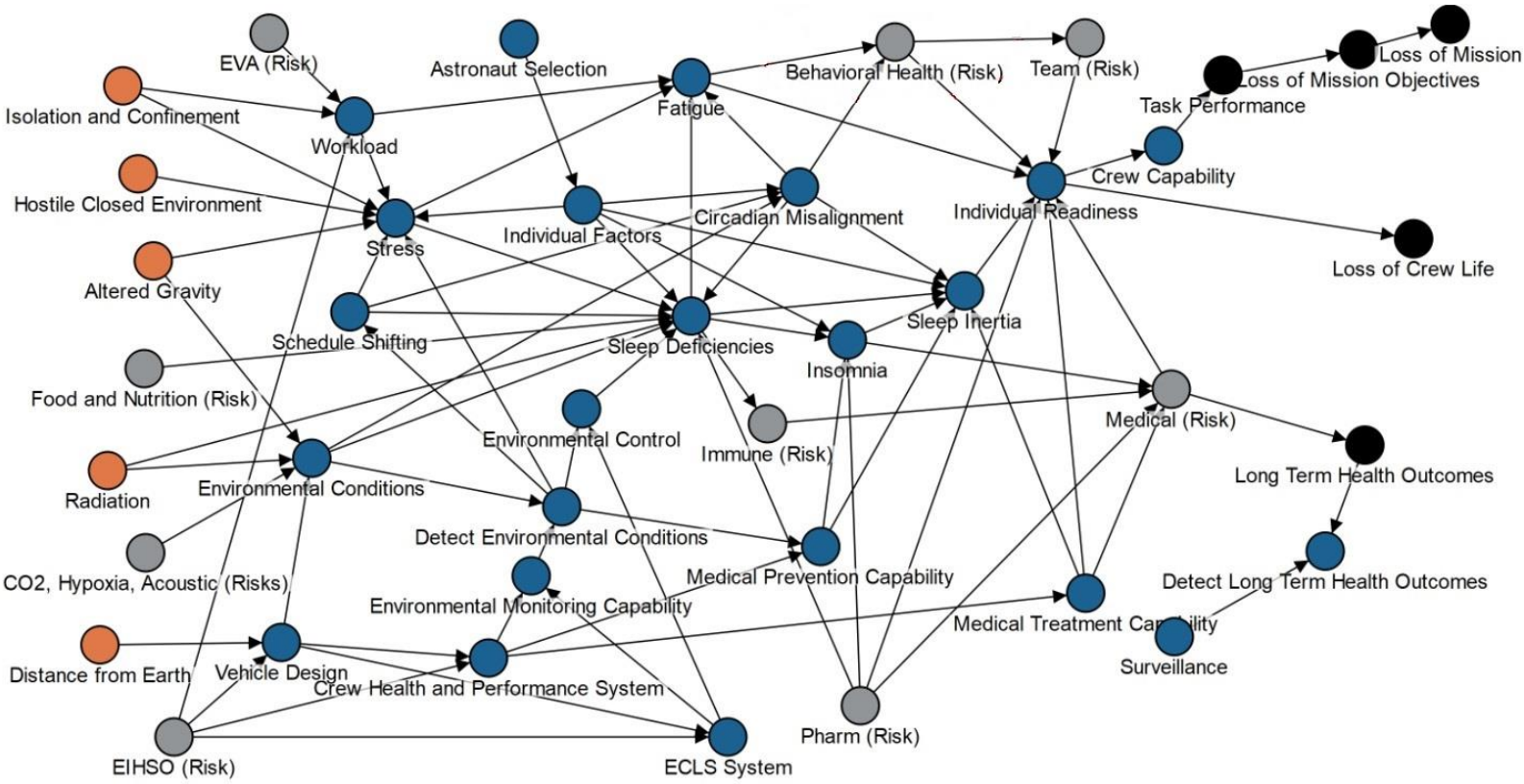
Sleep Risk DAG: Narrative

- 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. Transitional burns will require additional schedule shifting for lunar and Mars transits.
    - The **Workload** that an astronaut undertakes, including work tempo and 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 and sleep shifting to accommodate transitional burns 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 also leads to further medical issues requiring treatment.
  - **Sleep Deficiencies** have also been tied to Subclinical Immune Dysregulation seen in astronaut crews. Effective sleep is one of several countermeasures for the **Immune (Risk).**
- **Environmental Conditions** are defined by the **Vehicle Design** and the Environmental Control and Life Support **(ELCS) System** design and are dependent on **Standards/Requirements** and Human System Integration (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 Capability** enables **Detect Environmental Conditions** which 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** and that sleep deficiency may exacerbate radiation-induced performance impairment.
- 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 in the case of expected **Slam Shifting** for example.
- 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.


EVA (Risk)
Astronaut Selection
Behavioral Health (Risk)
Team (Risk)
Loss of Mission
Loss of Mission Objectives
Isolation and Confinement
Workload
Fatigue
Task Performance
Hostile Closed Environment
Crew Capability
Circadian Misalignment
Individual Factors
Individual Readiness
Stress
Loss of Crew Life
Altered Gravity
Sleep Inertia
Schedule Shifting
Sleep Deficiencies
Insomnia
Food and Nutrition (Risk)
Medical (Risk)
Environmental Control
Immune (Risk)
Radiation
Environmental Conditions
Long Term Health Outcomes
Detect Environmental Conditions
CO2, Hypoxia, Acoustic (Risks)
Medical Prevention Capability
Detect Long Term Health Outcomes
Environmental Monitoring Capability
Medical Treatment Capability
Distance from Earth
Vehicle Design
Surveillance
Crew Health and Performance System
Pharm (Risk)
EIHSO (Risk)
ECLS System