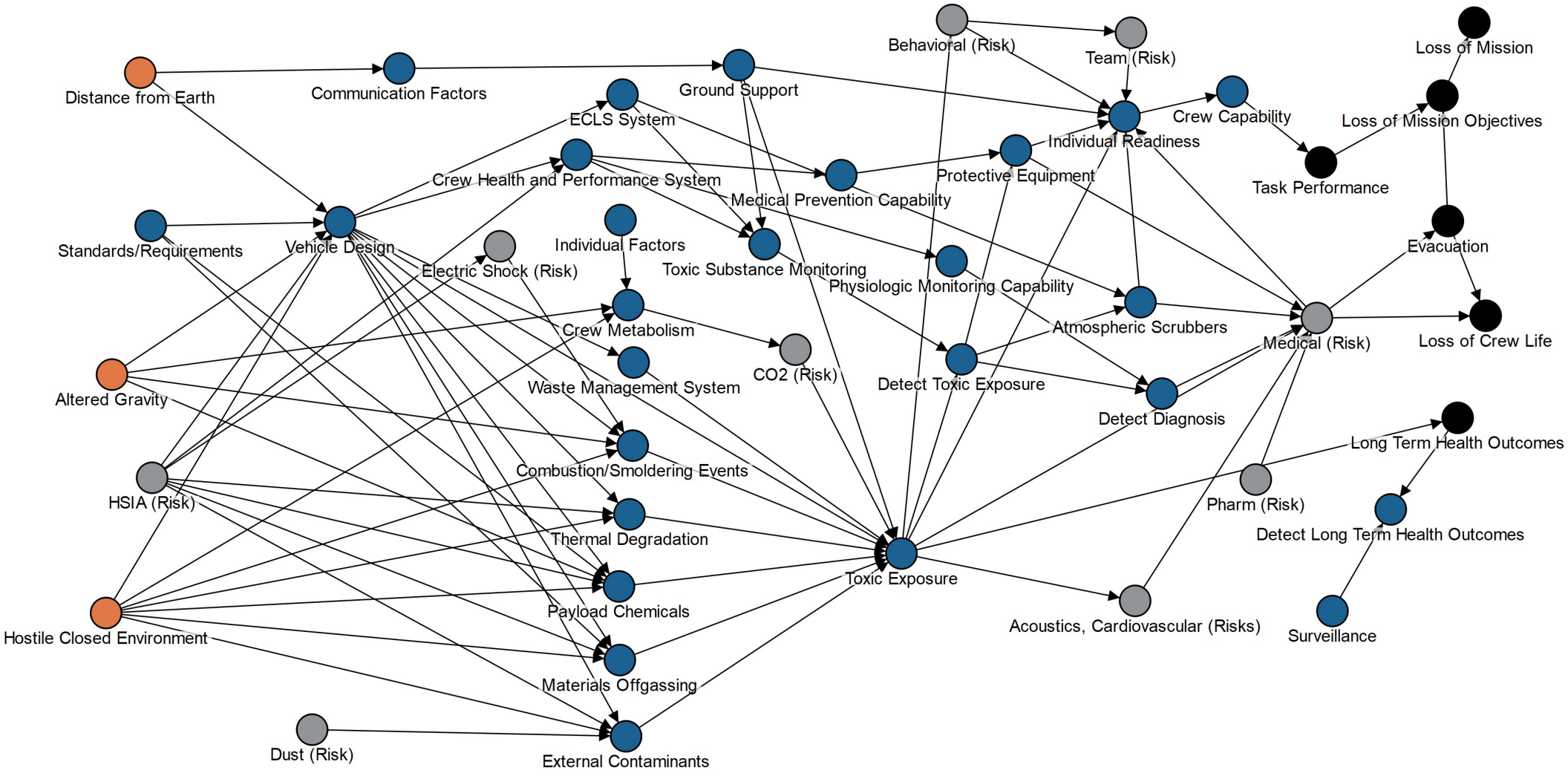
Risk of Toxic Substance Exposure

Directed Acyclic Graph – DAG (Narrative)

