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PI Name:	Carter, Dorothy Ph.D.		
Project Title:	Project FUSION: Facilitating Unified Systems of Interdependent Organizational Networks		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline-- Element/Subdiscipline:			
Joint Agency Name:		TechPort:	Yes
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) 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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Comments:	The Principal Investigator (PI) was previously at the University of Georgia.		
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No. of PhD Candidates:	5	No. of Master' Degrees:	0
No. of Master's Candidates:	3	No. of Bachelor's Degrees:	0
No. of Bachelor's Candidates:	12	Monitoring Center:	NASA JSC
Contact Monitor:	Williams, Thomas	Contact Phone:	281-483-8773
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	December 2018 report: Dr. Brandon Vessey is no longer a researcher on this project. All of his responsibilities on this project have been assumed by Dr. Lauren Landon.		
COI Name (Institution):	Contractor, Noshir Ph.D. (Northwestern University) Schecter, Aaron Ph.D. (University of Georgia) DeChurch, Leslie Ph.D. (Northwestern University) Shuffler, Marissa Ph.D. (Clemson University)		
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Task Description:

As we set our sights on Mars, and other destinations beyond lower Earth orbit, we must enable extreme forms of teamwork across Spaceflight Multiteam Systems (SFMTSs) composed of teams that are separated by unprecedented degrees of space and time. In “Project FUSION: Facilitating Unified Systems of Interdependent Organizational Networks,” we are engaging in a transformative research program rooted in the past decade of theory and research on MTSS, but breaking new ground in how MTSS are conceptualized and studied. Our programmatic research aims to illuminate the underlying forces that give rise to the psycho-social relational states (e.g., influence, trust, shared cognition) within and between teams that underpin mission success. These crucial relationships, and the drivers of their emergence, will need to be understood, monitored, and at times, circumvented using countermeasures in order to enable coordinated efforts across the SFMTSs involved in Long-duration Exploration Mission (LDEMs). This project constitutes a three-year, multi-pronged, multi-method, interdisciplinary project with three main research foci: (1) field investigations using NASA personnel; (2) development of an agent-based computational model capturing the drivers of relational states; and (3) controlled laboratory experiments and analog studies. Our research design is intended to be iterative. Findings within each foci will continually infuse the refinement and design of research in other foci. Project FUSION is an applied research project with the ultimate goal of delivering a countermeasure toolkit to facilitate SFMTS functioning during LDEMs. Our proposed countermeasure toolkit consists of: (1) a SFMTS task analysis procedure, (2) a decision-making guidebook based on our agent-based computational model of SFMTS dynamics, (3) a multiteam training countermeasure ready for operational implementation with astronauts and mission controllers, and (4) a multiteam debriefing protocol ready for operational implementation with astronauts and mission controllers.

Rationale for HRP Directed Research:**Research Impact/Earth Benefits:**

The findings from this project will have substantial implications for human life on Earth, and in particular, for the effectiveness of teams and larger systems of teams in organizations. The field studies, laboratory studies, and computer simulation studies aim to better understand the patterns of social relationships (e.g., trust, influence, information sharing) that are likely to form within and across teams in large interdependent organizational systems. By better understanding the patterns of relationships that are likely, we can help determine when and where teamwork interventions or “countermeasures” are necessary. Moreover, the ultimate goal of this applied research project is to develop and validate a toolkit of countermeasures, including training, debriefing procedures, and decision-making protocols that are designed to facilitate team and inter-team collaboration in complex organizational systems. These countermeasures will be able to be utilized widely across many organizational contexts beyond NASA (e.g., healthcare, the military, corporations).

Overview:

Project FUSION is combining findings from analyses of archival documents, interviews, and observations with NASA personnel (i.e., Research Foci 1), computational ‘agent-based’ models (i.e., Research Foci 2), and laboratory and analog environment experimental studies with human subjects (i.e., Research Foci 3), to better understand the functioning of the spaceflight multiteam systems or “SFMTSs” (i.e., interdependent systems comprised of multiple distinct teams; e.g., the Spaceflight Crew and the Mission Control Center teams) that will be involved in future long-duration space exploration missions (LDEMs). Project FUSION is an applied research project with the ultimate goal of translating findings gleaned through our three research foci in order to provide NASA with a countermeasure toolkit comprised of validated interventions that can be used to facilitate effective teamwork in SFMTSs.

In Year 1, our research team made substantial progress toward achieving the research goals of each foci and the development of our countermeasure toolkit. The first 6 months of Y1 constituted a “definitional” phase for this project. During the definitional phase, our research team addressed suggestions and concerns raised by NASA personnel related to our proposed project. We formalized our proposed approaches and completed a series of tasks related to each of our three research foci and our proposed countermeasure toolkit. The tasks completed during the definitional phase are now serving as the foundation of our research program and the development of our countermeasure toolkit.

Research Foci 1 and Countermeasure 1:

Research Foci 1 in Project FUSION is focused on understanding the specific demands, characteristics, constraints, and challenges facing the SFMTSs that will be involved in future LDEMs. In Research Foci 1, we plan to conduct a series of interviews and observational studies with NASA personnel as well as analyses of archival documentation related to SFMTS collaboration.

