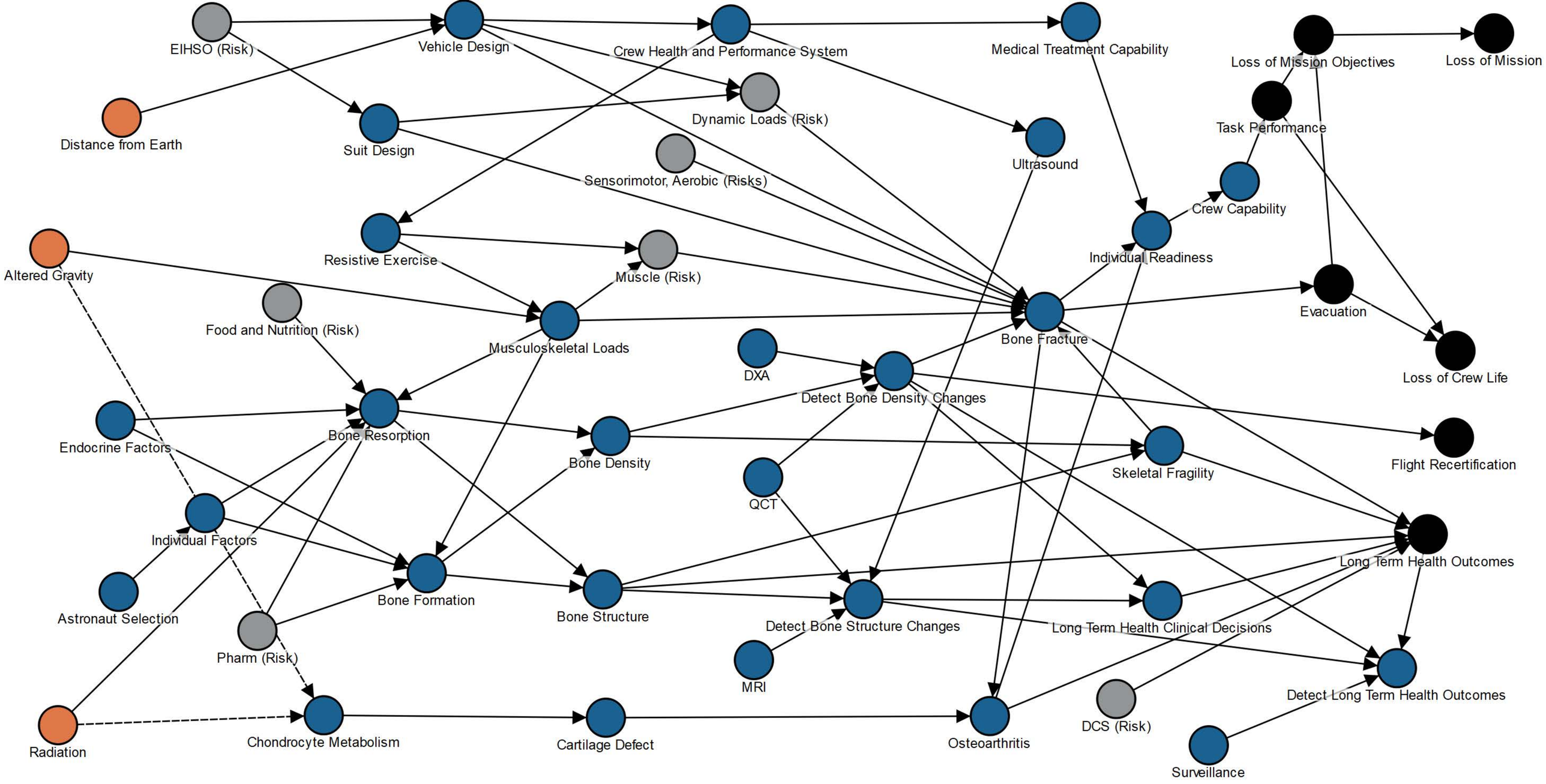
Bone Fracture Risk DAG Narrative

The Bone Fracture DAG centers around the **Bone Fracture** node that has two types of inputs. Those that affect the loads that the bone experiences, and those that make the bone more fragile i.e., **Skeletal Fragility**.

