National Aeronautics and
Space Administration

Crew Health & Performance 101

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NASA Johnson Space Center

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What is the Crew Health and Performance System?

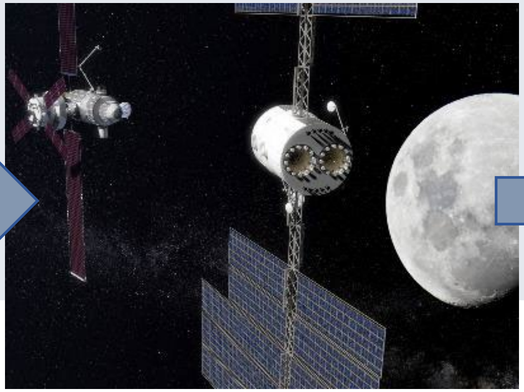
- The Exploration Crew Health and Performance System describes the principles, procedures and components required to work together to maintain the health and performance of the crew on an exploration class mission
  - The central focus of the CHP system is the human (human as a system)
  - The CHP System follows the crew through all mission phases (pre-flight, launch, landing and post-flight)
  - The components of the CHP include diverse hardware (medical diagnostics, exercise, environmental monitors, etc.) and dependencies on other vehicle systems (Communications, data, ECLSS, electronic procedures, etc.)

- NASA-STD-3001 and the Design Reference Missions (DRMs) drive the capabilities of the CHP System
  - NASA-STD-3001 is decomposed and tailored to a requirements document for each program based on the DRM's
  - Many of these requirements are vehicle design requirements such as anthropometric requirements, requirements for the force required to open an escape hatch or the need for a specific volume of water to be provided to maintain prevent dehydration, etc.
  - Other requirements are for specific capabilities (hardware/software) or consumables (food, pharmaceuticals, etc.)
  - All of these requirements/capabilities whether a part of an "all incompassing" core vehicle systems or part of an integrated solution (vehicle + external/GFE) must work together to support the human system and provide seemless health care

Exploration vs. LOE Missions from a Human Health & Performance Perspective

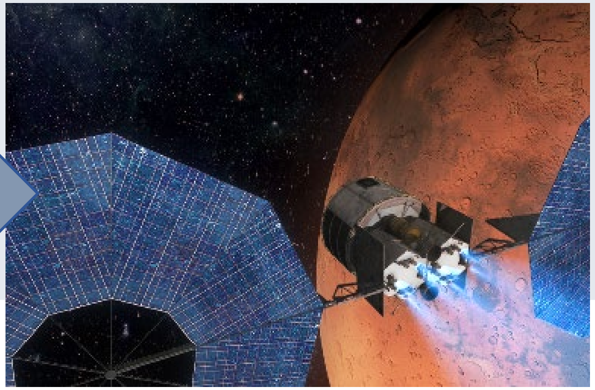
ISS

Gateway



Boots on the Moon

Mars Transit



Today

2025

2036

Increasing exposure to Hazards

Current State

- 6-12 month crew mission duration with strong consumables resupply
- Real Time Communications and data enable diagnosis/decision making centered at MCC
- Regular sample return to Earth allows detailed analysis if unknown problems/contaminants/symptoms emerge
- In the event of an emergency, crew to be stabilized and evacuated (1.5 – 36 hrs to terrestrial care)

Exploration Class Missions

- **Approx. 1000 days** with **No** Consumables Resupply
- No Real Time Communications or data. Crew must be enabled to **autonomously address emergencies or emerging** events.
- Primary enabler for crew will be **autonomous access to comprehensive data** quickly to support decision making
- Limited mass, power, volume and data will require **crew health systems to be integrated with the vehicle**. Need to develop in-situ analytical tools.
- **No Evacuation Capability**, crew must have sufficient supplies to treat issues to recovery, rather than stabilize for return.

The Need for Autonomy from the Human as a System Perspective

From 85+ to 4 people able to respond

MCC + MER

- 85 systems experts
- 660 years combined specific systems experience
- ~2 years to operator cert
- Additional years to specialist cert
- In-depth understanding of a single system
- Training builds academic engineering background
- Constantly using skills and studying flight rules

Astronauts

- 4 crew members
- 91 years combined relevant work experience
- 2 years ASCAN training
- ~ 2 years flight-assigned training
- *I&S, C&T, EPS, ETCS, ECLSS, ITCS, Emergency, MCS, OOM, Struc & Mech, Crew Systems, VV, Orb Mech, CMO, Med Ops, EVA, ROBO, Ops LAN, Photo/TV
- Time Gap between training and flight; degradation of knowledge may be significant

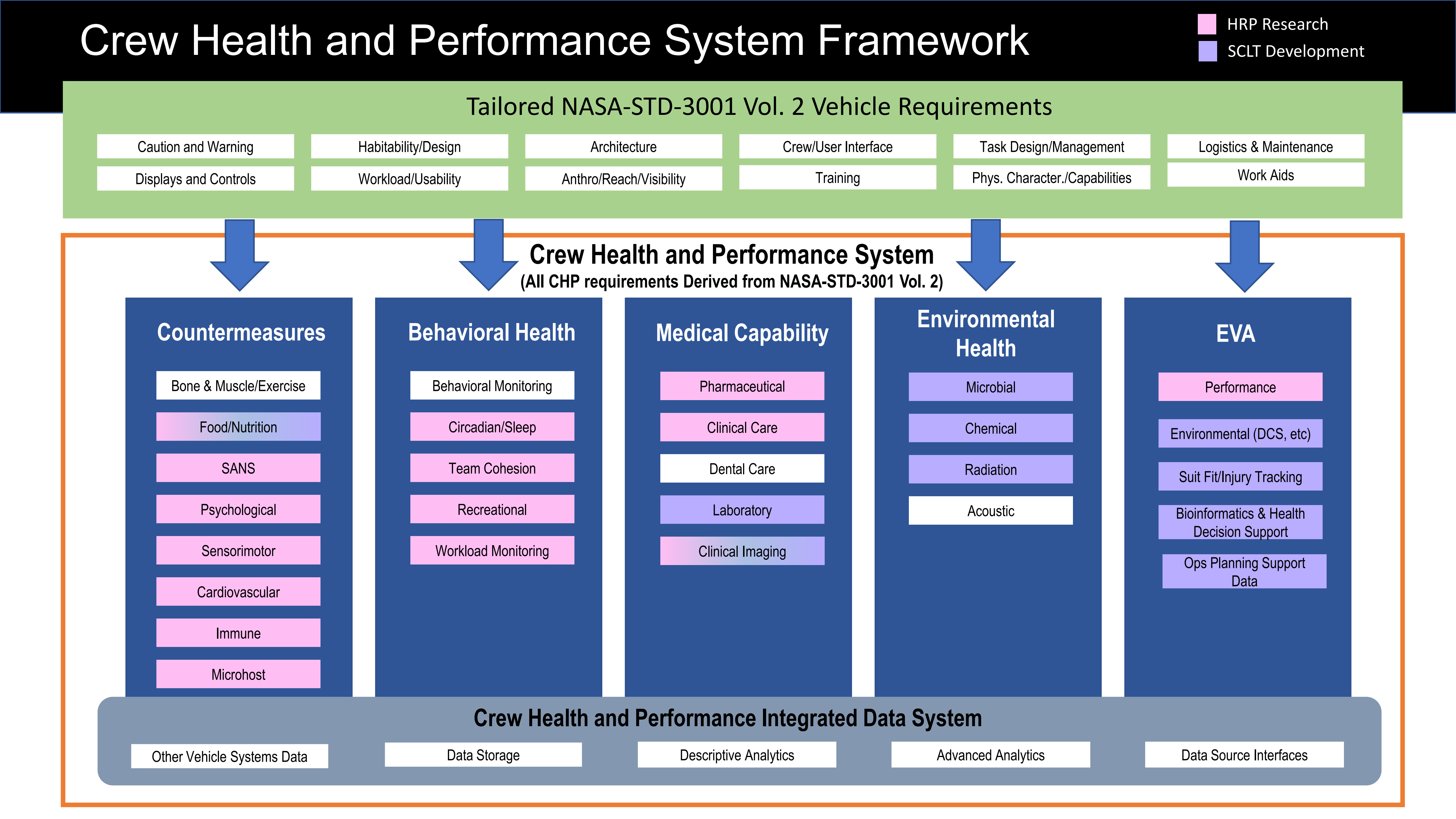
"4 people with 25 years experience each on 4 console positions cannot replace 10 people with 10 years of experience on 10 consoles positions even though both groups have 100 years total experience. It's not just the experience, it's the experience in unique console positions."

