Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition
(Food and Nutrition Risk)
Revision C

Food and Nutrition Risk DAG Narrative

- **The primary hazard for the Food and Nutrition Risk is distance from Earth due to inability to resupply and limited food shelf life.**
- **The central issue in the Food and Nutrition Risk encompasses six nodes in the center of the diagram that highlight the contribution of food to human health and performance.**
- **Energy (Calories)** - this is the amount of energy that food supplies to crew to enable them to live and perform. Insufficient energy in the diet leads to body mass loss, muscle loss, bone loss, oxidative stress, and cardiovascular deconditioning, and ultimately starvation and death.
- **Nutrients** - this includes macro and micronutrients that are a critical part of our diet and without which we develop nutrient deficiency diseases and other pathophysiologies. The term nutrition also encompasses thousands of phytochemicals that when sufficient can provide anti-inflammatory, anticarcinogenic, and other benefits. Some nutrients degrade with storage duration, which may be impacted either positively or negatively by storage conditions. There is some evidence that nutrients may be degraded by **Radiation** but the few studies to date have used higher levels and different sources of radiation than expected in human spaceflight. The dotted line indicates the low amount of evidence in this area.
- **Hydration** – hydration status is determined by total water intake and exit from the body. Dehydration can affect multiple other risks, including cardiovascular, renal stone, cognition, performance, and more.
- **Food Acceptability** – if food is not acceptable it does not matter if it has the required nutrition – they may not consume enough to get adequate nutrition. This is affected by storage duration and conditions and by Individual Factors such as food preferences and allergies which are part of the **Immune (Risk). Astronaut Selection** affects the extent of those factors present in a given crew.
- **Food Variety** – variety is part of acceptability – a nutritional variety of foods needs to prevent menu fatigue and provide choice to prevent risk of underconsumption and undernutrition
- **Food Safety** – if food is not safe it does not matter if it has the required nutrition – it will be a major risk to crew health and loss of mission.
- In conflict with this is another critical concept - resources. To date, nutrition, energy, acceptability, and variety have been cut by programs, regardless of unknown risk, when resources are not available. Mass/volume and power are limited by the **Vehicle Design, Crew Health and Performance System**, and highly dependent on **Distance from Earth** as well as the **HSIA (Risk).** This is also dependent on **Resupply**.
- Resources also impact:
  - **Food Preparation** includes items such as a water heater, food warmer, and other equipment that can determine the amount of time that preparation activities add to the

schedule as well as the acceptability and safety of the food for the astronauts. This is key to acceptability. Food and preparation equipment must be compatible with **Altered Gravity and Hostile Closed Environment.**

- **Food Storage Conditions** includes refrigeration and packaging of food. This is key to nutrition and acceptability and is affected by **Pre- Mission Food Storage Time** which historically has ranged from weeks to years. Refrigeration and packaging must be compatible with **Hostile Closed Environment**.
- **Food Production** which, if designed into the system may include necessary equipment for growing food and ensuring safety, and capability such as salad crops may be critical for acceptability on long duration missions with no resupply of fresh provisions. There is some evidence that **Radiation** may affect seed viability. Dotted line indicates the low amount of evidence in this area.
- **Recycling** primarily includes water.

❖ In order to mitigate risk, crew must intake an appropriate amount of **Energy (Calories), Nutrients**, and **Hydration**. The system must provide the necessary **Food Acceptability, Food Variety**, and **Food Safety** that supports adequate intake. Nutrition, acceptability, and safety must be maintained through the mission duration (adequate shelf life). Too little of these and **Nutrient Deficiencies, Starvation**, or medical conditions such as dehydration can occur. Excess nutrient intake may cause **Nutrient Toxicities** or other medical conditions such as polydipsia, hyponatremia, etc. Optimal nutrition can provide additional benefits, including anti-inflammatory (**Immune Risk**) and anticarcinogenic effects (**Radiation Carcinogenesis Risk**), which can be a key countermeasure to prevent disease on long duration missions. This balance affects other risks listed below that all contribute to non-optimal **Individual Readiness, Crew Capability** and through that affect **Task Performance**. Through the **Medical (Risk)** or through **Starvation**, **Nutrient Toxicities** or **Nutrient Deficiencies** these can also affect the likelihood of other **Mission Level Outcomes** including **Evacuation**, **Loss of Crew Life**, and **Long-Term Health Outcomes**.

