Fiscal Year:	FY 2015	**Task Last Updated:**	FY 07/05/2015
PI Name:	Fischer, Ute Ph.D.		
Project Title:	Protocols for Asynchronous Communication in Space Operations: Communication Analysis		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **BHP**:Behavioral Health & Performance (archival in 2017)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture (2) **Team**:Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	30332-0165	**Congressional District:**	5
Comments:	NOTE: The NSSC also lists the PI as Ute Fischer-Loss (Ed., March 2025).		
Project Type:	Ground	**Solicitation / Funding Source:**	2011 Crew Health NNJ11ZSA002NA
Start Date:	09/06/2012	**End Date:**	08/31/2016
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:		**No. of Master' Degrees:**	5
No. of Master's Candidates:	5	**No. of Bachelor's Degrees:**	3
No. of Bachelor's Candidates:	5	**Monitoring Center:**	NASA JSC
Contact Monitor:	Leveton, Lauren	**Contact Phone:**	
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Flight Program:			
Flight Assignment:	NOTE: End date is now 8/31/2016 per NSSC information (Ed., 6/23/16) NOTE: End date is now 6/30/2016 per NSSC information (Ed., 3/9/16) NOTE: End date is now 3/5/2016 per NSSC information (Ed., 6/8/15)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Mosier, Kathleen (California State University, San Fransisco)		
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Performance Goal No.:			
Performance Goal Text:			

Task Description:	Effective and efficient communication between Mission Control and space crews is essential for successful task performance and mission safety. The importance of team communication is heightened when unforeseen problems arise, such as system failures that are time-critical and require extensive coordination and collaboration between space and ground crews. During long duration missions and missions beyond Low Earth Orbit, space-ground communications will involve delays up to 20 minutes one way, a reality that poses a formidable challenge to team communication and task performance. This project will determine how transmission delays impact team communication, teamwork, and task performance in relation to varying task demands and media constraints. A series of four studies will be conducted involving laboratory experiments and research in space-analog environments. The overall aim of the proposed research is to develop and validate protocols supporting Mission Control–space crew communication and collaboration during long-duration space missions. Specific project goals are: (1) Determine the impact of communication delays on communication, teamwork, and task performance in relation to varying task demands, i.e., procedural tasks vs. tasks requiring analysis and decision making, and different communication media (voice vs. text). (2) Develop and validate measures to assess and characterize team communication effectiveness and task performance in relation to different operational tasks. (3) Develop and validate communication protocols to support joint problem solving and decision making by mission controllers and space crews during periods of asynchronous communication.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Our research will result in communication protocols and/or procedures that will support collaborative problem solving and decision making by teams that are distributed across Earth and space and communicating asynchronously. Communication protocols resulting from this research could also be used to support collaborative work within on-ground distributed synchronous teams, for instance, during military operations or in telemedicine. Moreover, the communication protocols also point to technological solutions. One example is the text tool that was adopted in one space simulation and assisted the crew with the temporal aspects of communication. Further improvements might be a less chat- and more email-like text tool that includes a subject header and links between related messages to make it easier for conversational partners to follow a conversational thread. A text tool could also provide a template that gives structure to a message and highlights its components. Likewise, voice communication could be facilitated if recordings of messages were available to both sender and receiver. Moreover, the recording could indicate when a message was transmitted, and it is conceivable that the recording tool would include prompts for specific message components.