The CHP System is an Evolution from ISS

- To overcome the increasing risks associated with exploration missions and enable crew health and performance, the CHP System must be fundamentally different from LOE systems and enable crew autonomy
  - Having the right information, at the right time, at the right place and in the right format allows crew situational awareness and enables rapid decision making and effective interventions
  - Support tools such as electronic crew procedures, just in time training and/or automated guidance will become more important than in LOE
  - Simplifying or automating functions such that critical crew time is not absorbed reconfiguring systems to get data, retrieve procedures or training material, reconfigure communications, will also be key to this effort.

- The CHP system will not be able to have every capability, so determining the right capabilities and information and focusing development effort on those elements will be key

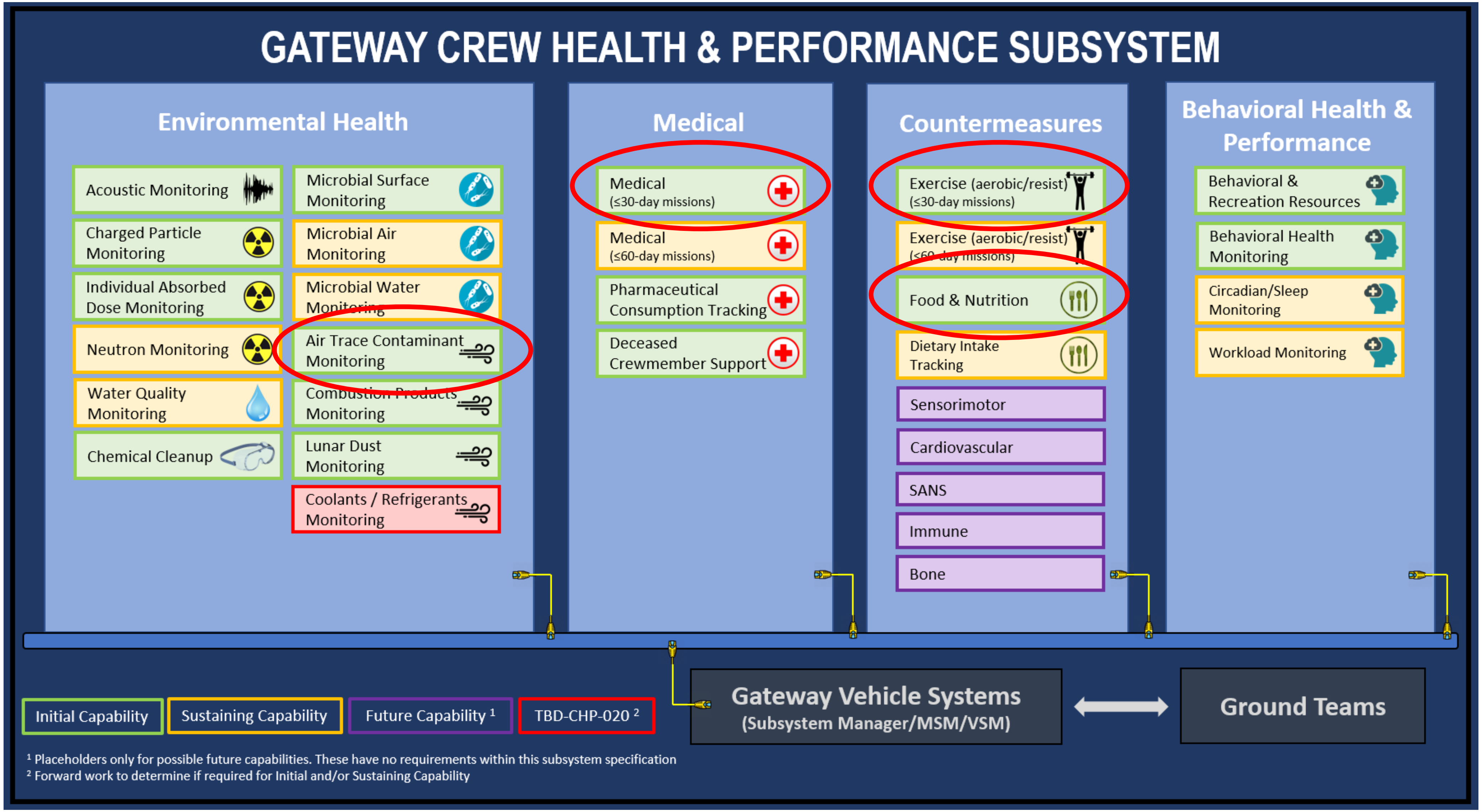
- To achieve these goals, the needs of the Human (NASA-STD-3000 and CHP System) must be considered during the very early formulation efforts for surface habitats and Mars Transit Habitats/Vehicle.