- Nodes that affect the loads the bone experiences include:
  - **Musculoskeletal Loads** is dependent in part by **Altered Gravity**, the **Resistive Exercise** designed into the **Crew Health and Performance System**, and the effects of **Muscle (Risk)** on the bone.
  - **Vehicle Design** and **Suit Design**.
  - **Dynamic Loads (Risk)** governs the loads experienced in landing scenarios for planetary surfaces. This is heavily influenced by **Vehicle Design** and **Suit Design** as well.
  - **Sensorimotor** and **Aerobic (Risks)** can influence the likelihood of experiencing high loads from falling or operational errors.
  - **Muscle (Risk)** includes the muscular loads on the bone and muscular support that change with muscular atrophy. This is dependent on the **Resistive Exercise** designed into the **Crew Health and Performance System**.
- Nodes that affect **Skeletal Fragility** include:
  - **Bone Density** refers to mass and mineral density within the bone.
  - **Bone Structure** refers to changes in the trabecular structure internal to the bone and areal structure of the bone.
  - Changes to both of these occur as a result of unbalanced **Bone Remodeling** here shown as two sub-nodes:
    - **Bone Resorption** performed by Osteoclast cells and dependent on **Musculoskeletal Loads**, **Endocrine Factors** such as estrogen, **Individual Factors**, medications used here represented by **Pharm (Risk)**, and **Nutrients** here represented by **Food and Nutrition (Risk).**
    - **Bone Formation** performed by Osteoblast cells and dependent on all of the same nodes as above *except* for **Food and Nutrition (Risk)**.
- It is hypothesized that **Chondrocyte Metabolism** may be affected by **Altered Gravity** and **Radiation.** These connections are shown as dotted lines because of the paucity of evidence supporting this assertion. If so, this can lead to **Cartilage Defects** and **Osteoarthritis** that can contribute to **Individual Readiness** and **Crew Capability** for example, when dealing with joint pain. **Osteoarthritis** can also occur in some cases of **Bone Fracture**.
- **Skeletal Fragility** if permanent can cause osteoporosis and contribute to **Long Term Health Outcomes**. Similarly chronic joint pain such as arthritis can contribute to **Long Term Health Outcomes**.
- Monitoring countermeasures that can be performed before and after flights such as **DXA**, **QCT**, and **MRI** enable us to **Detect Bone Density Changes** and **Detect Bone Structure Changes**. Detecting these can lead to **Long Term Health Clinical Decisions** such as orthopedic interventions or medication use that can decrease the likelihood or severity of **Long Term Health Outcomes.** Currently there is no arrow connecting **Detect Bone Structure Changes** to **Flight**

Recertification because we do not have a clinical trigger that is identified. However, research into both technology and clinical validation is in progress.

- Ultrasound may provide an option to **Detect Bone Structure Changes** occurring in flight if the capability is designed into the **Crew Health and Performance System**.


EIHSO (Risk)
Vehicle Design
Crew Health and Performance System
Medical Treatment Capability
Loss of Mission Objectives
Loss of Mission
Distance from Earth
Suit Design
Dynamic Loads (Risk)
Task Performance
Ultrasound
Sensorimotor, Aerobic (Risks)
Crew Capability
Resistive Exercise
Muscle (Risk)
Individual Readiness
Altered Gravity
Evacuation
Food and Nutrition (Risk)
Musculoskeletal Loads
Bone Fracture
Loss of Crew Life
DXA
Detect Bone Density Changes
Endocrine Factors
Bone Resorption
Bone Density
Skeletal Fragility
Flight Recertification
QCT
Individual Factors
Long Term Health Outcomes
Astronaut Selection
Bone Formation
Bone Structure
Detect Bone Structure Changes
Long Term Health Clinical Decisions
Pharm (Risk)
MRI
Detect Long Term Health Outcomes
DCS (Risk)
Radiation
Chondrocyte Metabolism
Cartilage Defect
Osteoarthritis
Surveillance