

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

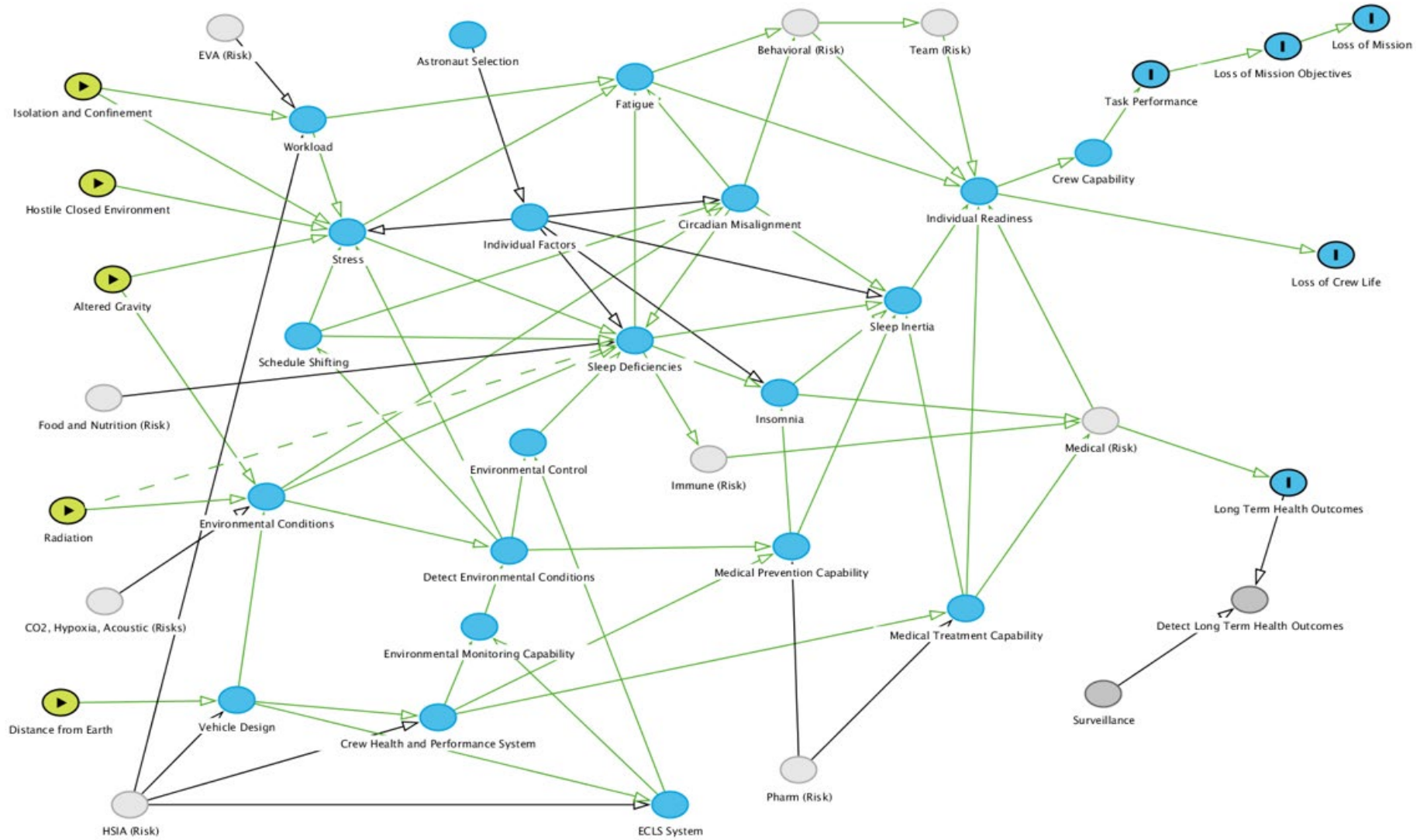
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**Directed Acyclic Graphs: A Tool for Understanding the NASA
Spaceflight Human System Risks**

Human System Risk Board

October 2022

Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload (Sleep Risk)



Sleep Risk DAG Narrative

The Sleep Risk is driven mainly by the hazards of **Isolation and Confinement**, **Hostile Closed Environment**, and **Altered Gravity** each of which impacts the **Stress** of the crewmember.