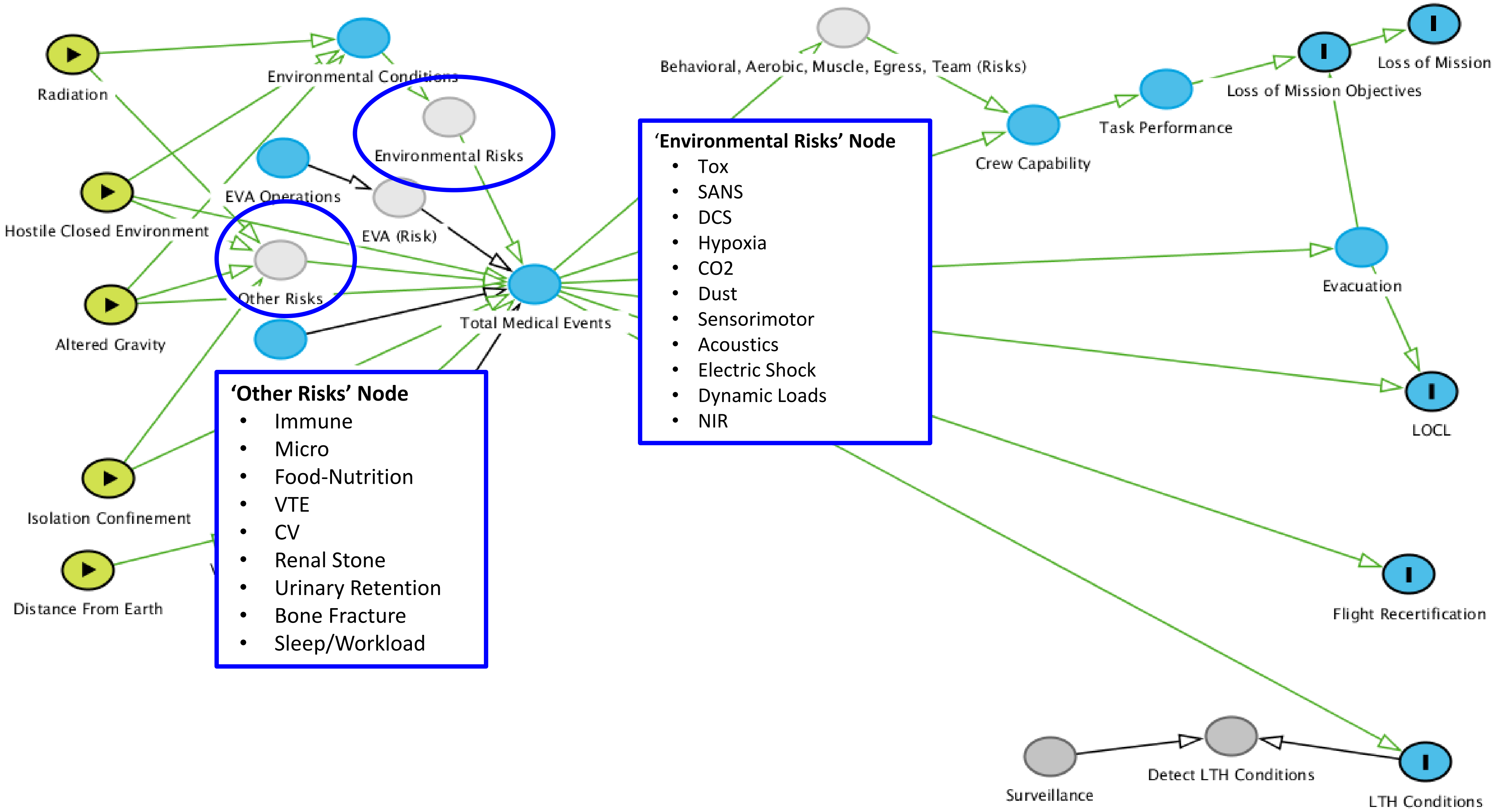
Crew Health and Performance System Framework
HRP Research
SCLT Development
Tailored NASA-STD-3001 Vol. 2 Vehicle Requirements
Caution and Warning
Displays and Controls
Habitability/Design
Workload/Usability
Architecture
Anthro/Reach/Visibility
Crew/User Interface
Training
Task Design/Management
Phys. Character./Capabilities
Logistics & Maintenance
Work Aids
Crew Health and Performance System
(All CHP requirements Derived from NASA-STD-3001 Vol. 2)
Countermeasures
Bone & Muscle/Exercise
Food/Nutrition
SANS
Psychological
Sensorimotor
Cardiovascular
Immune
Microhost
Behavioral Health
Behavioral Monitoring
Circadian/Sleep
Team Cohesion
Recreational
Workload Monitoring
Medical Capability
Pharmaceutical
Clinical Care
Dental Care
Laboratory
Clinical Imaging
Environmental Health
Microbial
Chemical
Radiation
Acoustic
EVA
Performance
Environmental (DCS, etc)
Suit Fit/Injury Tracking
Bioinformatics & Health Decision Support
Ops Planning Support Data
Crew Health and Performance Integrated Data System
Other Vehicle Systems Data
Data Storage
Descriptive Analytics
Advanced Analytics
Data Source Interfaces

Example of Tailored CHP System

Gateway CHP System Overview (Rev A)



Medical Risk DAG - Other Risk Interactions



Example—Environmental Health Monitoring

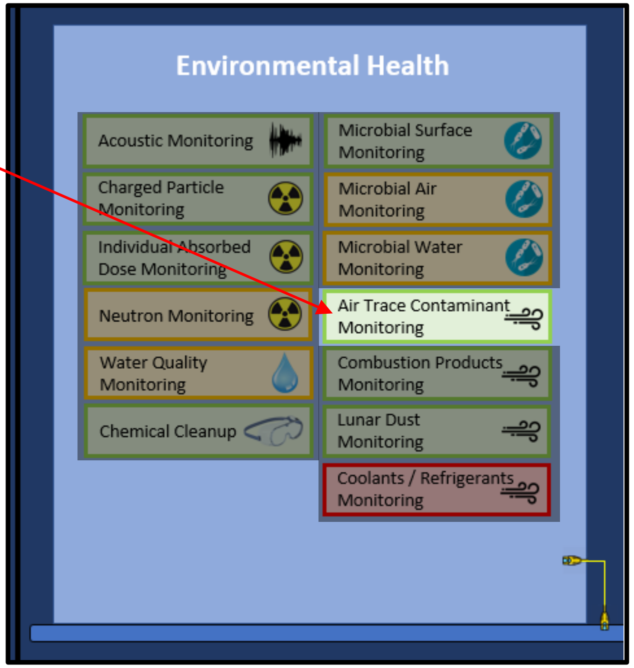
Air Trace Contaminant Monitoring

6.2.7.2 Trace Constituent Monitoring and Alerting NASA-STD-3001, Vol2, Rev B

[V2 6023] The system **shall** monitor trace volatile organic compounds (VOCs) in the cabin atmosphere and alert the crew when they are approaching defined limits.

