

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

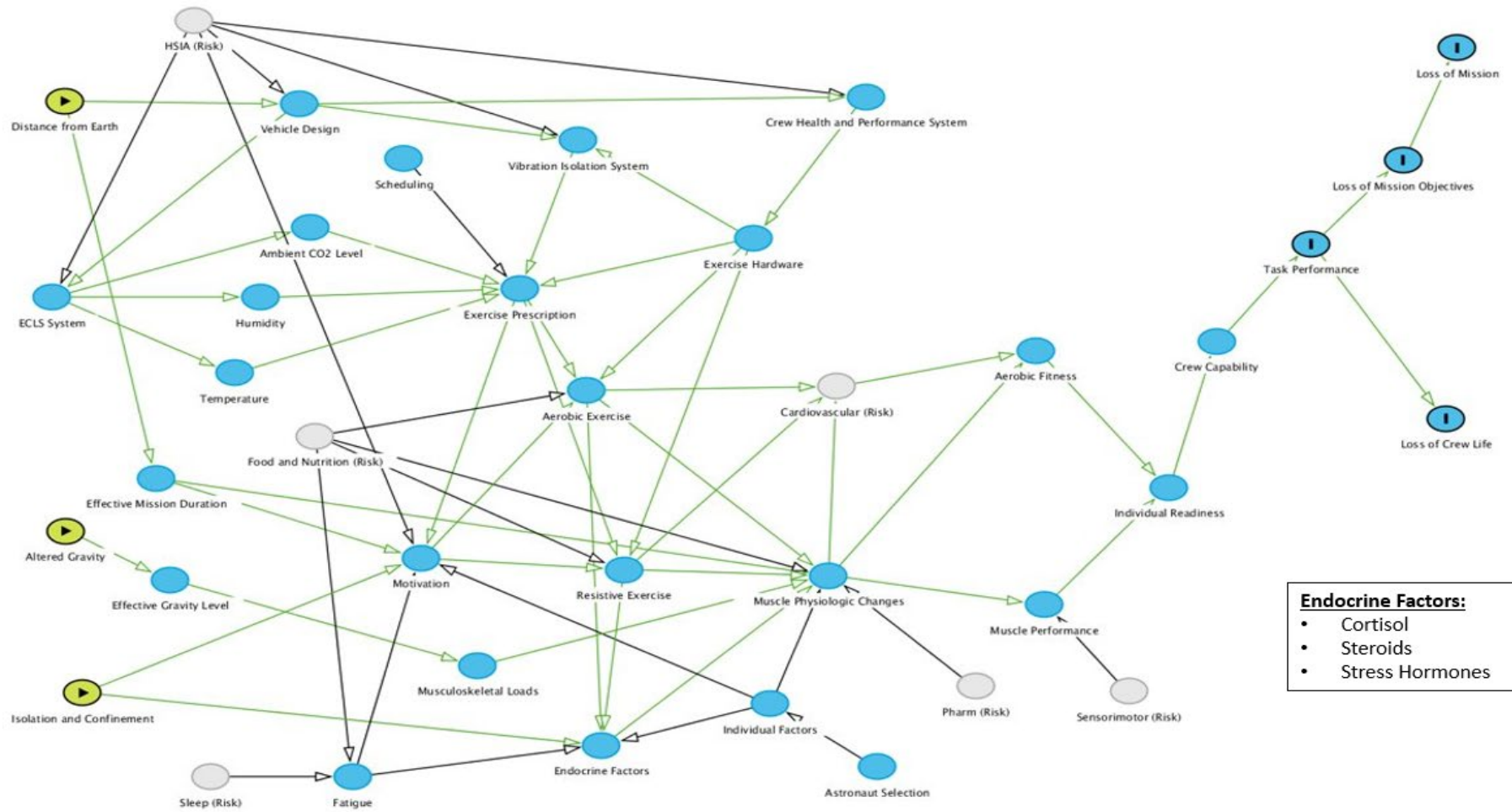
**NASA/TP-20220015709**

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

**Human System Risk Board**

**October 2022**

# Risk of Impaired Performance Due to Reduced Muscle Size, Strength, and Endurance (Muscle Risk) and Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity (Aerobic Risk)



## Muscle and Aerobic Risks DAG Narrative

- **Altered Gravity** across all DRMs includes microgravity, lunar gravity, Mars gravity and Earth Gravity. This affects **Effective Gravity Level** experienced by crew and through that **Musculoskeletal Loads**.
- **Isolation and Confinement**, especially over long **Effective Mission Durations** can induce monotony and anhedonia affecting the **Motivation** to perform needed exercise.
- **Distance from Earth** determines the mass and volume allocations for **Vehicle Design** and **Suit Design** and affects the **Effective Mission Duration**.
- The central focus of the Muscle and Aerobic Risk DAG is on **Aerobic Fitness** and **Muscle Performance** levels being adequate for crew to do the tasks that are expected of them (**Task Performance**). These directly influence **Individual Readiness** and crew readiness or fitness for duty (**Crew Capability**).
- When these nodes are negatively affected, the performance of EVAs - **EVA (Risk)** - and the performance of post-landing tasks – **Crew Egress (Risk)** may be threatened.
- **Aerobic Fitness** and **Muscle Performance** are directly affected by the **Muscle Physiologic Changes** that occur at the level of cardiac, smooth, and skeletal muscle throughout the body as a result of the duration of exposure to the spaceflight environment. **Aerobic Fitness** is also directly dependent on the functionality of the Cardiovascular system (**Cardiovascular Risk**).
- These **Physiologic Changes** are the result of several contributing factors:
  - **Musculoskeletal Unloading** that occurs as a result of the **Altered Gravity** Environment.
  - Endocrine Factors that are related to the Isolation and Confinement experienced.
- Countermeasures to these include:
  - Resistive Exercise.
  - Aerobic Exercise.
  - Medications - Pharm (Risk).
  - Nutrients - Food and Nutrition (Risk).
- Other contributing factors can include the **Motivation** to exercise which is impacted by **Fatigue** through the **Sleep (Risk)** and **Food and Nutrition (Risk)**, **Effective Mission Duration** that can induce monotony, design and maintenance challenges from the **HSIA (Risk)**.
- The exercise capability that protects **Aerobic Fitness** and **Muscle Performance** is the result of the **Vehicle Design** process, the **HSIA (Risk)**, and the fielded **Crew Health and Performance System**. These define and limit the presence and reliability of the **Exercise Hardware** that is available in a mission. The **Exercise Prescription** that can be accomplished by crew is limited by the **Schedule**, **Vibration Isolation System**, **Previous Injury**, and environmental factors such as **Temperature**, **Humidity**, and **CO2 (Risk)** that are a function of the **ECLS System**.