During the definitional phase, we laid the groundwork for this research foci in multiple ways. For example, we expanded existing “team” task analysis procedures to create a prototype of our “FUSION Multiteam Task Analysis Procedure” (i.e., Countermeasure 1). The FUSION Multiteam Task Analysis Procedure is intended to be used by researchers and NASA personnel to help clarify the projected goals and tasks of SFMTSs, the patterns of intra-team and inter-team relationships and interactions that are necessary to achieve projected goals, and key performance indicators reflective of goal achievement. To create the prototype of this countermeasure, we expanded and combined existing team task analysis procedures, as well as interview and observational protocols which have been used by members of our research team in other multiteam system contexts. Whereas a team task analysis is a structured approach used to understand the task-related and interpersonal competencies and conditions necessary for the success of a single team, a multiteam task analysis is used to understand both the intra-team as well as the inter-team task-related and interpersonal competencies and conditions necessary for the success of a larger interdependent system.

The FUSION research team is leveraging our multiteam task analysis procedure within Research Foci 1 in Project Years 1 and 2 to better understand the demands facing the types of SFMTSs that are likely to be involved in future LDEMs. Findings from the SFMTS Task Analysis are providing a foundation for the entire Project FUSION research program – informing the research activities in other Foci and the development of all countermeasures. Our approach to complete the multiteam task analysis draws information from multiple sources, such as archival documentation, interviews, and observations, to build a coherent depiction of the focal SFMTSs.

During the definitional phase, our team generated a detailed description of the steps we are taking to leverage the multiteam task analysis procedure as the basis of our research program. We specified our interview and observational protocols and procedures. Additionally, we (1) compiled archival documents related to SFMTS functioning, (2) categorized these documents based on their relevance to different SFMTS structures that are likely to be involved in LDEM, and (3) evaluated their viability for inclusion in our analyses. To meet the criteria for inclusion, each identified resource contained information pertaining to a substantial challenge in multiteam collaboration and coordination in a

spaceflight or analogous context.

After exiting the definitional phase, we have continued to refine our multiteam task analysis procedures by further articulating our interview protocols and continuing discussions with NASA personnel related to the collection of interview and observational data. Further, we have conducted an extensive analysis of identified documents pertaining to NASA's Mission Control Center (MCC). Our analysis of these documents reveals key details about the history and evolution of the multiteam collaboration processes within MCC since the inception of the space program and has resulted in a journal submission completed this Fall.

Research Foci 2 and Countermeasure 2:

Given that SFMTSs are highly complex and dynamic, it is often difficult for personnel involved in mission planning and support to project the combined effects of all possible internal and external factors that may impact SFMTS functioning throughout the duration of a LDEM. To help address these challenges, Research Foci 2 aims to supplement findings from Research Foci 1 in order to build an Agent-Based Model (ABM) of SFMTS dynamics that can be used to make predictions about the functioning of SFMTSs, and in particular, when and among whom mission-critical breakdowns in collaboration and coordination are likely to occur.

Broadly, ABMs are computer simulations that provide insights into patterns of emergent behavior resulting from actions and interactions within complex systems. In an ABM, a set of agents, for example, crew and MCC members in a SFMTS, are seeded with a set of characteristics (e.g., demographics, personality, team memberships, training experience) which replicate the composition of actual SFMTS component teams, as well as a set of theoretically-derived rules guiding their actions and interactions with other agents.

In our FUSION SFMTS ABM, the agents in the model (i.e., SFMTS members) will interact with one another in accordance with rules derived from our theoretical framework of multiteam functioning. The agents' interactions will generate networks of important psycho-social relationships, like trust, influence, communication, or information sharing, within and between teams. The key goal of our FUSION SFMTS is to better understand the patterns of psycho-social relationships that are likely to arise in SFMTSs under different circumstances. We will compare the patterns of psycho-social relationships that are likely to occur to the patterns that are likely to be effective. We aim to help NASA identify situations in which the patterns of relationships that are likely to occur are unlikely to be effective, and therefore, help determine when certain countermeasures (e.g., training, debriefing) need to be implemented in order to facilitate multiteam coordination and performance.

At the conclusion of the project, all code and documentation associated with the FUSION SFMTS ABM will be delivered to NASA. In addition to the computer code and associated documentation, we will use the results of virtual experiments to develop and deliver a FUSION Decision-Making Guidebook Countermeasure (Countermeasure 2) for use by NASA personnel involved in mission planning and support. The guidebook will be designed to be used by Behavioral Health and Performance (BHP) personnel to provide recommendations for the strategic application of other countermeasures (e.g., training, debriefing, mission planning) to best support mission success. To build the guidebook, Project FUSION researchers will begin by working closely with BHP personnel to identify approximately 20-30 core research questions related to multiteam collaboration in future missions that will be tested using ABM virtual experimentation.