[Rationale: Monitoring and alerting are required to identify when hazardous contaminants are detected and to alert the crew so they can take appropriate actions to maintain health and safety. Trace contaminant monitoring is important for identifying a wide range of contaminants that may impact human health and safety, including toxic substances that cannot be predicted now or substances that are not normally thought of as part of the atmosphere. Accepted limits may be based on SMACs or on agreements from international partners. There may be specific mission scenarios (e.g., short-duration missions and alternate controls) where trace contaminant monitoring may not be required.]

Tie to HSR Risk--monitoring



Child Requirements	
• In-Flight Alerts	NASA-STD-3001 *(6023)*
• Remote Control	Derived. Driven by dormancy risk. Supports pre-ingress
• Local Control	Derived. Allows flexibility
• Connect to Vehicle Power and Data	Derived. Precludes need for batteries and establishes data path to Ground
• On-Orbit Performance Validation	Derived. Reduces resupply needs

Example—Environmental Health Monitoring

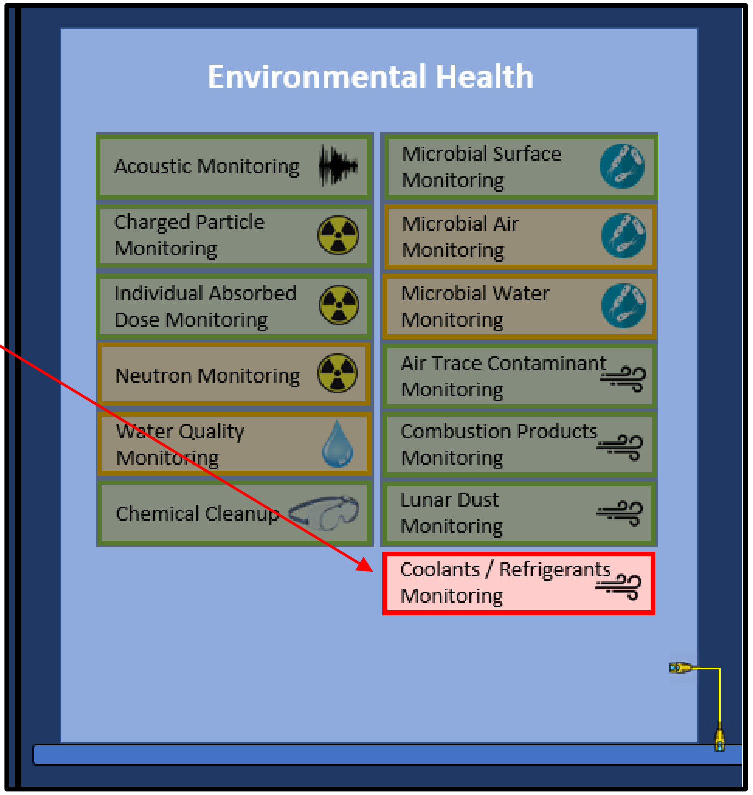
Coolants/Refrigerants Monitoring

6.2.7.4 Contamination Monitoring and Alerting NASA-STD-3001, Vol2, Rev B

[V2 6025] The system **shall** monitor and display atmospheric compound levels that result from contamination events, e.g., toxic release, systems leaks, or externally originated, before, during, and after an event and alert the crew in sufficient time for them to take appropriate action.

[Rationale: Alerting the crew when contaminants are present is necessary for them to take appropriate action to maintain health and safety. In addition, monitoring after the event is important to verify that levels are safe for human exposure. Monitoring is required to identify when components are detected so that alerting can occur. Potential contaminants, e.g., hydrazine, monomethylhydrazine (MMH), nitrogen tetroxide/nitrogen dioxide and ammonia, need to be monitored after EVA.]

TBD: Dependent on cooling system design. If no creditable leak path, no need for monitoring.



Example--Medical

7.5.1 Medical Capability — **NASA-STD-3001, Vol2, Rev B**

[V2 7043] A medical system **shall** be provided to the crew to meet the medical requirements of NASA-STD-3001, Volume 1, in accordance with Table 15, Medical Care Capabilities.

Table 15—Medical Care Capabilities

Level of Care	Space Environment	Mission Duration	Capability
I	LEO	<8 days	Space Motion Sickness, Basic Life Support, First Aid, Private Audio, Anaphylaxis Response
II	LEO	<30 days	Level I + Clinical Diagnostics, Ambulatory Care, Private Video, Private Telemedicine
III	Beyond LEO	<30 days	Level II + Limited Advanced Life Support, Trauma Care, Limited Dental Care
IV	Lunar	>30 days	Level III + Medical Imaging, Sustainable Advanced Life Support, Limited Surgical, Dental Care
V	Mars Expedition		Level IV + Autonomous Advanced Life Support and Ambulatory Care, Basic Surgical Care

7.5.4 Medical Treatment Restraints — **NASA-STD-3001, Vol2, Rev B**

[V2 7046] The capability **shall** exist to position and restrain a patient, care provider, and equipment during treatment.

Requirements

Parent: (Medical Kit):	
• Lighted Imaging	Derived from NASA-STD-3001 for LoC III *(7043)*
• Ultrasound	Derived from NASA-STD-3001 for LoC III *(7043)*
• Wound Closure	Derived from NASA-STD-3001 for LoC III *(7043)*
• Nail Trephination	Derived from NASA-STD-3001 for LoC III *(7043)*
• Finger Injury Splinting	Derived from NASA-STD-3001 for LoC III *(7043)*
• Distal Extremity Injury Splinting	Derived from NASA-STD-3001 for LoC III *(7043)*
• Patient Restraint	NASA-STD-3001 *(7046)*
• Medical Equipment Restraint	NASA-STD-3001 *(7046)*
• Wound Care Consumables	Derived from NASA-STD-3001 for LoC III *(7043)*
• CO-oximetry	Derived from NASA-STD-3001 for LoC III *(7043)*
• CPAP Breathing Support	Derived from NASA-STD-3001 for LoC III *(7043)*
• Personal Hearing Protection	NASA-STD-3001 *(9057)*
Children:	
• Portable	Derived. Drives flexibility
• Connect to Vehicle Data	Derived. Establishes data path to Ground

9.8.1.2.2 Hearing Protection Provision — **NASA-STD-3001, Vol2, Rev B**

[V2 9057] Appropriate personal hearing protection **shall** be provided to the crew during all mission phases for contingency or personal preference.

