

## Directed Acyclic Graph – 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<sub>2</sub> and N<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>.
  - **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 **EIHSO (Risk)**.