- Numerous sources of toxic substances onboard spacecraft are impacted by the Hazards
  - **Altered Gravity** results in increased exposure risk to floating particles and liquids, reduced dispersion of gases in areas that aren't well ventilated, and greater difficulty in capturing and cleaning a release
  - A **Hostile Closed Environment** limits removal capabilities and increases exposure likelihood (small volume for gases and volatiles to fill)
- **Toxic Substance Exposure** is dependent on the release of toxic substances into the interior of the spacecraft or spacesuit that can affect the health and performance of the astronauts. This can be caused by:
  - **Crew Metabolism** includes the CO2 (Risk) exhaled by the crew which in some cases can reach toxic levels. Biovariability is determined by **Individual Factors.**
  - **Waste Management System** includes the above as well as chemicals used for neutralizing/cleaning and waste from bodily functions.
  - **Combustion/Smoldering Events** have happened in prior spaceflight and can result in release of Carbon Monoxide, weak acids, and other toxic substances. This is in part dependent on the **Electric Shock (Risk)**.
  - **Thermal Degradation** is the result of heated materials such as plastics that are not combusting but are releasing toxic vapors into the local atmosphere.
  - **Payload Chemicals** refers to chemicals that may be brough on-board by a visiting spacecraft or payload that is not always present in the vehicle systems.
  - **Materials Off-Gassing** occurs for plastics, rubbers, and other substances that are not thermally dependent.
  - **External Contaminants** such as lunar or Martian Dust (Risk) may be brought into the vehicle or habitat.
- All of these except Crew Metabolism are dependent on Vehicle Design and the HSIA (Risk).
- If a **Toxic Substance Exposure** occurs, there are several pathways to affect **Individual Readiness** and **Crew Capability** including:
  - Some toxicants have cardiovascular toxicities – **Cardiovascular (Risk)** - that can lead to dysrhythmias and myocardial tissue damage.
  - Some toxicants are Ototoxicants and can affect the **Acoustics (Risk)**.
  - Several toxins can cause **Environmental Injuries** such as CO poisoning or Ammonia inhalation that can occur from coolant release and other **Medical (Risk)** issues that can lead to consequences such as **Evacuation**, **Loss of Crew Life** or **Long-Term Health Outcomes**.
  - These can also lead to **Behavioral (Risk)** issues including altered mental status, effects on **Cognitive Function**, and **Psychological Status** that can affect the **Team (Risk)**.
- If a **Toxic Substance Exposure** occurs, then the ability of the crew to mitigate the problem depends on the **Vehicle Design**, including the **Crew Health Care System/Crew Health and Performance System** and the **ECLS System**.
- **Toxic Substance Monitoring** enables **Detect Toxic Exposure** which can drive countermeasure use such as using **Atmospheric Scrubbers** or donning **Protective Equipment**. **Protective Equipment** is part of the **Medical Prevention Capabilities** designed into the **Crew Health Care System/Crew Health and Performance System**.
- **Physiologic Monitoring Capability** can include physical and laboratory biomarkers that can identify the physiologic response of an affected astronaut and help **Detect Diagnosis** to tailor medical care which is part of the **Medical (Risk)**.
- Effectiveness of medical interventions is in part dependent on the **Pharm (Risk)** for **Pharmaceutical Effectiveness**.
- Historically the detection of system issues that can lead to **Release of Toxic Substances** has in large part depended on **Ground Support** from **Mission Control**. This is available in LEO, but **Communication Factors** must be considered in DRMs that have more **Distance from Earth**. Increased autonomy needs for crews may drive an increased monitoring capability to reduce the risk of toxic exposures.
- Some **Toxic Substance Exposures** can lead to **Long-Term Health Outcomes** such as cardiovascular, pulmonary, renal, and other medical conditions. **Surveillance**, such as occupational health surveillance post-flight and post career, is critical to **Detect Long-Term Health Outcomes** and better characterize the magnitude of the Long-Term Health risks.


Behavioral (Risk)
Team (Risk)
Loss of Mission
Distance from Earth
Communication Factors
Ground Support
ECLS System
Crew Capability
Loss of Mission Objectives
Individual Readiness
Crew Health and Performance System
Protective Equipment
Task Performance
Medical Prevention Capability
Standards/Requirements
Vehicle Design
Individual Factors
Toxic Substance Monitoring
Evacuation
Electric Shock (Risk)
Physiologic Monitoring Capability
Crew Metabolism
Atmospheric Scrubbers
Medical (Risk)
Loss of Crew Life
CO2 (Risk)
Waste Management System
Detect Toxic Exposure
Altered Gravity
Detect Diagnosis
Long Term Health Outcomes
Combustion/Smoldering Events
HSIA (Risk)
Pharm (Risk)
Thermal Degradation
Detect Long Term Health Outcomes
Toxic Exposure
Payload Chemicals
Acoustics, Cardiovascular (Risks)
Surveillance
Hostile Closed Environment
Materials Offgassing
Dust (Risk)
External Contaminants