Example--Countermeasures Subsystem

Exercise

7.4.1 Physiological Countermeasures Capability NASA-STD-3001, Vol2, Rev B

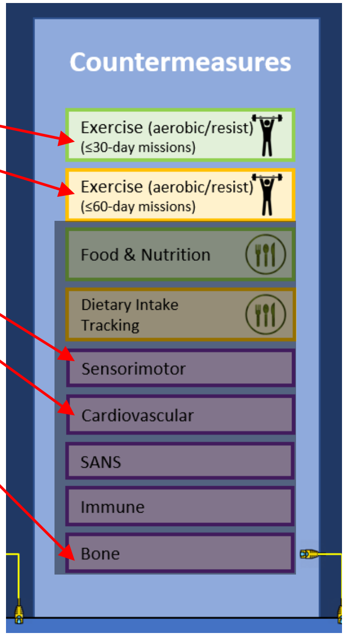
[V2 7038] The system **shall** provide countermeasures to meet crew bone, muscle, sensory-motor, and cardiovascular requirements defined in NASA-STD-3001, Volume 1.

[Rationale: Exercise is used to maintain crew cardiovascular fitness (to aid in ambulation during gravity transitions and to minimize fatigue), to maintain muscle mass and strength/endurance, for recovery from strenuous tasks and confined postures, and to rehabilitate minor muscle injuries. Exercise also has behavioral health benefits. Exercise is to commence as early as possible during the mission and continue throughout all mission phases in accordance with results from the Apollo crew's participation in the June 2006 Apollo Medical Summit

7.4.3 Physiological Countermeasure Operations NASA-STD-3001, Vol2, Rev B

[V2 7040] The physiological countermeasure system design **shall** allow the crew to unstow supplies, perform operations, and stow items within the allotted countermeasure schedule.

[Rationale: The ease and the efficiency of the countermeasure system assist in the crew's being able to perform their countermeasure activities. The crew needs these activities to maintain health and fitness. It can be expected that daily countermeasure activity will occur.]



Child Requirements	
• Aerobic Capability	Derived from NASA-STD-3001 *(7038)*
• Muscle Strength & Endurance	Derived from NASA-STD-3001 *(7038)*
• Bone Mass Density	Derived from NASA-STD-3001 *(7038)*
• Connect to Vehicle Power	Derived. Not expected to run off battery power
• Connect to Vehicle Data	Derived. Establishes data path to Ground
• System Deploy Time	Derived from NASA-STD-3001 *(7040)*

Example—Countermeasures Subsystem
Nutrition

NASA-STD-3001, Vol2, Rev B

7.1.1.1 Food Quality

[V2 7001] The food system **shall** provide the capability to maintain food safety and nutrition during all phases of the mission.

7.1.1.2 Food Acceptability

[V2 7002] The system **shall** provide food that is acceptable to the crew for the duration of the mission.

7.1.1.3 Food Caloric Content

[V2 7003] The food system **shall** provide each crewmember with a minimum number of calories per day, based upon estimated energy requirements (EER) with an activity factor of 1.25 (active) as calculated according to Table 11, EER Equations.

7.1.1.4 EVA Food Caloric Content

[V2 7004] For crewmembers performing EVA operations, the food system **shall** provide an additional 837 kJ (200 kcal) per EVA hour above nominal metabolic intake as defined by section 7.1.1.3, Food Caloric Content [V2 7003], in this NASA Technical Standard.

NASA-STD-3001, Vol2, Rev B

7.1.1.5 Food Macronutrients

[V2 7005] The diet for each crewmember **shall** include macronutrients in the quantities listed in Table 12, Macronutrient Guidelines for Spaceflight.

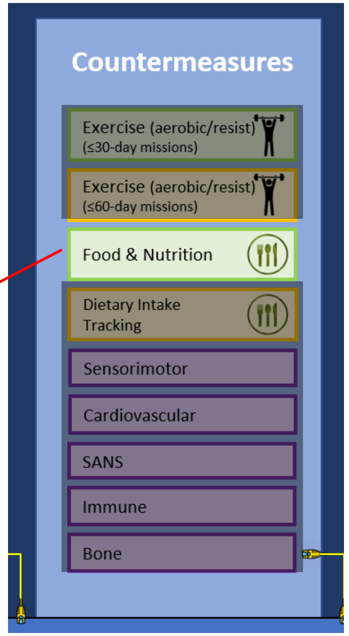
7.1.1.6 Food Micronutrients

[V2 7006] The diet for each crewmember **shall** include micronutrients in the quantities listed in Table 13, Micronutrient Guidelines for Spaceflight.

7.1.1.7 Food Microorganism Levels

[V2 7007] Microorganism levels in the food **shall** not exceed those specified in Table 14, Food Microorganism Levels (JSC-16888, Microbiology Operations Plan for Spaceflight).

Requirements	
• Acceptability	NASA-STD-3001 *(7002)*
• Microbial Levels	NASA-STD-3001 *(7007)*
• Nutrients	NASA-STD-3001 *(7005, 7006)*
• Quantity (IVA)	NASA-STD-3001 *(7003)*
• Quantity (EVA)	NASA-STD-3001 *(7004)*
• Maintaining Food Quality	NASA-STD-3001 *(7001)*



