

This Directed Acyclic Graph and write-up is an excerpt from a larger NASA document.

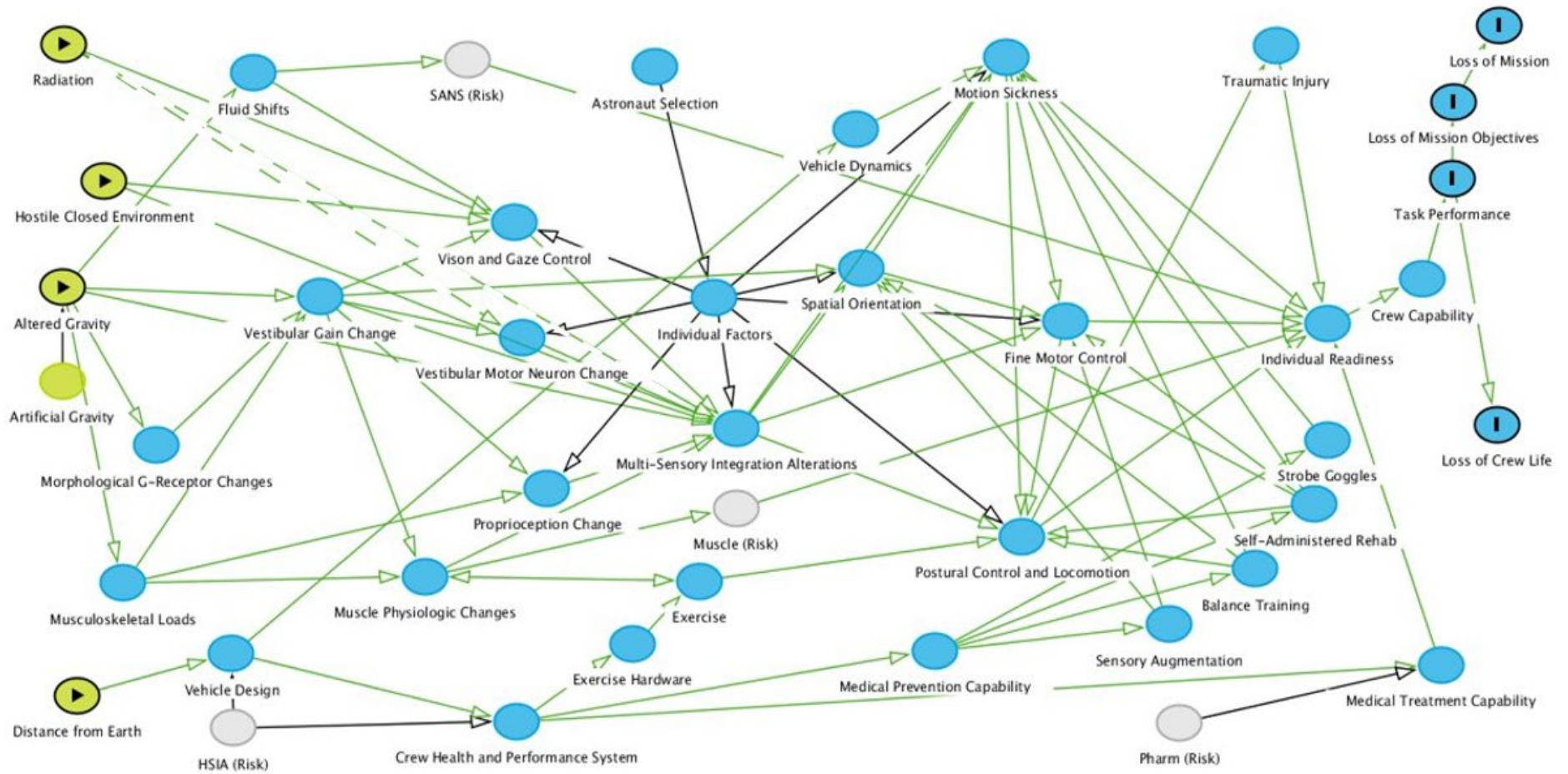
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**Directed Acyclic Graphs: A Tool for Understanding the NASA  
Spaceflight Human System Risks**

**Human System Risk Board**

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## Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks (Sensorimotor Risk)



## Sensorimotor Risk DAG Narrative

- The Sensorimotor Risk is primarily derived from **Altered Gravity** environmental changes but also has effects from **Radiation** and **Hostile Closed Environment**.
- Time spent in an **Altered Gravity** environment causes physical changes to the body including:
  - **Fluid Shifts** – fluid shifts from the lower body towards the upper body.
  - **Musculoskeletal Loads** – end-organ changes (e.g., otoconia size, changes in neural synapses) to physical unloading.
  - **Morphological G-Receptor Changes** – cellular responses to physical unloading.
- These changes lead to physiologic changes that affect:
  - **Vision and Gaze Control** - vision is the ability to see and gaze control is the ability to orient the eyes, and maintain fixation, on a desired visual target. **Radiation** can induce cataracts that affect vision.
  - **Vestibular Gain Changes** - the relationship between accelerations, including gravitational and vestibular responses.
  - **Vestibular Motor Neuron Changes** - vestibular neurons adapt to reduced or increased firing rates and become more or less sensitive. **Radiation** and the **Hostile Closed Environment** are suspected to affect motor neurons.
  - **Proprioception** - a global term that encapsulates multiple internal sensors that monitor the relationship between one body segment and another.
  - **Muscle Physiologic Changes** - reduced loading on muscle, tendons, and ligaments that cause both structural and functional changes in strength.
- All of these physiologic changes send signals that must be interpreted by the brain and here is represented by **Multi-Sensory Integration Alterations**. **Radiation** and the **Hostile Closed Environment** effects on the central nervous system is suspected to affect this central processing.
- The central nervous system must integrate information from all of these systems. **Multi-Sensory Integration Alterations** lead to functional impairments such as:
  - **Motion Sickness** occurs when vestibular and ocular signals from the brain are conflicting.
  - **Fine Motor Control** limits the ability to perform tasks that require delicate control.
  - **Postural Control and Locomotion** refer to the balance and ability to walk that are required to perform physical tasks in a gravity environment.
- The severity of these functional impairments directly impacts **Individual Readiness** and **Crew Capability** and specific tasks including:
  - Manual Control of Vehicles which depends on Fine Motor Control and perception.
  - EVA (Risk) through the increased likelihood of falls or injury.
  - Crew Egress (Risk) through the increased likelihood of falls or injury.
- These affect **Individual Readiness**, **Crew Capability** and through them **Task Performance** and other Mission Level.

- **Distance from Earth** affects the mass, power, volume, and bandwidth allocations for **Vehicle Design** the **Crew Health and Performance System** in particular. These include:
  - Exercise including Exercise Hardware which affects Postural Control and Locomotion.
  - Medical Prevention Capabilities such as the following are still experimental and include:
    - Strobe Goggles.
    - Self-Administered Rehab.
    - Sensory Augmentation.
    - Balance Training.
- **Medical Treatment Capabilities** can include medications such as Phenergan, etc. that are susceptible to stability issues included in the **Pharm (Risk)**.
- **Artificial Gravity** as a countermeasure holds the potential to significantly reduce the Sensorimotor Risk but is high cost to implement.