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

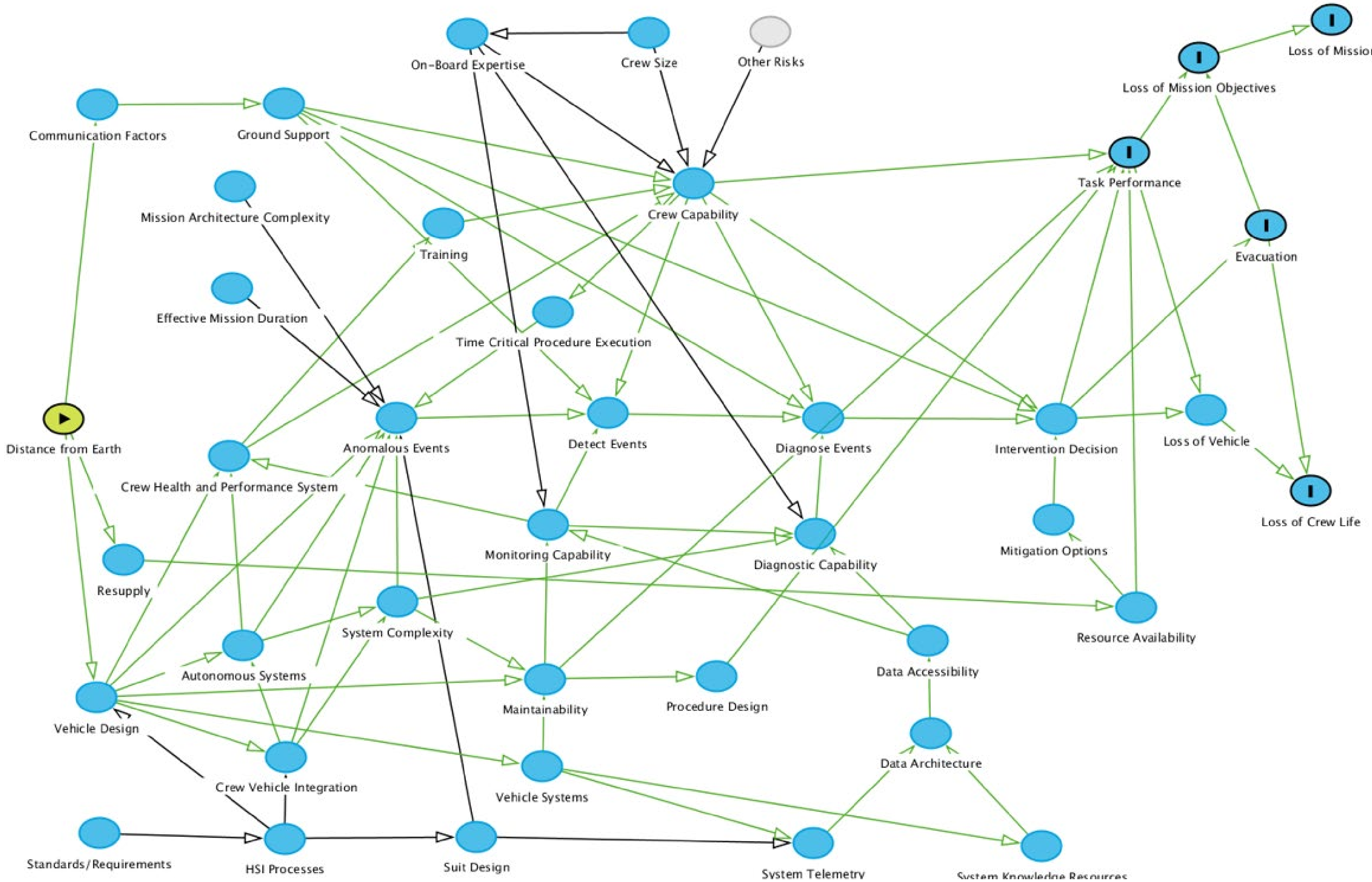
NASA/TP-20220015709

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

Human System Risk Board

October 2022

Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture (HSIA Risk)