	The safety and success of future space missions will depend on the ability of crewmembers and mission control to collaborate effectively, even when communication between them is delayed. As missions travel further from the Earth, space-ground communication will involve significant delays, up to 20 minutes one way for missions to Mars. While the presence of communication delay will require future space crews to operate more autonomously than crews in current operations, the necessity of space-ground collaboration will remain. Solutions to mitigating the impact of communication delay that focus on faster transmission technology may succeed some day in providing seamless communication but current technology is not able to do so. It is therefore essential to explore solutions that focus on the communication process itself rather than transmission speed. In past research supported by this grant we identified specific communication issues associated with transmission delay and developed communication protocols to mitigate them. Our most recent efforts focused on the assessment of these protocols. Specifically, major accomplishments for the past year are: (1) The feasibility of communication protocols to space missions was assessed in two analog environments [Human Exploration Research Analog (HERA) and NASA Extreme Environment Mission Operations NEEMO)]. (2) A complementary laboratory study examined whether the availability of protocols enhanced team communication and task performance of remote teams during communication delay. (3) Interviews with domain experts (Flight Surgeons and PayCom) were conducted to identify challenges of space-ground communication and strategies to mitigate them. 1. Research to Assess the Feasibility of Communication Protocols to Space Operations. The aim of this research was to assess the usability of voice- and text-based communication protocols for space operations. Protocols are structured communication templates designed to facilitate the collaboration of mission control and space crews under time-delayed conditions utilizing medium-specific affordances. The content of the protocols addresses the problems associated with asynchronous communication that were identified in our research during years 1 and 2 (see previous Task Book reports--Fischer & Mosier, 2014; Fischer, Mosier & Orasanu, 2013) as well as recommendations by Love and Reagan (2013); their structural characteristics were informed by schema-based approaches to instruction design (Morrow & Rogers, 2008; Morrow et al., 1996). The effectiveness of the protocols was assessed in several space-analog simulation studies. One set of studies was conducted at the NASA Extreme Environment Operations (NEEMO) facility, an undersea research station 62 feet below sea level off Key Largo. A second set of studies took place in NASA's Human Exploration Research Analog (HERA), a space-analog habitat located at Johnson Space Center. Participants in NEEMO-18 and NEEMO-19 agreed to use the protocols on the days on which communication with mission control was delayed, either by 5 or 10 minutes. Each mission involved four crewmembers from the astronaut corps of NASA and its international partners (Canadian Space Agency-CSA; European Space Agency-ESA; Japanese Space Exploration Agency-JAXA). Participants in the HERA missions were astronaut-like research volunteers; that is, they were comparable to astronauts in terms of education, personality, and age. Each HERA mission included four crewmembers. Communication between crewmembers and mission control was delayed on 2 days by 10 minutes one-way. NEEMO crewmembers and two of the four HERA crews received 30 minutes of communication training prior to their missions. HERA crewmembers of missions 1 and 2 served as control and thus did not participate in any communication training. Communication training discussed the challenges of asynchronous communication and explained the elements of the communication protocols and conventions. In all NEEMO and HERA missions communication delay occurred on consecutive mission days, on four days in NEEMO and 2 days in HERA. Copies of the communication protocols were given to trained participants at the start of a mission to serve as a reference aid on days with a communication delay. Daily surveys were administered throughout a mission asking participants to rate the effectiveness of their interactions with mission control. On days with a communication delay participants were also asked to evaluate the extent to which

Task Progress:	the protocol was effective in supporting communication with mission control during specific tasks. A final survey requested feedback on individual elements of the communication protocols. Descriptive analyses indicate that trained participants generally considered the protocols to be effective in supporting crew-mission control communication when there was a transmission delay. Moreover, participants thought that the effectiveness of their interactions with mission control did not suffer when communication was delayed. In contrast, untrained HERA crewmembers gave considerably lower effectiveness ratings on time-delayed days compared to days with synchronous communication. Untrained HERA participants also commented that they were less willing to contact mission control for guidance on tasks when their communication was delayed. As a result, as Mission Control noted, they performed the tasks improperly and required time-consuming additional assistance from ground. Trained participants generally rated protocol elements as fairly critical to ensuring effective communication during asynchronous conditions. However, ratings for some items—most notably, pushing and chunking information and tracking time—were surprisingly low and pointed to specific training needs and technological improvements. Communication training