Human System Risk Framework

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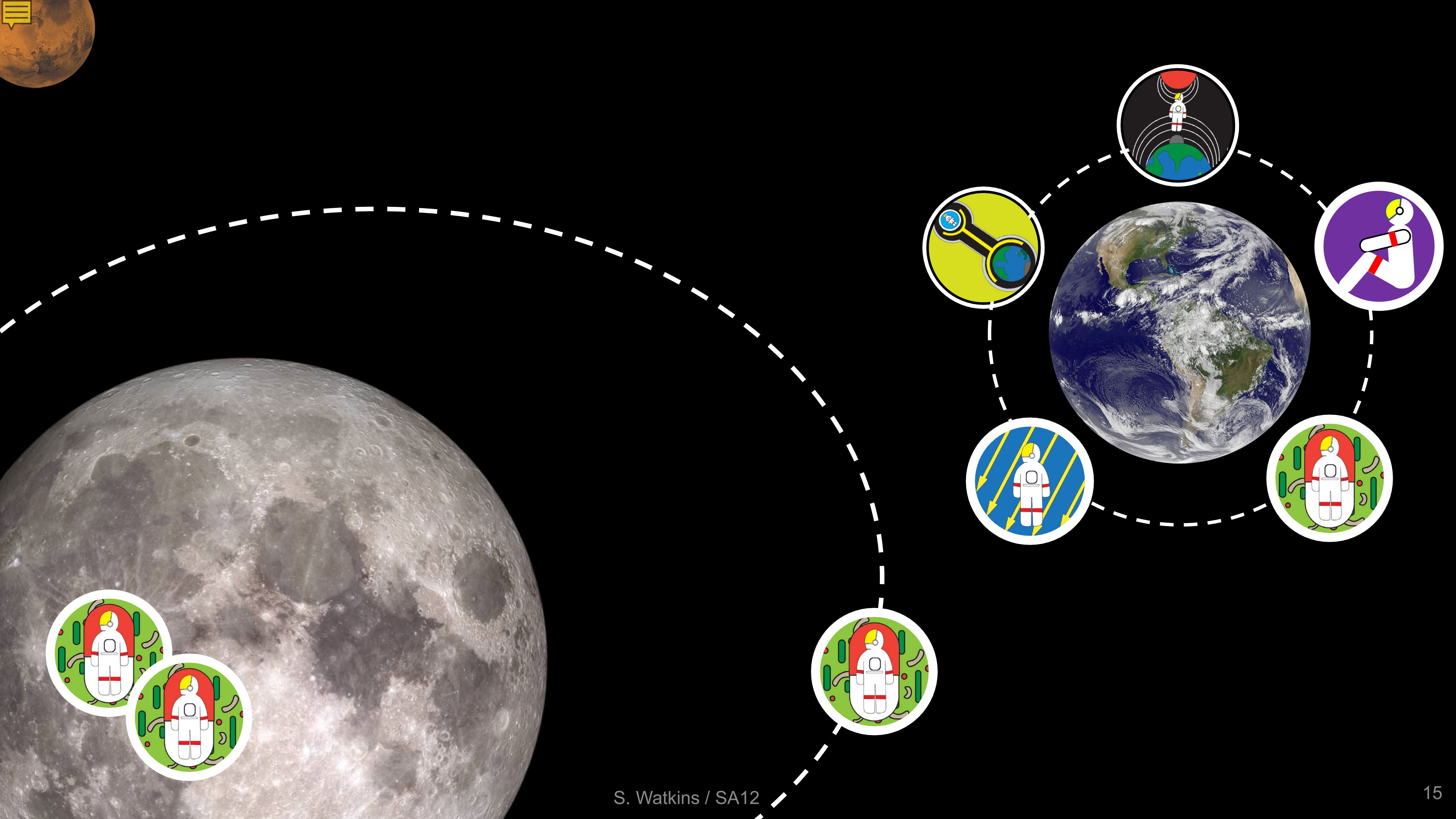
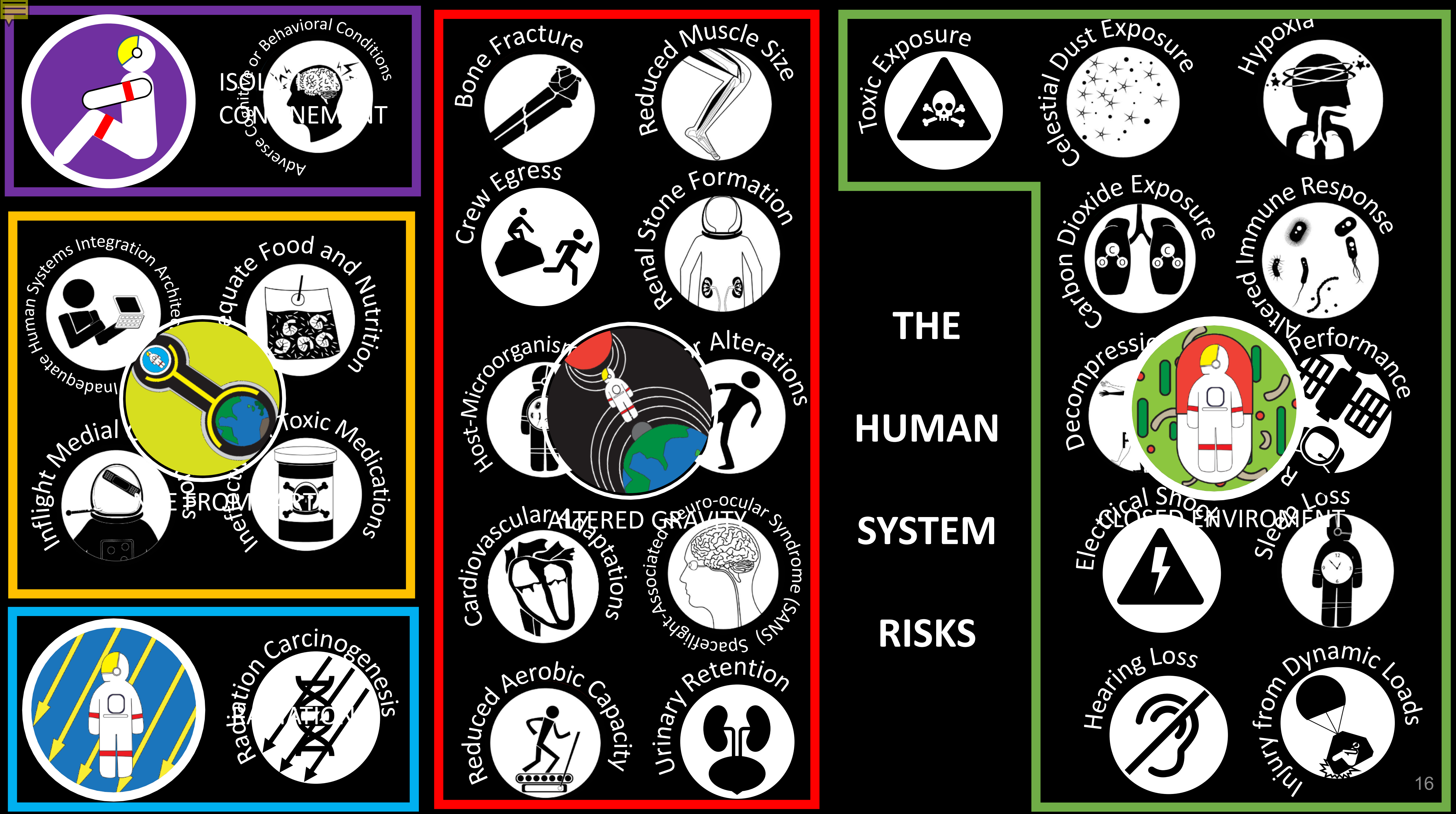
Risk Integrators
Erin Connell
Kimberly-Michelle Lowe

