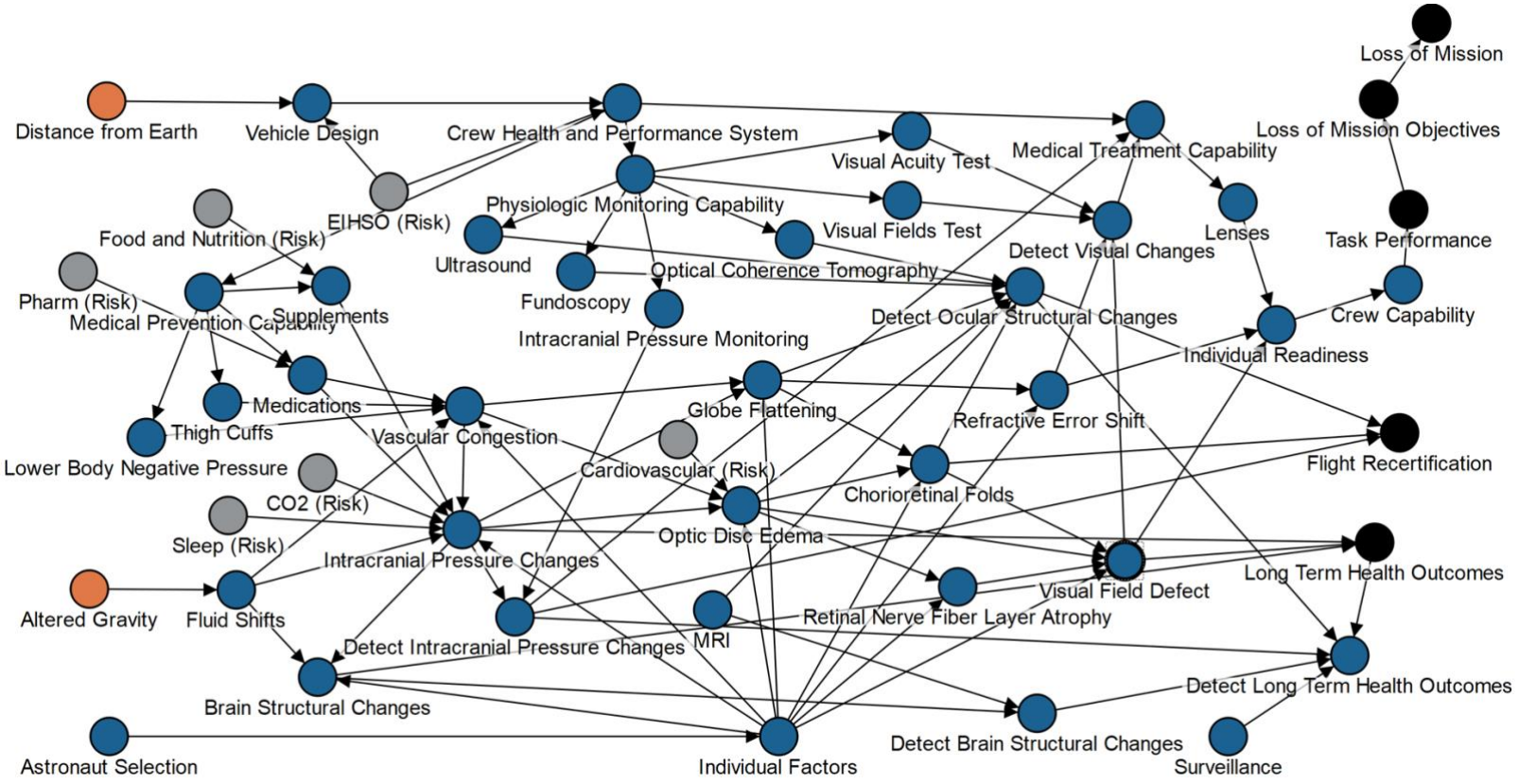
SANS Risk Directed Acyclic Graph – DAG Narrative

- **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. **CO_2 (Risk)** and **Sleep (Risk)** may have a causal connection to **Intracranial Pressure Changes** as CO_2 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.
- **Cardiovascular (Risk)** may have a causal connection to the possibility of vascular disruption and leakage at the blood-retinal and/or blood-brain barrier resulting from radiation exposure beyond low earth orbit.
- **Brain Structural Changes** are hypothesized to result from the cephalad fluid shift, but potential acute performance effects and/or **Long- T e r m 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 are affected by the **EIHSO (Risk).**
  - **Medical Prevention Capabilities** include**:**
    - **Astronaut Selection** affects and limits the **Individual Factors** present in the crewmembers. Those Individual Factors affect the degree of bio variability of multiple nodes including **Brain Structure Changes, Intracranial Pressure Changes, Vascular Congestion, Optic Disc Edema, Globe Flattening, Chorioretinal Folds, Retinal Nerve Fiber Layer Atrophy, Refractive Error Shift and Visual Field Defects. This does not imply that all outcomes that may be influenced by Individual Factors are assessed at Astronaut Selection.**
    - **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:
  - Hardware currently in use on ISS requires real-time remote guidance support that will be impacted by communication delays with increased distance from Earth.
  - **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
  - **Visual Acuity Tests** and **Visual Field Tests** assess the optical fidelity 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.


Loss of Mission
Distance from Earth
Vehicle Design
Crew Health and Performance System
Loss of Mission Objectives
Visual Acuity Test
Medical Treatment Capability
EIHSO (Risk)
Physiologic Monitoring Capability
Food and Nutrition (Risk)
Visual Fields Test
Lenses
Task Performance
Ultrasound
Optical Coherence Tomography
Detect Visual Changes
Pharm (Risk)
Medical Prevention Capability
Supplements
Fundoscopy
Detect Ocular Structural Changes
Crew Capability
Intracranial Pressure Monitoring
Individual Readiness
Medications
Globe Flattening
Thigh Cuffs
Refractive Error Shift
Vascular Congestion
Flight Recertification
Lower Body Negative Pressure
Cardiovascular (Risk)
Chorioretinal Folds
CO2 (Risk)
Sleep (Risk)
Optic Disc Edema
Intracranial Pressure Changes
Long Term Health Outcomes
Visual Field Defect
Altered Gravity
Fluid Shifts
Retinal Nerve Fiber Layer Atrophy
MRI
Detect Intracranial Pressure Changes
Detect Long Term Health Outcomes
Brain Structural Changes
Detect Brain Structural Changes
Astronaut Selection
Individual Factors
Surveillance