The Sleep Risk focuses around two key nodes:

- **Sleep Deficiencies** occur for a variety of reasons in human spaceflight including:
 - **Schedule Shifting** including slam shifting that has been a common occurrence given arrivals and departures of vehicles from different parts of the world, etc.
 - The **Workload** that an astronaut undertakes, including the strenuous demands of any EVAs represented by the **EVA (risk)**.
 - **Stress** encountered in the mission environment for example as relates to alarms and emergencies.
 - **Environmental Conditions** that are present in the sleep quarters including temperature, humidity, noise, privacy, etc.
 - **Food and Nutrition (Risk)** represents the connection between the food that astronauts are given and can include effects of specific substances like caffeine and insulin and meal-timing relative to sleep timing.
- Circadian Misalignment is dependent on:
 - **Environmental Conditions** specifically including lighting as the intensity, wavelength, and timing of lighting exposure drives circadian entrainment.
 - **Schedule Shifting** including slam shifting that creates an inappropriate series of lighting cues as well.
 - There is also a dependence on **Behavioral (Risk)** and **Team (Risk)** not shown here due to the acyclic requirement.
- When these occur, they can lead to other issues including:
 - **Fatigue** which as a category can include mental fatigue, physical fatigue, sleepiness/drowsiness etc. These all can affect **Crew Capability** by impacting readiness for **Task Performance**.
 - **Sleep Inertia** is amplified when astronauts are chronically sleep deprived, wakes at an adverse circadian phase or from deep sleep or when crew take hypnotic medications. This can affect **Individual Readiness** and **Crew Capability** including the timing to response to alarms for example.
 - **Insomnia** is when sporadic sleep deficiencies become persistent and meet the definition of a clinical medical condition. This is an inability to get adequate sleep when provided adequate opportunity. This is part of the **Medical (Risk)** and leads to further medical issues requiring treatment.
- **Environmental Conditions** are defined by the Vehicle Design and the ELCS System design and are dependent on Standards/Requirements and HSI Processes that are part of the HSIA (Risk). This is specifically true for private sleep quarters IF they are designed into the systems.
 - **Radiation**, including **Solar Particle Events**, can cause **Environmental Conditions** to change.

- **Environmental Monitoring** enables **Detect Environmental Changes** can cause **Schedule Shifting** when responding (i.e., reconfiguring mass to mitigate radiation exposures) and **Stress** among the crew in the case of **Solar Particle Events**.
- There is weak evidence that suggests that Radiation may cause Sleep Deficiencies.
- The **Crew Health and Performance System** includes several potential countermeasures for sleep issues:
 - **Environmental Monitoring** which provides the ability to **Detect Environmental Conditions** relevant to sleep. And, when designed into the **ECLS System**, the ability for the crew to exercise **Environmental Control** over the relevant parameters that disrupt sleep in the sleeping quarters.
 - **Medical Prevention Capability** includes Hypnotic and other medications that may be used in anticipation of **Sleep Deficiencies** that could occur for example in the case of expected Slam Shifting.
 - In cases where sleep issues are not expected or growing, **Medical Treatment Capabilities** may be brought to bear to minimize the consequences of the **Sleep Disturbances** or **Insomnia**.
- Sleep issues can lead to other **Medical (Risk)** issues as well as **Long Term Health Outcomes** including diabetes, hypertension, etc. that should be monitoring in post-flight and post-career crew through **Surveillance** in order to **Detect Long Term Health Outcomes** and better inform the magnitude of the long term health risks associated with Sleep.