Habitation Forum – June 3, 2022

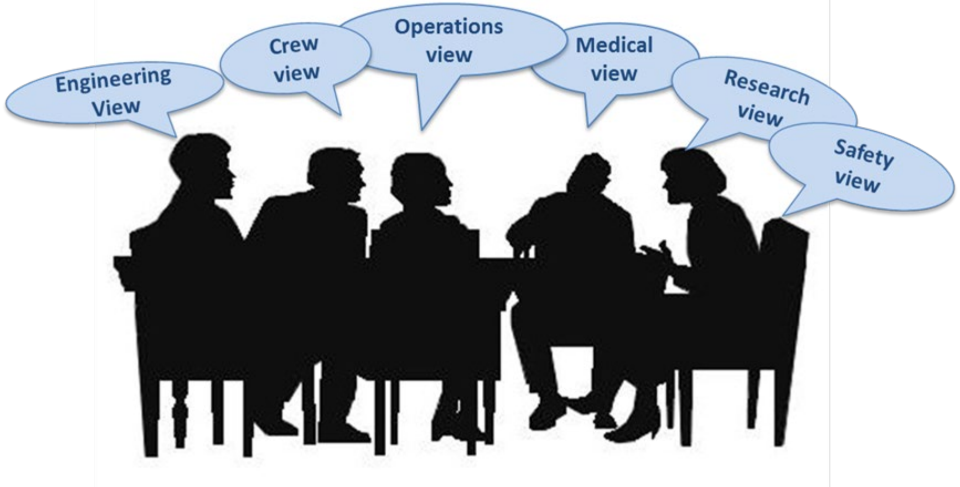




Adverse Cognitive or Behavioral Conditions
ISOLATION CONFINEMENT
Bone Fracture
Reduced Muscle Size
Crew Egress
Renal Stone Formation
Host-Microorganis
r Alterations
Cardiovascular Adaptations
ALTERED GRAVITY
Spaceflight-Associated Neuro-ocular Syndrome (SANS)
Reduced Aerobic Capacity
Urinary Retention
Toxic Exposure
Celestial Dust Exposure
Hypoxia
Carbon Dioxide Exposure
Altered Immune Response
Decompressi
Performance
Electrical Shock
CLOSED ENVIRONMENT
Sleep Loss
Hearing Loss
Injury from Dynamic Loads
Human Systems Integration Archite
Inadequate
quate Food and Nutrition
Inflight Medical
Toxic Medications
Ineffect
Radiation Carcinogenesis
RADIATION
THE HUMAN SYSTEM RISKS

HMTA Process to Assess Human System Risks

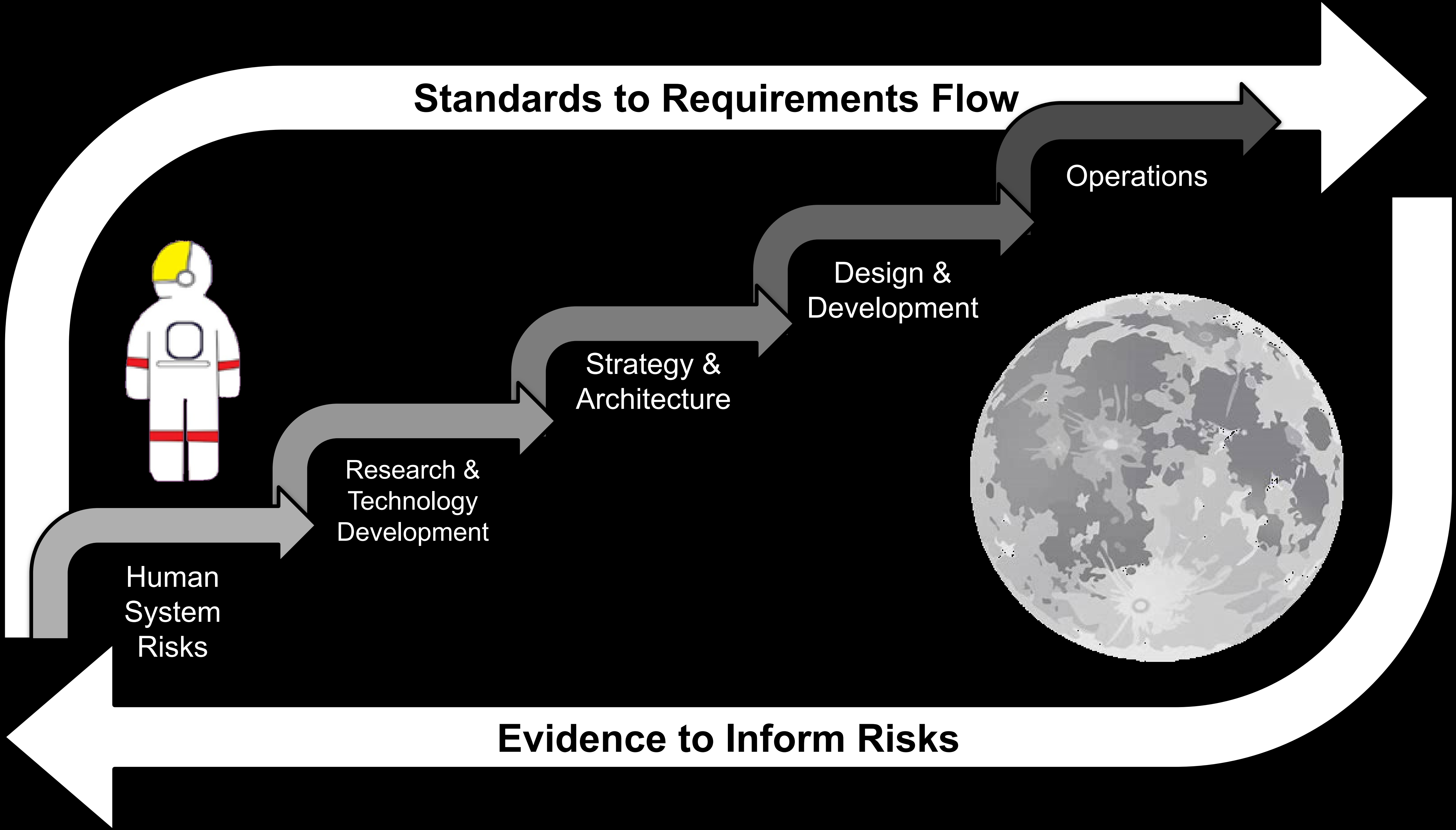
- **The Human System Risk Board**
  - Reviews all evidence for all human system risks and concerns on a regular basis with members from
    - Medical Operations
    - Human Research Program (HRP)
    - Epidemiologists/data science
    - Flight Operations Directorate
    - Safety and Engineering Directorates



- HSRB assesses Program agnostic risk postures based on Design Reference Mission Categories
- Likelihood and consequence scores are assessed for each of the 30 risks.
- Feedback from Programs to HSRB for updating or establishing human systems risks

