Risk of Mission Impacts and Long-Term Health Issues due to Decompression Sickness (Revision C)

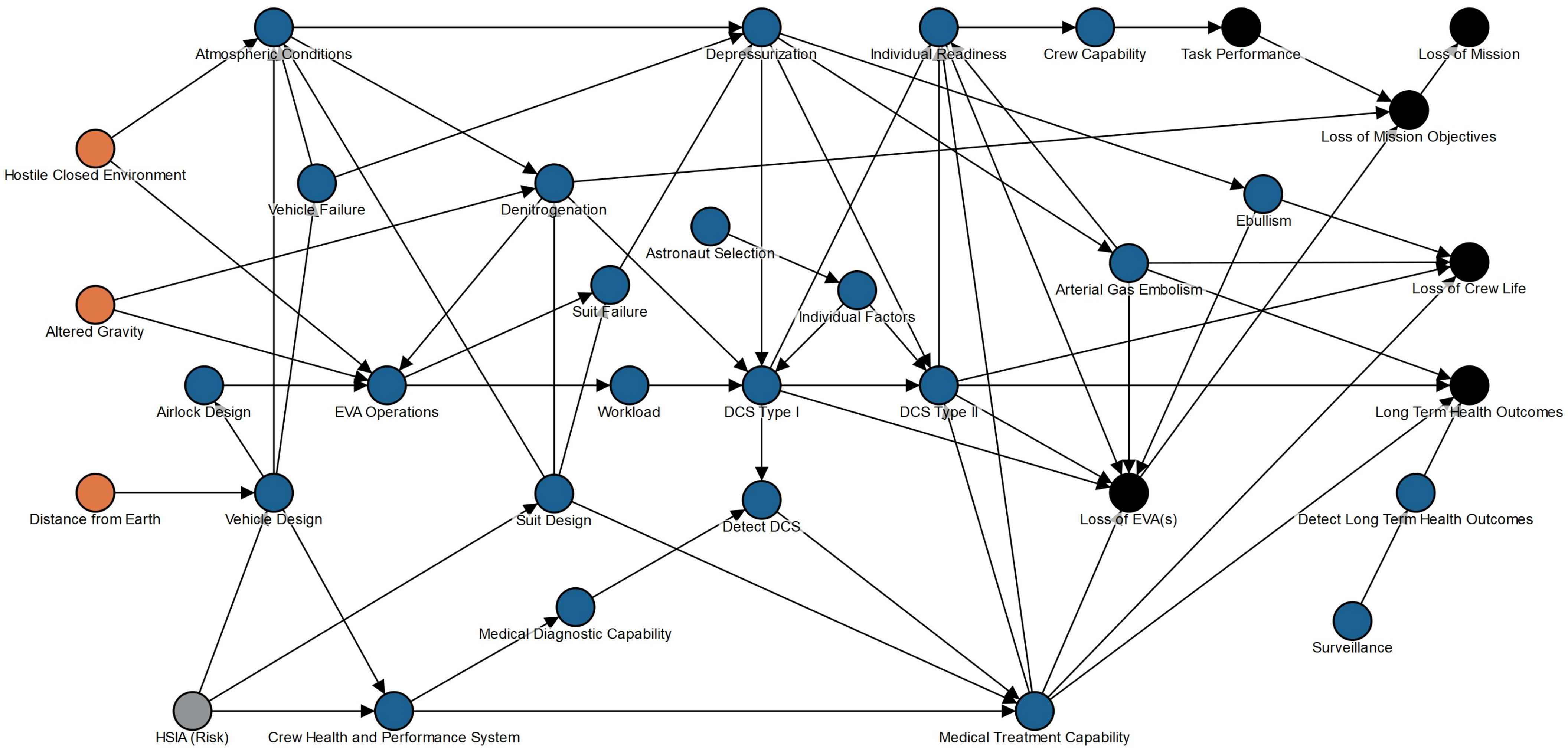
Decompression Risk DAG Narrative

- The primary spaceflight hazard impacting decompression sickness (DCS) is the **Hostile Closed Environment** – with a closed environment, the chosen total pressure in addition to O_2 and N_2 partial pressures for the vehicle and space suit drive the DCS risk and treatment capability.
- Secondary hazards include **Altered Gravity** – expected increases in EVA workload, weight-bearing tasks, and joint forces associated with planetary gravity EVA increase DCS risk as compared to microgravity EVA, and **Distance from Earth** – drives the vehicle design and provides limits to resources and consumables. Additionally, it can impact the ability to return a crewmember to the ground for definitive medical care.
- DCS is represented by two nodes – **DCS Type I** is a mild environmental injury that primarily affects the joints, skin, and lymphatic vessels. **DCS Type II** is a severe, potentially life-threatening environmental injury that often affects vital organ systems, including the brain and spinal cord, respiratory system, and circulatory system. It is possible for **DCS Type I** to progress to **DCS Type II**.
- In the spaceflight environment, four important factors contribute to DCS occurrence.
  - **Denitrogenation** is the reduction of nitrogen from blood and body tissues to minimize the formation of gas bubbles and mitigate DCS.
  - **Depressurization** can lead to DCS; therefore, it occurs after **Denitrogenation** to minimize DCS risk.
  - **EVA Operations** are directly affected by **Denitrogenation** (including O_2 prebreathe time), which depends on **Atmospheric Conditions**. For example, Exploration Atmospheres are altered **Atmospheric Conditions** designed to decrease **Denitrogenation** time while keeping the risk of DCS acceptably low and minimizing the potential for **Loss of Mission Objectives**.
  - **Individual Factors** that may contribute to DCS exist**.** An example is major cardiac abnormalities such as atrial/ventricular septal defects are screened for during **Astronaut Selection,** but other defects such as a patent Foramen Ovale (PFO) are not. Previous decompression illness experiences are also discussed and dispositioned on an individual case basis.
