INCORPORATION OF HUMAN RISK DIRECTED ACYCLIC GRAPHS (DAG) WITH MISHAP INVESTIGATIONS TO UN-SILO KNOWLEDGE

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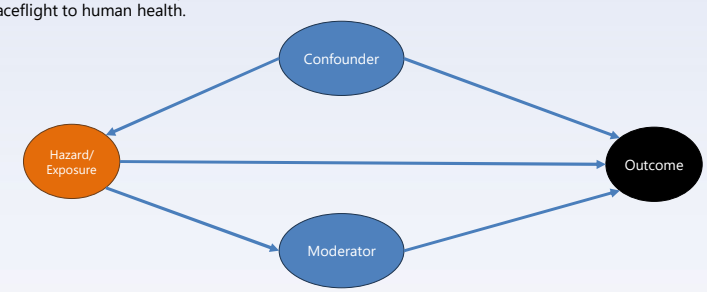
Purpose: The breadth of knowledge at NASA covers an overwhelming number of disciplines, each learning about the complexities of space flight in different ways. Ultimately this can lead to information becoming silo-ed within different divisions and projects. This project aims to help un-silo some of this knowledge by bringing together efforts to characterize the causal mapping of human health risks with mishap investigations to merge theoretical and practical knowledge.

What is a Directed Acyclic Graph (DAG)?

Directed Acyclic Graphs (DAGs) are a style of causal modeling that map the relationship between nodes classified as hazards/exposures, outcomes of interest, confounders, and other contributing factors. As the name implies, the edges between these nodes are directed, and one way, and cannot form loops or cycles.

These graphs help to provide a display of collective knowledge pertaining to the potentially complex relationships exposures, outcome, and other contributing factors, which in turn helps communicate across shareholders. The Human Systems Risk Board (HSRB) utilized DAGs for the communication of the risks of spaceflight to human health.



What is the Human Systems Risk Board?

The Human System Risk Board (HSRB) manages the process by which scientific evidence is utilized to establish and reassess the postures of the various risks to the Human System during all of the various types of existing or anticipated crewed missions. The HSRB operates as part of the Health and Medical Technical Authority of the Office of the Chief Health and Medical Officer of NASA via the JSC Chief Medical Officer. Further information can be found on the HSRB website (see QR Code).

This board's ongoing efforts are intended to act as a collaboration across different silos of human health research and operations. To help further utilize HSRB tools and information, this DAG development project was conceived as a proof of concept of how we may further un-silo some of this information to incorporate information from engineering operations information into a human health framework.

What was the Mishap?

In 2013, EVA 23 experienced a near miss due to 1 to 1.5 liters of water leaking into the helmet of a crewmember. While this was ultimately resolved with no loss of life or injury to crew, this was a serious incident that took a coordinated response from EVA participants, on-board crew, and ground crew to safely navigate the situation. After the incident, multiple investigations occurred and concluded that inorganic material had contaminated the water supply and built up in the water separator of the cooling systems.

Mishap investigation reports found the technical failures that lead to the event but also identified cultural norms and practices that prevented inquiry into previous events of water in the helmet such as in EVA 22, immediately preceding the near miss event. The report ultimately brought about change to the reported gaps and water in the helmet was less normalized and continued to be monitored.

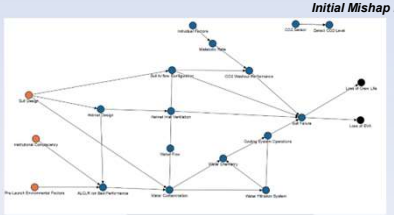
This mishap provides a real-world example of the concepts described in several of the HSRB DAGs. Utilizing the information gathered and analyzed in the mishap investigations can help identify where remediation has addressed the gaps, how those gaps are represented within the HSRB risks, and potentially identify new areas of interest that can help assure further safety.