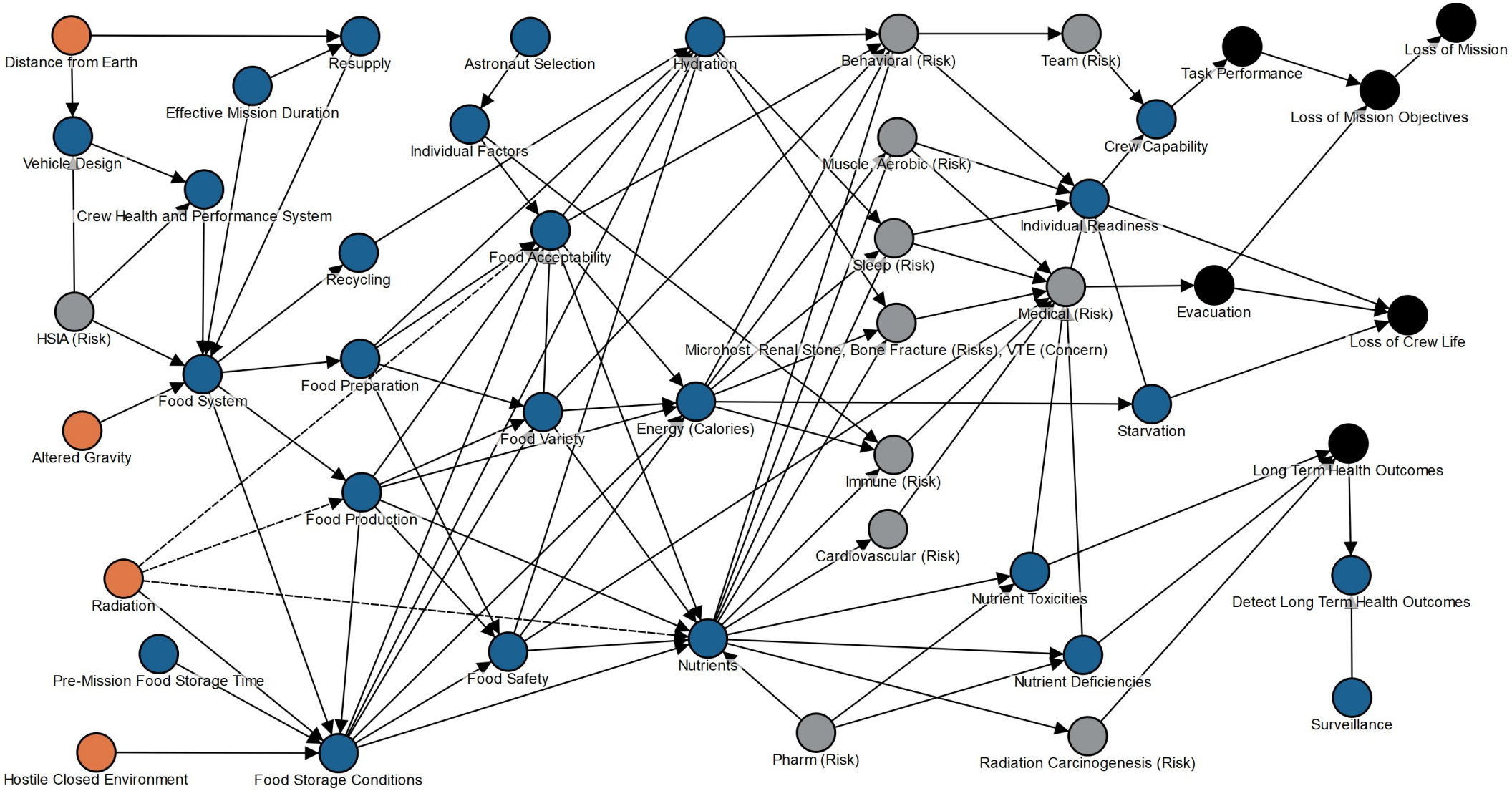
❖ **Food system (including nutrient deficiencies and/or toxicities) directly affects the likelihood of other risks listed below:**

- **Behavioral (Risk)** Prolonged isolation and confinement can be a contributing factor to inadequate food and nutrition intake, and an inadequate food system / inadequate nutrition will adversely impact mood, cognition, and performance, serving as an additional stressor in the exploration environment.
- **Muscle** and **Aerobic (Risks)** fitness levels including stamina and strength can be affected.
- **Sleep (Risk)** affects factors such as physiological health, behavioral health, and cognitive function.
- **Microhost, VTE, Renal Stone, and Bone Fracture (Risks)** – all have nutritional underpinnings and can lead to specific medical conditions occurring in mission.
- **Immune (Risk)** system dysregulation can occur as a result of inadequate energy and nutrient intake. This also includes hypersensitivity reactions like food allergies which are affected by **Individual Factors**.
- **Cardiovascular (Risk)** function and **SANS (Risk)** through vitamin issues or other single nutrient deficiencies.
- **Nutrient Toxicities** occur when too much of a required nutrient is ingested. These can include vitamin and mineral toxicities if astronauts consume too much in-mission and affect **Long-Term Health Outcomes** (e.g., liver damage from Vitamin A overconsumption; neuropathy

from excess B-vitamin or manganese intakes)

- **Nutrient Deficiencies** occur when too little of a required nutrient is ingested. Scurvy from a lack of vitamin C or rickets from a lack of vitamin D are historic examples that can lead to **Long-Term Health Outcomes**.
- Antioxidants and other nutrients may play a role in affecting **Radiation Carcinogenesis** likelihood and **Long-Term Health Outcomes** for long missions.

❖ **Surveillance** enables us to detect **Long-Term Health Outcomes** and better characterize the risk as we gather more evidence.


Distance from Earth
Resupply
Effective Mission Duration
Vehicle Design
Crew Health and Performance System
Recycling
HSIA (Risk)
Food System
Altered Gravity
Astronaut Selection
Individual Factors
Food Acceptability
Food Preparation
Food Variety
Food Production
Radiation
Pre-Mission Food Storage Time
Hostile Closed Environment
Food Storage Conditions
Food Safety
Hydration
Behavioral (Risk)
Muscle, Aerobic (Risk)
Sleep (Risk)
Microhost, Renal Stone, Bone Fracture (Risks), VTE (Concern)
Energy (Calories)
Immune (Risk)
Cardiovascular (Risk)
Nutrients
Pharm (Risk)
Team (Risk)
Crew Capability
Individual Readiness
Medical (Risk)
Starvation
Nutrient Toxicities
Nutrient Deficiencies
Radiation Carcinogenesis (Risk)
Task Performance
Loss of Mission
Loss of Mission Objectives
Evacuation
Loss of Crew Life
Long Term Health Outcomes
Detect Long Term Health Outcomes
Surveillance