- DCS can impact **Individual Readiness, Crew Capability**, and **Task Performance** by introducing functional impairments that can lead to **Loss of EVA(s)**, **Loss of Mission Objectives**, or **Loss of Mission**. **DCS Type II**, **Arterial Gas Embolism**, and **Ebullism**, should they occur, can lead to **Loss of Crew Life** or permanent **Long Term Health Outcomes**. The ability to **Detect Long Term Health Outcomes** depends on ground-based **Surveillance** programs.
- The likelihood of experiencing DCS is associated with physical exertion (i.e., metabolic rate and joint forces) captured here as **Workload**. This factor depends on **EVA Operations**, a category node that includes **EVA Frequency**, **EVA Duration**, **Planned EVA Content**, **EVA Task Timeline**, and **EVA Decision Support**. These components of **EVA Operations** are explicitly demonstrated in the EVA Risk DAG.
- **Vehicle Design** determines:
  - **Atmospheric Conditions** – The primary DCS concern is the partial pressure of N_2.
  - **Airlock Design** - The **Depressurization** and repressurization rates factor into barotrauma prevention, DCS risk, and treatment capability. The combination of **Suit Design**, prebreathe/**Denitrogenation** protocol, and **Airlock Design** may necessitate different

Depressurization and repressurization cycles as well.

- **Crew Health and Performance System** determines the level of **Medical Diagnostic Capability** and **Medical Treatment Capability**. The **Medical Diagnostic Capability** is important to **Detect DCS** and distinguish between mild DCS symptoms and other injuries. It also includes specific training of the crewmember on DCS symptoms and treatment. **Medical Treatment Capability** depends in part on **Suit Design**. For example, the space suit, which is capable of over-pressurization, provides DCS treatment on the International Space Station (ISS).

❖ The likelihood of **Vehicle** or **Suit Failure,** which can lead to **Depressurization,** is affected by **Vehicle Design**, **Suit Design,** and limitations of the **HSIA (Risk)**.



Atmospheric Conditions
Depressurization
Individual Readiness
Crew Capability
Task Performance
Loss of Mission
Loss of Mission Objectives
Hostile Closed Environment
Vehicle Failure
Denitrogenation
Ebullism
Astronaut Selection
Arterial Gas Embolism
Loss of Crew Life
Altered Gravity
Suit Failure
Individual Factors
Airlock Design
EVA Operations
Workload
DCS Type I
DCS Type II
Long Term Health Outcomes
Distance from Earth
Vehicle Design
Suit Design
Detect DCS
Loss of EVA(s)
Detect Long Term Health Outcomes
Medical Diagnostic Capability
Surveillance
HSIA (Risk)
Crew Health and Performance System
Medical Treatment Capability