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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		
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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
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Flight Program:			
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Key Personnel Changes/Previous PI:			
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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 MTSSs 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). Project FUSION is a 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 are continually infusing the refinement and design of research in other foci. Further, Project FUSION is an applied research project with the ultimate goal of translating findings from 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. The countermeasure toolkit under development in this project 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 operating in high-stakes environments. 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).

In the 'Spaceflight Multiteam Systems' (SFMTSs) involved in LDEMs, there are countless opportunities for breakdowns in collaboration both within teams, and especially across the boundaries of different 'component' teams. Therefore, NASA has identified a need for research investigating the key factors underpinning effective SFMTS functioning, as well as a need for countermeasures designed to mitigate the risks stemming from inadequate cooperation, coordination, communication, and psychosocial adaptation both within, as well as between, the component teams of SFMTS involved in LDEMs. Project FUSION seeks to fill this need through investigations in three iterative research foci: (1) field studies, (2) computational 'agent-based' modeling, and (3) laboratory and analog studies. Collectively, these investigations will result in the delivery of a validated 'countermeasure toolkit' of interventions and associated recommendations to NASA.

RESEARCH FOCI 1: The goal of Research Foci 1 is to provide contextually rich, in-depth information gathered from relevant academic literature and archival resources as well as NASA, analog, and international spaceflight personnel in order to define the key characteristics, potential triggers, and performance outcomes for SFMTSs and better understand and evaluate existing interventions and advance new countermeasures for SFMTS coordination and performance. Given the unique characteristics of LDEM SFMTSs, such detailed information is necessary to both understand current multiteam systems (MTSSs) involved in spaceflight as well as begin to predict the critical challenges of future LDEMs. By capturing this rich information, our research team will be able to better tailor our eventual countermeasures to the unique challenges facing MTSSs operating in spaceflight contexts, and in particular those tasked with completing LDEMs.

During the current reporting period, our research team completed extensive reviews of several areas of academic literature relevant to the focus of Project FUSION. These included reviews of research on MTSSs and interventions to support MTSS functioning, the literature pertaining to team membership change events (i.e., members joining or departing from work teams), and research on leadership in interteam contexts. Additionally, we completed a synthesis archival documents tracking the development and adaptation of Mission Control Center (MCC) over the course of NASA's 60 year operational history. Further, we began two archival document-based studies of adaptation in NASA's SFMTSs more broadly, expected to conclude during the first half of Y3. Finally, we laid the groundwork for observational and interview studies to take place in Y3 by conducting a series of pilot interviews with NASA personnel and formalizing procedures and documentation needed for the forthcoming data collection. The results of these and subsequent efforts in Y3 will be used to guide our investigations in the remaining two research foci, as well as our eventual recommendations regarding the application of our countermeasure toolkit.

As part of Research Foci 1, we are developing and evaluating a "FUSION Multiteam Task Analysis Procedure" (i.e., Countermeasure #1). The FUSION SFMTS 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. We are leveraging key elements of the FUSION SFMTS task analysis procedure (e.g., archival analyses, interviews, observations) within Research Foci 1 to better understand the demands facing the types of SFMTSs that are likely to be involved in future LDEMs.

RESEARCH FOCI 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

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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 the FUSION SFMTS ABM 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, etc.) 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 Y2, we constructed a detailed plan for building this computer model which will involve combining and expanding two other ABMs being developed in two other NASA-funded research projects. Early in Y3, at the conclusion of the current Human Experimentation Research Analog (HERA) Campaign 5, our research team will complete the construction of our model using data collected with human subjects during Y1 and Y2. During this process, the model is 'trained' using data collected from human subjects (as part of Research Foci 3).

RESEARCH FOCI 3: Research Foci 3 consists of a series of MTS laboratory and analog study experiments with human subjects located in university laboratories and/or the Human Exploration Research Analog (HERA) environment in Houston, Texas. These experiments are intended to: (1) collect data from human subjects needed to refine and validate our SFMTS ABM (Foci 2); (2) test hypotheses about the motivations and behaviors involved in interactions within SFMTSs; (3) test hypotheses about the conditions that lead to effective coordination and performance in SFMTSs; and (4) evaluate two of our countermeasures: expanded training and debriefing procedures for use in SFMTSs. The experiments in Foci 3, are designed to reflect key attributes of SFMTSs, including teams that are very different from one another in a number of ways (e.g., expertise, physical location), as well as environmental limitations that are likely to be in place during future LDEMs (e.g., communication delays).

In Y2, we collected data in conjunction with HERA Campaign 5. Our experiments in Y2 evaluated the factors contributing to patterns of relationships within SFMTSs, and in particular, on the role that differences between the teams comprising the system might play in these patterns. This round of laboratory and analog environment data collection is expected to conclude successfully during the final mission of Campaign 5 during the early portion of Y3. Data from Foci 3 Y2 will form the basis for the generation and estimation of our SFMTS ABM (Foci 2). We also conducted several evaluations of our countermeasure materials during Y2, including a classroom evaluation of our expanded multiteam training procedure. The Project RED FUSION Training teaches trainees about the 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 interteam communication, collaboration, and coordination that might arise during LDEMs. Project RED FUSION Training builds on team training programs that are currently implemented by NASA. Project RED FUSION expands current training focused within teams to emphasize the additional between-team collaboration demands associated with working in a larger system. Initial validations of our training procedure conducted within two samples of MBA students indicate that it is effective in orienting participants towards a shared-system level goal, leading them to prioritize this higher-order goal over their individual or team-level goals.

Bibliography Type:	Description: (Last Updated: 01/24/2024)
Articles in Peer-reviewed Journals	Pendergraft JG, Carter DR, Tseng S, Landon LB, Slack KJ, Shuffler ML. "Learning from the past to advance the future: The adaptation and resilience of NASA's spaceflight multiteam systems across four eras of spaceflight." <i>Frontiers in Psychology</i> . 2019 Jul 12;10:1633. eCollection 2019. https://doi.org/10.3389/fpsyg.2019.01633 ; PubMed PMID: 31354603 ; PubMed Central PMCID: PMC6639738 , Jul-2019
Articles in Peer-reviewed Journals	Carter DR, Cullen-Lester C, Jones J, Gerbasi A, Chrobot-Mason D, Nae E. "Functional leadership in interteam contexts: Understanding 'what' in the context of why? where? when? and who?" <i>The Leadership Quarterly</i> . 2020 Feb;31(1):101378. https://doi.org/10.1016/j.leaqua.2019.101378 ; PMID: 32863680 ; PMCID: PMC7454171 , Feb-2020