TOOLS FOR SYSTEMATIC IDENTIFICATION OF CROSS-DISCIPLINARY RESEARCH RELEVANT TO EXPLORATION MISSIONS. M. J. Shelhamer[1] and J. A. Mindock[2], [1]Johns Hopkins University, School of Medicine, 710 Ross Bldg., 733 N. Broadway, Baltimore MD 21205, mshelhamer@jhu.edu, [2]KBRWyle, 2400 NASA Parkway, Houston TX 77058, jennifer.a.mindock@nasa.gov.

Introduction: Long-duration flights in deep space are made difficult by a unique set of hazards [1]: altered gravity level, distance from Earth, radiation, hostile and closed spacecraft environment, isolation and confinement. These hazards lead to specific risks to human health and performance. The NASA Human Research Program (HRP) is investigating these risks in a rigorous manner, and many other organizations within NASA are equally absorbed with associated engineering and operational issues. Human research in a Deep Space Gateway (DSG) will offer an unprecedented opportunity to investigate many of these areas in the more challenging environment of deep space. Even more so, it presents a fresh opportunity to investigate interactions between key variables across traditional disciplines.

The Problem of Interactions: HRP has a good handle on the main risks to health and performance and a broad research program to address them. What is needed, however, is a way to systematically identify and track interactions [2]. This should include not only the life sciences but also involve engineering and operational aspects. There are many compelling reasons to identify and track these interactions:

- A very practical reason of immediate relevance is that this provides a systematic and objective way to prioritize experiments and select experiment complements for DSG missions: those factors that have many interactions with other factors might have a higher priority, and the interacting set of factors could suggest related investigations that form a natural complement to be performed together.
- When examining risks one at a time, it is possible that each would be sufficiently mitigated on its own, but that their interactions would lead to an unanticipated problem. Thus it is possible to fool oneself into thinking that the robustness of the overall mission is acceptable based solely on the performance of each subsystem independently.
- Aerospace mishaps are almost invariably the result of a cascade of interacting effects, none of which by itself would cause an overall mission failure.
- Explicitly examining interactions is true to physiology, psychology, performance, and behavior.

A Solution: A tool is needed to identify key interactions to help guide the selection of investigations that might form a coherent complement for implementation on a DSG mission. We propose one such tool. It is based on a Contributing Factor Map (CFM): a systematic categorization of the many factors that contribute to the success of a long-distance long-duration human space flight [3]. These factors span the range from task and mission design to training to spacecraft design to psychology and physiology and finally mission outcomes. While simply a taxonomy at this point, the CFM provides a foundation for examining interactions by identifying connections between factors. This might be done with a form of text analytics, in which technical and scientific documents from the different disciplines (factors) are searched for common features such as keywords, authors, or concepts and related using the common language of the CFM factors. Commonalities in this literature analysis can be inferred to represent connections between factors, which can be indicated on the CFM by interconnecting lines, the width of each depending on the strength of the connections thus identified.

This map, in the form of a network, could then guide the process of selecting a complement of investigations for a DSG mission that purposely incorporates an interrelated set of factors. This provides a deliberate approach to examining important interactions, rather than an *ad hoc* approach or one that tries to examine interactions *post hoc* among investigations that were not designed with interactions in mind (lacking simultaneous synchronized data acquisition across disciplines, with corresponding metadata, as an example). These investigations would then provide valuable data to inform human health, performance, and mission-risk models for future missions.

Final Thoughts: Even if this approach is successful, implementation challenges will remain. Availability of organizational resources is one issue: when there is insufficient time and money to solve known problems within each discipline, there is little remaining to investigate interactions. Nevertheless the approach described here provides a common language and a unifying principle to guide DSG experiment planning and cross-disciplinary risk mitigation.

References: [1] Francisco D. and Romero E. (2016) *NASA's Human System Risk Assessment Process*. Presentation at Human Research Program Investigators' Workshop. [2] White R. J. and Averner M. (2001) Nature, 409, 1115-1118. [3] Mindock J. A. and Klaus D. M. (2014) *IEEE Trans Hum Mach Sys, 44*, 591-602.