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

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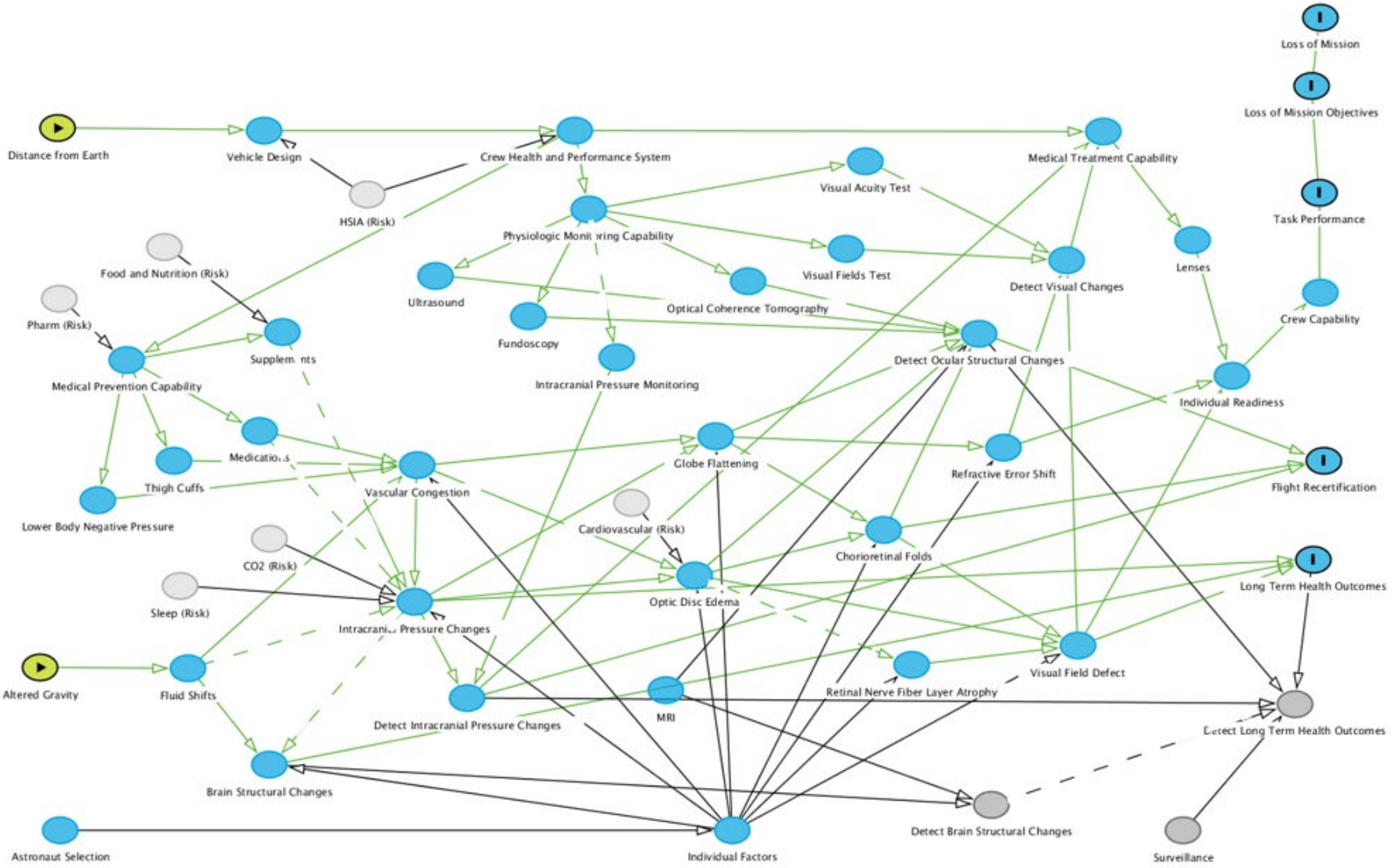
Directed Acyclic Graphs: A Tool for Understanding the NASA Spaceflight Human System Risks

