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

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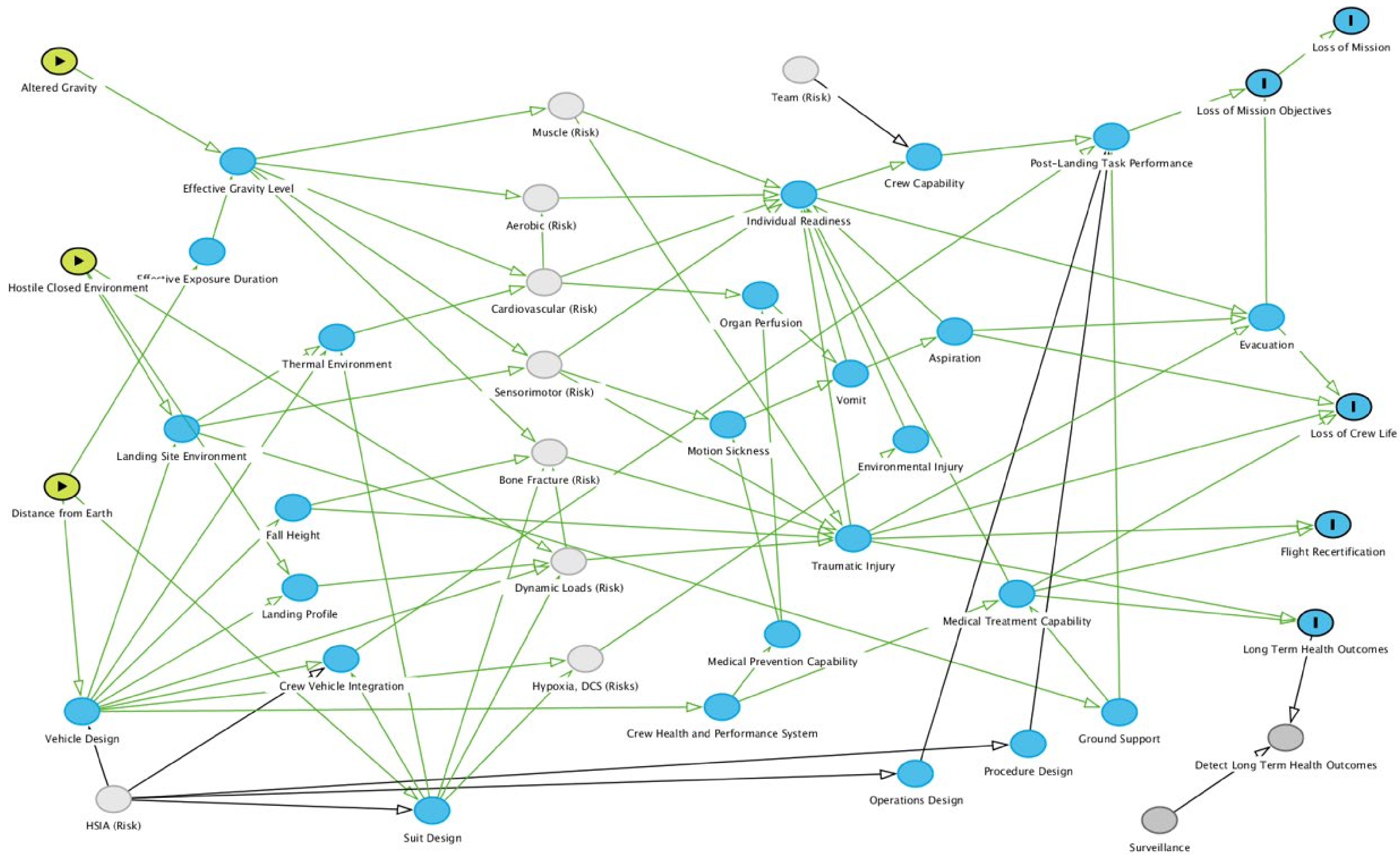
Directed Acyclic Graphs: A Tool for Understanding the NASA Spaceflight Human System Risks

Human System Risk Board

October 2022

Risk to Vehicle Crew Egress Capability and Task Performance as Applied to Earth and Extraterrestrial Landings (Crew Egress Risk)