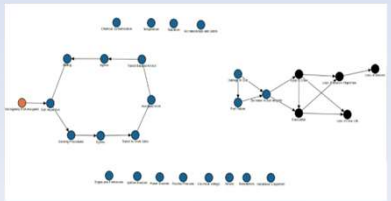
Image from John Uri article on 10-year anniversary of the mishap. Water droplets in the helmet during and on-orbit recreation test

https://www.nasa.gov/general/10-years-ago-eva-23-how-a-high-visibility-close-call-cut-short-a-spacewalk/

How was this DAG Developed?

Initial Mishap DAG Iterations





Reference Materials

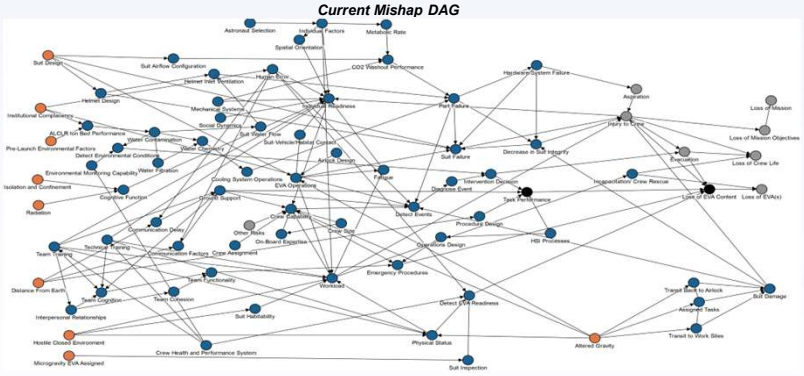
Source	Category
Failure Analysis Results and Corrective Actions Implemented for the Extravehicular Mobility Unit 3011 Water in the Helmet Mishap	NASA Investigation
Carbon Dioxide Washout Testing Using Various Inlet Vent Configurations in the Mark-III Space Suit	NASA Investigation
Status of the Redesign of the Extravehicular Mobility Unit Airlock Cooling Loop Recovery Assembly	NASA Investigation
The Spacewalk That Almost Killed Him	External Article
NASA vows to correct problems that led to dangerous EVA leak	External Article
ISS EVA 23 Lessons Learned	NASA Investigation
NASA Man-Systems Integration Standards Volume 1 Section 14	NASA Resource
Current spacesuits won't cut it on the moon. So NASA made new ones.	External Article
How Space Suits Work	External Resource
International Space Station (ISS) EVA Suit Water Intrusion High Visibility Close Call	NASA Investigation

The development of the Mishap DAG was derived from resources developed through NASA investigations, external interviews, and general NASA resources with information pertaining to EVA system.

Through an iterative process, we combined the knowledge of mishap resources and previously developed HSRB DAGs. The resultant product includes other HSRB risks: EVA, Earth Independent Human Systems, Decompression Sickness, Team, Dynamic Loads, and some other tangential risks to move from the initial ideas in the figures above, to the current iteration shown below.

Each draft was reviewed by the DAG development working group servicing the HSRB.

Current Mishap DAG



How does this DAG impact future work?

This project was conceived to provide tangible examples of the HSRB risks, un-silo current knowledge bases, and explore/audit current risk DAGs within an applicable mishap. While the development of this has assisted with some of these goals, to fully see the desired outcomes, groups outside the HSRB community must provide their input as we seek to collaborate on this project. One example of this is already occurring through a review process headed by Safety and Mission Assurance Directorate.

Another way that this DAG, and the other risk DAGs are furthering the reach of knowledge is through nodes being linked to relevant technical requirements within NASA Spaceflight Human-System Standard (NASA-STD-3001). This effort aims to show how the conceptual mapping of the DAGs is relevant to current NASA programs. Additional efforts to further integrate knowledge from different disciplines into human health research/operations and integrate human health research/operations knowledge and tools into other disciplines, will help provide a more robust knowledge data base across NASA and prevent knowledge loss across disciplines and centers.