-University of Calicut, 46(1/2), 21-27.

Durso, F.T., Hackworth, C.A., Truitt, T., Crutchfield, J., and Manning, C.A. (1998). Situation awareness as a predictor of performance in en route air traffic controllers, Air Traffic Quarterly, 6, pp. 1-20.

Bibliography Type: Description: (Last Updated: 10/29/2023)