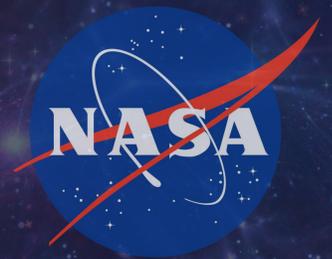# A PROPOSED METHOD FOR QUANTIFYING THE INFLUENCE OF SPACEFLIGHT HAZARDS IN NASA'S COMPOSITE HUMAN SYSTEM RISK NETWORK

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Background

The Human System Risk Board (HSRB) at the National Aeronautics and Space Administration (NASA) uses **causal diagrams** as part of the process of continuous risk management of the human system risks of spaceflight. These diagrams create a visual representation of how the **hazards of spaceflight** initiate a cascade of events that, without intervention, eventually may lead to one or more of **7 Mission-Level Outcomes (MLO)**. Understanding the relative contributions of the hazards of spaceflight to the MLO is not intuitive, especially when spaceflight hazards and outcomes can be temporally distant and/or separated by many intermediate events. What is required is a **method by which to quantify the influence of the hazards**. Using the HSRB's composite Human Systems Risk Network (HSRN), we use network analysis to quantify and compare the influence of the hazards on various MLO.

Methods

We chose node-specific measures to capture various ways that hazards may exert influence on the overall network and the MLOs:

- **Inverse Alpha centrality** is the Alpha centrality computed from the network with arrow directions inverted. As it is a function of both the number of downstream connections and their interconnectedness, it measures hazards' influence on the total network.

- **Adhesions:** The total number of paths between the hazards and outcomes. This measure was selected to trace how many outcomes each hazard touches, and by how many pathways.

- **Out-degree** is the number of factors upon which a hazard has direct influence. Indexes the difficulty in interrupting a hazard's influence close to the source.
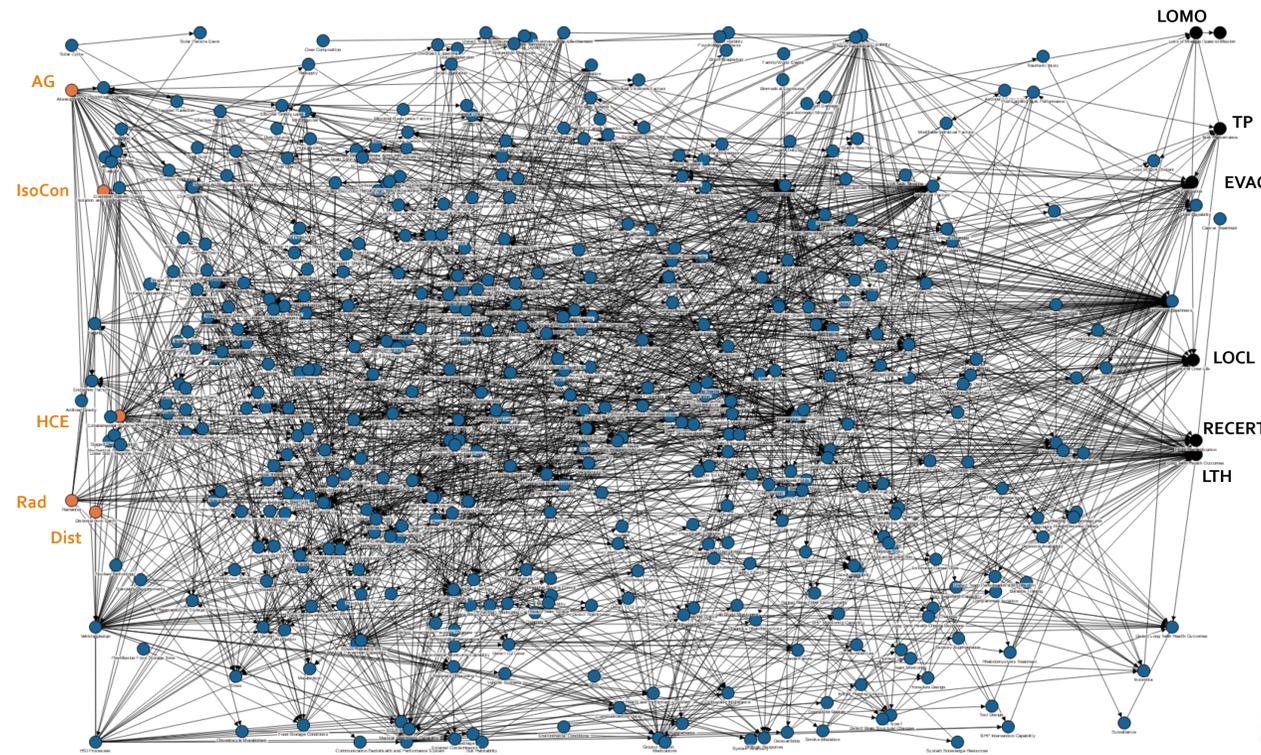

Figure 1: The HSRB Composite Risk Network ("MegaDAG")

MegaDAG Network

- *Composition of 29 networks (Fig. 1)*
  - *451 Nodes*
  - *1,653 links*
- *Hazards:*
  - *Altered Gravity (AG)*
  - *Hostile Closed Environment (HCE)*
  - *Distance from Earth (Dist)*
  - *Isolation and Confinement (IsoCon)*
  - *Radiation (Rad)*
- *Outcomes:*
  - *Task performance (TP)*
  - *Loss of mission objective (LOMO)*
  - *Loss of crew life (LOCL)*
  - *Need for evacuation (EVAC)*
  - *Long-term health (LTH)*
  - *Flight recertification (RECERT)*

Results

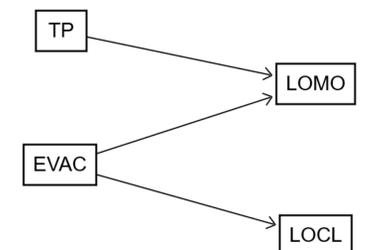| Hazards	Centrality Measures		Outcome Adhesions					
	Inverse Alpha	Out degree	Evac	LTH	LOCL	LOMO	RECERT	TP
Distance from Earth	35566.3	11	11	11	11	7	11	6
Altered Gravity	1671.5	35	30	33	33	7	16	5
Radiation	233.0	19	18	17	17	6	15	3
Hostile Closed Environment	20.9	40	31	37	34	7	16	5
Isolation and Confinement	12.2	12	10	8	10	5	7	2

Figure 2: Relationships between outcomes

Conclusions

- *Distance from Earth has the greatest overall influence*
- *Altered Gravity and Hostile Closed Environment have many immediate effects and pathways to health outcomes, making it difficult to stem their downstream influence*
- *Evacuation, Long-term Health, and Loss of Crew Life have the largest number of pathways from hazards*
- *At least 1 path can be traced from every hazard to every outcome*
- *Loss of Mission Objective and Task Performance have the fewest connections because of how hazards relate to one another (Fig. 2), meaning the adhesions to other outcomes might be a better indicator of influence*