Human System Risk Board

October 2022

Risk of Spaceflight Associated Neuro-ocular Syndrome (SANS Risk)



SANS Risk DAG Narrative

- **Altered Gravity** removes (0 g) or reduces (partial g) the hydrostatic pressure gradient, causing a cephalad **Fluid Shifts** within the arterial and venous systems and within the cerebrospinal fluid column. **Individual Factors** such as age, sex, genetic predispositions, pre-existing medical conditions and more influence variability in biologic response to the spaceflight environment. This can affect multiple nodes discussed below.
- These cause physiologic changes including **Venous Congestion** and possibly **Intracranial Pressure Changes** in the brain. **CO2 (Risk)** and **Sleep (Risk)** may have a causal connection to Intracranial Pressure Changes as CO2 is known to cause vasodilation of cerebral arterioles, and impaired sleep may reduce lymphatic/glymphatic clearance from the brain and eye. Invasive measures of **Intracranial Pressure Changes** have not been obtained in-flight.
- These physiologic changes are hypothesized to underlie the structural changes in the eye including **Optic Disc Edema**, **Globe Flattening**, and **Chorioretinal Folding.** Terrestrially, **Optic Disc Edema** can lead to **Retinal Nerve Fiber Layer Atrophy** but this has not been observed in the astronaut population.
- In-mission, these structural changes lead to functional changes in the eye including **Refractive Error Shifts,** and reversible **Visual Field Defects** have been detected postflight. These in turn affect **Individual Readiness** for mission tasks that can progressively affect **Crew Capability** and **Task Performance** overall.
- **Brain Structural Changes** are hypothesized to result from the cephalad fluid shift, but potential acute effects and/or **Long Term Health Outcomes** are unknown.
- To characterize the risk, **Surveillance** is required to **Detect Long Term Health Outcomes** that may present as cognitive or visual decrements post-flight or post-career.
- To assess and counteract the SANS issues in flight, the **Vehicle Design** must include a **Crew Health and Performance System** that provides mass and volume allocations for several countermeasure pathways. Inclusion of these pathways are affected by the **HSIA (Risk).**
- Medical Prevention Capabilities include:
  - **Astronaut Selection** affects and limits the **Individual Factors** present in the crewmembers.
  - **Lower Body Negative Pressure** is under consideration as a preventive countermeasure for many effects of **Fluid Shifts**.
  - Veno-occlusive Thigh Cuffs may reduce Fluid Shifts and may improve Venous Congestion and Intracranial Pressure Changes.
  - **Supplements** such as B vitamins are hypothesized to affect homocysteine pathways and improve microvascular function and reduce edema. These are related to the **Food and Nutrition (Risk).**
  - **Medications** have been considered to prevent **Intracranial Pressure Changes** and these are affected by the **Pharm (Risk).**
- Monitoring Capabilities include:
  - **Optical Coherence Tomography** is used pre-, post-, and in-flight to assess the retina, choroid, and optic nerve head.
  - In-flight **Fundoscopy** to assess gross structural changes in the optic nerve head and retina.

  - Pre- and post-flight **MRI** to track structural changes in the eye and brain.
  - Pre-, post-, and in-flight Ultrasound to assess structural changes within and posterior to the eye.
  - Testing for **Visual Acuity** and **Visual Fields** assess the functional state of the eye. These allow us to **Detect Visual Changes** and guide **Medical Treatment Capability** in-mission.
  - In-Flight direct **Intracranial Pressure Monitoring** is of interest but has not been performed to date. It is speculated that this information could enable us to **Detect Intracranial Pressure Changes** and that information could be used to guide **Medical Treatment Capabilities** in the future.
- Medical Treatment Capabilities:
  - **Corrective Lenses** are the current treatment modality in-mission for visual changes that may affect **Individual Readiness.** This requires the ability to provide corrective lenses with the appropriate corrective power.
  - There is currently no proven inflight pharmaceutical treatment available for SANS.
- **Flight Recertification** has been affected when ocular structure changes (e.g., severe **SANS findings**) and **Intracranial Pressure Changes** have been **detected** post flight.