for current HERA crewmembers has been modified as a result of these findings. Training has been increased to 60 minutes to give participants time to analyze examples of team communication under delayed conditions and to discuss how protocol elements can mitigate the challenges of asynchronous team communication. Research is ongoing to assess the effectiveness of these revisions. The importance of technological improvements is apparent in NEEMO 19. During this mission the crew opted to use exclusively text as their communication medium on time-delayed days. The crew's preference may reflect the implementation in this mission of a new text tool (VOXER) whose features seem better suited to meet the demands of asynchronous communication than the text tool available to the NEEMO-18 crew and the HERA crews. Overall these research findings suggest that asynchronous communication may be facilitated by protocols that aid remote team members in keeping track of conversational threads and the temporal sequence of messages. A complementary lab study with a larger N has been conducted to test this hypothesis. 2. Laboratory Study to Assess the Effectiveness of the Communication Protocols. The same task environment (AutoCAMS) as in our research in years 1 and 2 was used to assess whether the availability of protocols enhanced team communication and task performance of remote teams during communication delay. AutoCAMS (Manzey et al., 2008) simulates the life support system of a spacecraft, and in our task design, requires teams of three participants to diagnose and repair system failures. One participant in each team is assigned the role of Flight Systems Engineer (FSE) whom the Pioneer crew, comprised of the other two team members, have to contact for assistance with failures in the life support system onboard their exploration spacecraft. The FSE is located onboard the fictional US Space Station. Teams were randomly assigned to either the Protocol (i.e., experimental) or No-Protocol (i.e., control) condition. Participants in the experimental group received the communication protocols and 30 minutes of communication instruction as part of their position-specific (FSE or Pioneer crewmember) task training. Participants in the control group received only task specific training. After training, participants completed two 90-min sessions, one in which the communication between the Pioneer crew and the FSE was voice-based, and one that provided only text communication. Communication between remote team members in both sessions was delayed by 5 minutes. During each mission, the Pioneer crew and the FSE had to collaborate on two system failures. Initial analysis showed that the availability of communication protocols did not have a significant effect on teams' task performance in terms of time to resolve failures, incorrect repair attempts, or number of correct repairs. Communication protocols, however, did facilitate team communication. Specifically, communication by teams in the Protocol condition was more coherent (i.e., involved fewer anaphoric expressions, incomplete transmissions, missing responses, or unnecessary requests due to insensitivity to the transmission delay) and tended to be more compact (i.e., related information, such as diagnostic cues, were presented together in one communication rather than across several communications). As some teams in the experimental group apparently did not comply with instructions while teams in the control group adopted ad-hoc protocol-like conventions, additional analyses are planned to account for participants' adherence to protocol elements in relation to task performance and team communication. 3. Interviews with Domain-Experts on the Challenges of Space-Ground Communication. Interviews were conducted with two Flight Surgeons and one PayCom to characterize challenges of space-ground communication in current operations, to discuss the impact of communication delay, and to learn about communication strategies operational experience taught them. A common sentiment was that space-ground communication is especially critical in situations that are time-limited and dynamically changing, and in which mission control needs to aid crewmembers who have less technical or medical knowledge and expertise. Voice communication was the preferred medium that as required by a task, should be augmented by video and text. Experts mentioned several strategies to ensure effective communication: avoid the use of technical jargon and rely on generic terms instead, or establish a shared vocabulary up front; clearly structure your communication and, dependent on the situation, anticipate potential task outcomes and information needs; provide detailed instructions and specify what information the crew needs to report back; mentally tag individual communications to maintain the thread. Experts also emphasized the importance of joint training of ground support and crewmembers to establish mutual trust. These strategies are consistent with the communication protocols we developed as well as our current training approach that involves a joint session with HERA crews and HabComs. References: Love, S. G. & Reagan, M. L. (2013). Delayed voice communication. Acta Astronautica 91, 89-95. Morrow, D. G. & Rogers, W. A. (2008). Environmental support: An integrative framework. Human Factors 50(4), 589-613. Morrow, D. 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Papers from Meeting Proceedings	Gonzalez K, Mosier KL, Lam J, Fischer U. "Characteristics impacting teamwork and performance for space operations." 59th Annual Meeting of the Human Factors and Ergonomics Society, Los Angeles, CA, October 26–30, 2015. Proceedings of the Human Factors and Ergonomics Society, Los Angeles, CA, October 26–30, 2015. In press as of July 2015. , Jul-2015
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