Crew Egress Risk DAG Narrative

- **Altered Gravity** across all DRM categories includes microgravity, lunar gravity, Mars gravity and Earth gravity. This affects **Effective Gravity Level** which is mission dependent.
- The **Hostile Closed Environment** here refers to the **Landing Site Environment** (including waves for water landings) and accelerations that are experienced in the **Landing Profile** that affect the **Dynamic Loads (Risk).**
- **Distance from Earth** determines the mass and volume allocations for **Vehicle Design** and **Suit Design** and affects the **Effective Mission Duration**.
- **Individual Readiness** and the **Crew Capability** to perform **Post-Landing Tasks Performance** is strongly dependent on several other Human System risks as well as the **Effective Exposure Duration** to whatever **Effective Gravity Level** is encountered as these factors determine the extent of deconditioning crew will face. This can range from microgravity (0g) to lunar gravity (1/6g) to Mars gravity (3/8g) to Earth Gravity (1g). **Post Landing Tasks** include egress from the vehicle, safing the vehicle, and more. As mission duration increases, the confluence of other risks can lead to a variety of issues.
- Those risks include **Muscle (Risk), Aerobic (Risk), Cardiovascular (Risk), Sensorimotor (Risk), Bone Fracture (Risk), Dynamic Loads (Risk), DCS** and **Hypoxia (Risks)** serve to decondition crew depending on **Effective Exposure Duration**.
- **HSIA (Risk)** varies depending on **Distance from Earth** and effective implementation of standards, requirements and HSI Processes in vehicle and mission design.
- The **Muscle (Risk), Aerobic (Risk), Sensorimotor (Risk),** and **Cardiovascular (Risk)** can all directly affect **Crew Capability** and through that Task Performance. Effective exercise can help reduce these risks.
- Medical issues that can lead to reduced **Individual Readiness** and **Crew Capability** include:
  - **Organ Perfusion** can be decreased because of orthostatic intolerance which is represented by the **Cardiovascular (Risk)**. One outcome of this is higher likelihood of **Vomiting** as well as crew passing out and these can be exacerbated by the **Thermal Environment** of the landing vehicle.
  - **Motion Sickness** can lead **to Vomiting** and **Aspiration** which may lead to **Loss of Crew Life** in cases where crew cannot turn their head, remove a helmet quickly, or otherwise cannot protect their airway. This can be exacerbated by the **Landing Site Environment**, particularly if there is a water landing with waves.
- **Traumatic Injury** likelihood can be increased through several means:
  - **Sensorimotor (Risk)** changes affecting balance and proprioception can lead to an increased likelihood of falls in a deconditioned state.
  - **Dynamic Loads (Risk) - Landing Profiles,** which are the accelerations/deceleration profiles that the crew experience in re-entry determine the loads that crew experience and affect the likelihood of traumatic injuries that will occur. The design of occupant protection measures such as restraints and seat designs are included in the vehicle and spacesuits.
  - **Bone Fracture (Risk)** changes due to spaceflight may result in an increased chance of fracture when traumatic injuries are sustained. Bone changes that predispose to fracture are minimized by effective exercise in mission.

- **Fall Height** is a factor that can affect the likelihood of **Traumatic Injury** including in lander designs, ladder heights, and tasks that crew may be asked to perform as part of Post-Landing Tasks.
- **Traumatic Injuries** that are incurred can result in issues with **Flight Recertification** or **Long Term Health Outcomes**. **Occupational Surveillance** ensures that we **Detect Long Term Health Outcomes** of our astronauts.

- **DCS and Hypoxia (Risks)** contribute to possible **Environmental Injuries** that may occur depending on the use of staged denitrogenation prior to landings and EVAs on the surface of the Moon or Mars.
- Medical Issues can be in part mitigated through capabilities designed into the **Crew Health and Performance System** or, in the case of Earth landings, brought along by **Ground Support**.
  - **Medical Prevention Capability** such as medications to prevent motion sickness and vomiting, and fluid loading to prevent orthostatic intolerance.
  - **Medical Treatment Capability** such as pain medications to treat pain, nausea and other medical treatments as needed.
- In the special case of Earth landings, the medical capability that is brought by **Ground Support** also serves to mitigate risk but is unavailable for lunar or Mars landings.
- **HSIA (Risk)** influences the level of **Crew Capability** and likelihood of successful **Post-Landing Task Performance** in several ways:
  - **Vehicle Design**, **Suit Design**, and **Crew Vehicle Integration** all affect the ability of astronauts to perform the tasks they have been given. These affect adequate exit paths, hatch openings, restraint during landing, ability to remove restraints in an emergency, potential **Fall Height**, and more.
  - **Operations Designs** including appropriate flight rules or overly complicated **Procedure Designs** can also enhance or adversely affect successful **Post Landing Task Performance**.