During the definitional phase, we began by expanding our proposed theoretical framework for the FUSION SFMTS ABM. Additionally, we produced documentation clarifying how ABMs being produced in three other NASA-funded projects will be expanded, leveraged, and combined to produce the FUSION SFMTS ABM in this project. Further, we produced documentation detailing our plan for meeting NASA's established standards for modeling and simulation studies. Finally, we established and articulated our plans for utilizing human data gathered from the Human Exploration Research Analog (HERA) environment in Johnson Space Center (JSC) to inform the creation of our models. We clarified the conceptual criteria that will be included in our model by establishing their formal definition, their corresponding indicators in data collected during the lab and analog studies, and the anticipated relationships among these criteria. After the definitional phase, we have continued to refine our theoretical model and finalize our plans for collecting the human subjects data that will be used to refine and validate the model parameters.

Research Foci 3 and Countermeasures 3 and 4:

Research Foci 3 consists of a series of experiments with human subjects located in university laboratories and/or the Human Exploration Research Analog (HERA) environment. These experiments are intended to: (1) collect the human subjects data needed to refine and validate the model parameters in our SFMTS ABM (Foci 2); (2) test our hypotheses about the drivers of psycho-social relationships in SFMTSs; (3) test our hypotheses about the antecedents of SFMTS coordination and performance; and (4) evaluate the validity of our third and fourth countermeasures (i.e., training, and debriefing, respectively).

The experiments in Foci 3 are designed to reflect key attributes of the Spaceflight MTSSs, such as high levels of differentiation between teams based on differences in geographic location, functional areas of expertise, communications delays, goals, and teamwork norms. The experiments leverage the Project RED (Red planet Exploration & Development) computerized SFMTS simulation. In a Project RED simulation, four interdisciplinary teams work interdependently as a 12-person SFMTS to solve a complex task: designing a well to support a human colony on Mars. The Project RED simulation has been implemented in other NASA-funded projects and has demonstrated utility in examining the teamwork risks present in LDEMs. The simulation provides metrics of individual, team, and system performance.

During the definitional phase, our research team delivered documentation to NASA containing: (1) experimental protocols for the first set of experimental studies which will be implemented in HERA Campaign 5 beginning January 2019; (2) institutional review board approval documents; (3) data collection and evaluation plans; and (4) participant training materials. Since the conclusion of the definitional phase, we have continued to refine our protocols and experimental materials. To support this process, we conducted several successful pilot sessions of the laboratory experiments. Further, we have continued to refine practices and protocols in advance of the start of Campaign 5 data collection.

Additionally, as part of Research Foci 3, we created initial prototypes of the third and fourth countermeasures in our proposed toolkit: The Project RED FUSION Training Procedure (i.e., Countermeasure 3) and the FUSION Multiteam Debrief Procedure (i.e., Countermeasure 4). The Project RED FUSION Training teaches trainees about the

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	<p>communication, leadership/coordination, and situational awareness/risk assessment demands of working in a SFMTS. The training leverages a simplified table-top (paper-and-pencil) version of the Project RED computerized simulation being implemented in the laboratory and analog environment experiments. The training intervention is designed to facilitate trainees' understanding of the potential breakdowns in inter-team communication, collaboration, and coordination that might arise due to differences between teams and environmental uncertainty. Project RED FUSION Training builds on the foundation of team skills learned within team training programs that are currently implemented, such as Spaceflight Resource Management (SFRM). However, Project RED FUSION expands current "intra-team-focused" training to emphasize the additional inter-team collaboration demands associated with working in a larger system. Preliminary analyses from an initial evaluation study of the Project RED FUSION Training implemented in a master's-level university course suggest that the training program produces desired effects. For example, findings suggest that over the course of the training, members of all teams come to better understand and assign greater priority to the overall superordinate goal of the system, relative to their more proximal team- or individual-level goals.</p> <p>The FUSION Multiteam Debrief Procedure (Countermeasure 4) is a structured 'after-action review' procedure designed for use in situations where multiple teams work together on shared goals. Team debriefing protocols are often designed to reinforce team members' understanding and development teamwork skills taught during team training and to prepare teams for subsequent phases of team performance. For example, SFRM materials implemented currently in NASA provide substantial guidance for team leaders or debrief facilitators with regard to structuring debriefs to most effectively reinforce SFRM concepts and ensure that teams learn to "self correct." The FUSION Debrief Protocol is being designed to expand on NASA's current SFRM Debriefing protocols in two key ways. First, the FUSION Debrief will retain the valuable teamwork lessons emphasized within previous SFRM debriefing protocols while also adding additional content intended to reinforce lessons learned within Project RED FUSION Training about the inter-team collaboration demands of SFMTSs. Second, the FUSION Debrief Protocol will expand current SFRM Debriefing protocols, which are meant to be used within a single team, to support debriefing of multiple MTS component teams, and/or representatives from multiple teams, simultaneously.</p>
Bibliography Type:	Description: (Last Updated: 01/24/2024)
Articles in Peer-reviewed Journals	Shuffler ML, Carter DR. "Teamwork situated in multiteam systems: Key lessons learned and future opportunities." Am Psychol. 2018 May-Jun;73(4):390-406. http://dx.doi.org/10.1037/amp0000322 ; PubMed PMID: 29792456 , May-2018