HSIA Risk DAG Narrative

The central issue in the Human Systems Integration Architecture Risk is that **Anomalous Events** occur in human spaceflight, and the chain of steps that takes place after an **Anomalous Event** occurs is affected by known factors. The chain includes:

- **Anomalous Event** with one or more vehicle systems occurs.
- The crew (or **Ground Support**) must be able to **Detect Events** that have occurred or there will be no further steps.
- The crew (or **Ground Support**) must be able to accurately **Diagnose Events** that have occurred or they will not be able to intervene appropriately to resolve the event.
- Once diagnosed, the crew (or **Ground Support**) must make an **Intervention Decision** based on the **Mitigation Options** available.
- The **Intervention Decision** could lead to tasks required to fix a problem. Successful completion of these is **Task Performance**. If the **Diagnosis** and **Intervention Decision** were correct, then the anomaly will be resolved. If it was incorrect, then the anomaly will not be addressed. Failure to resolve vehicle system **Anomalous Events** or inadequate **Mitigation Options** can force **Intervention Decisions** that can lead to **Loss of Mission Objectives**, **Evacuation**, or **Loss of Vehicle**.

Crew Capability denotes the functional capacity of the crew as well as their knowledge, skills and abilities. This is affected by:

- The level and type of **Ground Support** available. This is dependent on **Communication Factors** including latency related to **Distance from Earth**.
- **Training** performed before and during a mission.
- **On-Board Expertise** that exists within the crew. This is also a function of **Crew Size**.
- Crew deterioration experienced by the cumulative impact of all of the **Other Risks** (Human System Risks). These contribute through **Individual Readiness** and **Team Functionality.**
- Effectiveness of the **Crew Health and Performance System** in offsetting the deterioration from **Other Risks**.

Task Performance is the degree of success the entire crew has in performing mission tasks. Inadequate **Task Performance** in the case of repairs can lead to **Loss of Vehicle** or **Loss of Mission Objectives** These are affected by:

- **Crew Capability** as represented above. Note that a 100% functional crew may not be able to perform some tasks because of the following factors.
- **Procedure Design** which denotes the design of procedures that respects human limitations in terms of strength, reach, complexity, etc.
- **Maintainability** which includes accessibility for maintenance and repairs and tool dependence and availability is dependent on **Vehicle Design** and the design of **Vehicle Systems**.
- **Resource Availability** such as availability of necessary spare parts is dependent on **Resupply** related to **Distance from Earth**.

The rest of this narrative focuses on what can affect the success of each of these factors in the central chain.

- The number any type of **Anomalous Events** are affected by **Vehicle Design**, the level of **Crew-Vehicle Integration** achieved, contributions from **Autonomous Syste**ms, **System Complexity**, **Mission Architecture Complexity** (single vehicle, multiple vehicles, docking, planetary landings, etc.), and Effective **Mission Duration**. In cases of EVA, **Suit Design** also influences **Anomalous Events**. It is also affected by **Time Critical Procedure Execution** when performed by crew with reduced **Crew Capability** In other words, crew with functional impairments or insufficient knowledge, skills and abilities can make mistakes that lead to **Anomalous Events** in vehicle systems.
- The ability to **Detect Events** is dependent on **Crew Capability**, **Ground Support**, and **Monitoring Capability** present in the vehicle.
- The ability to **Diagnose Events** is dependent on **System Complexity**.
- **Monitoring Capability** and **Diagnostic Capability** are heavily data dependent and are both affected by **Data Accessibility**. This is provided by the **Data Architecture** within the vehicle that makes available to crew **System Telemetry** and **System Knowledge Resources** needed for diagnosis and monitoring of the **Vehicle Systems** as determined by **Vehicle Design**. In the case of EVA, **System Telemetry** from the space suite is affected by the **Suit Design**.

As **Distance from Earth** increases, the available mass, power, volume and data bandwidth become more restricted. The **Standards/Requirements** and **HSI Processes** that are used to influence **Vehicle Design**, **Suit Design**, and **Crew-Vehicle Integration** will functionally determine what vehicle and systems are fielded, how complex and maintainable they are, and how information on system state is provided back to crew and ground support. The ability to detect, diagnose, and effectively intervene on **Anomalous Events** that occur ultimately determines how much HSIA Risk the mission will carry.