Human System Risk Summary – Risks by Hazard

Human Spaceflight Risks	Low Earth Orbit (Short)	Low Earth Orbit (Long)	Lunar Orbital (Short)	Lunar Orbital (Long)	Lunar Orbital + Surface (Short)	Lunar Orbital + Surface (Long)	Mars (Preparatory)	Mars (Planetary)
	< 30 D	30 D - 1 Y	< 30 D	30 D - 1 Y	< 30 D	30 D - 1 Y	< 1 Y	730-1224D
Distance from Earth								
Human Systems Integration Architecture (HSIA) [5x5]								
Inflight Medical Conditions [5x5]								
Inadequate Food and Nutrition								
Ineffective or Toxic Medications								
Isolation and Confinement								
Cognitive or Behavioral Conditions [5x5]								
Psychosocial Adaptation within a Team								
Altered Gravity								
Sensorimotor Alterations [5x5]								
Bone Fracture								
Cardiovascular [5x5]								
Renal Stone Formation								
SANS								
Crew Egress [5x5]								
Host-Microorganism Interactions [5x5]								
Urinary Retention								
Reduced Aerobic Capacity								
Reduced Muscle Size								
Venous Thromboembolism (VTE) Concern								
Hostile Closed Environment								
EVA								
Dynamic Loads								
Carbon Dioxide Exposure								
Toxic Exposure [5x5]								
Altered Immune Response								
Sleep Loss								
Decompression Sickness								
Hypoxia **(LTH)**								
Celestial Dust Exposure								
Electrical Shock [5x5]								
Hearing Loss **(LTH)**								
Radiation								
Radiation Carcinogenesis **(LTH)**								
Non-Ionizing Radiation								


Standards to Requirements Flow
Human System Risks
Research & Technology Development
Strategy & Architecture
Design & Development
Operations
Evidence to Inform Risks

Human System Risk Complexity

Exposure Sources
- •Carbon dioxide
- •Celestial dust
- •Toxic
- •Sunlight
- •Radiation

Isolation
- •Cognitive, behavioral, psychiatric disorders
- •Cooperation, coordination, psychosocial adaptation

Work
- •Sleep loss
- •Circadian desynchronization
- • Work overload

Altered body function
- •Immune response
- •Hypobaric hypoxia
- •Decompression
- •Renal stone
- •Bone fracture
- •Host-microorganism interactions
- •Urinary retention
- •Orthostatic intolerance
- •Cardiac rhythm
- •Back pain

Preparedness
- •Food and nutrition
- •Inflight medical conditions
- •Medication

Injury sources
- •Dynamic loads
- •EVA
- •Electrical shock

Reduced capacities
- •Hearing loss
- •Intracranial hypertension/vision alteration
- •Vestibular/sensorimotor alteration
- •Muscle mass, strength, endurance
- •Aerobic capacity

How Crew Is ***Impacted*** by Mission

Anomaly Response

Causal Diagnostics

Next Worst Outcome Analysis

Knowledge Integration

Contingency Planning

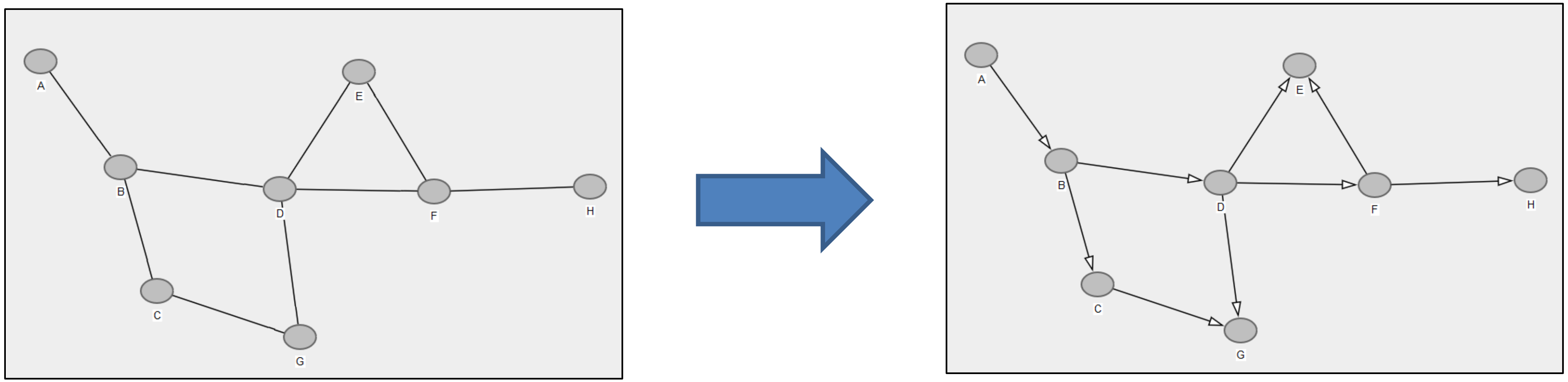
Complex Procedure Execution

Risk Assessment / Time to Criticality

How Crew Is ***Impacting*** Mission

Use of Directed Acyclic Graphs (DAG)

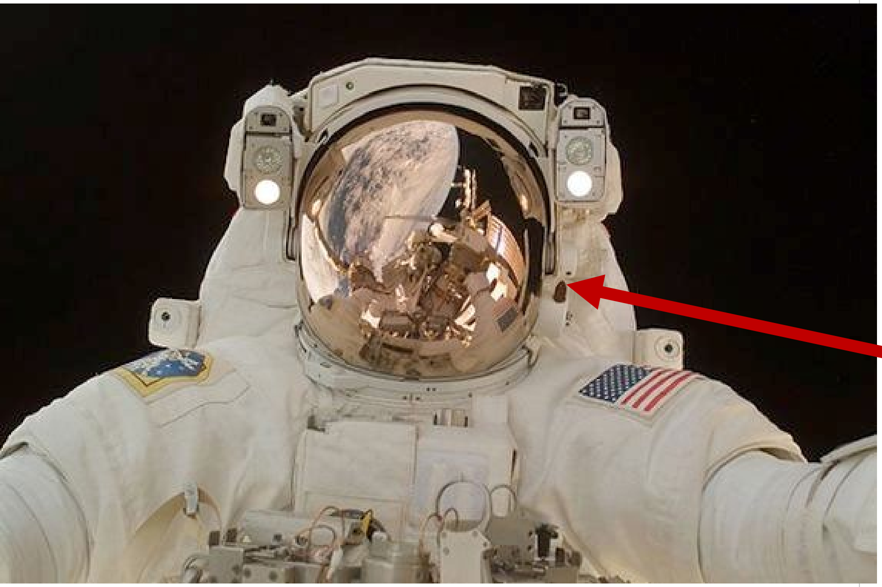
- **Visual representation of <u>causality</u> in a network graph format**
  - **Directed**: single-headed arrows show direction of relationship
  - **Acyclic**: no 'cycles' (feedback loops); relationship goes one way and there are no directed paths back to a node once we've left it

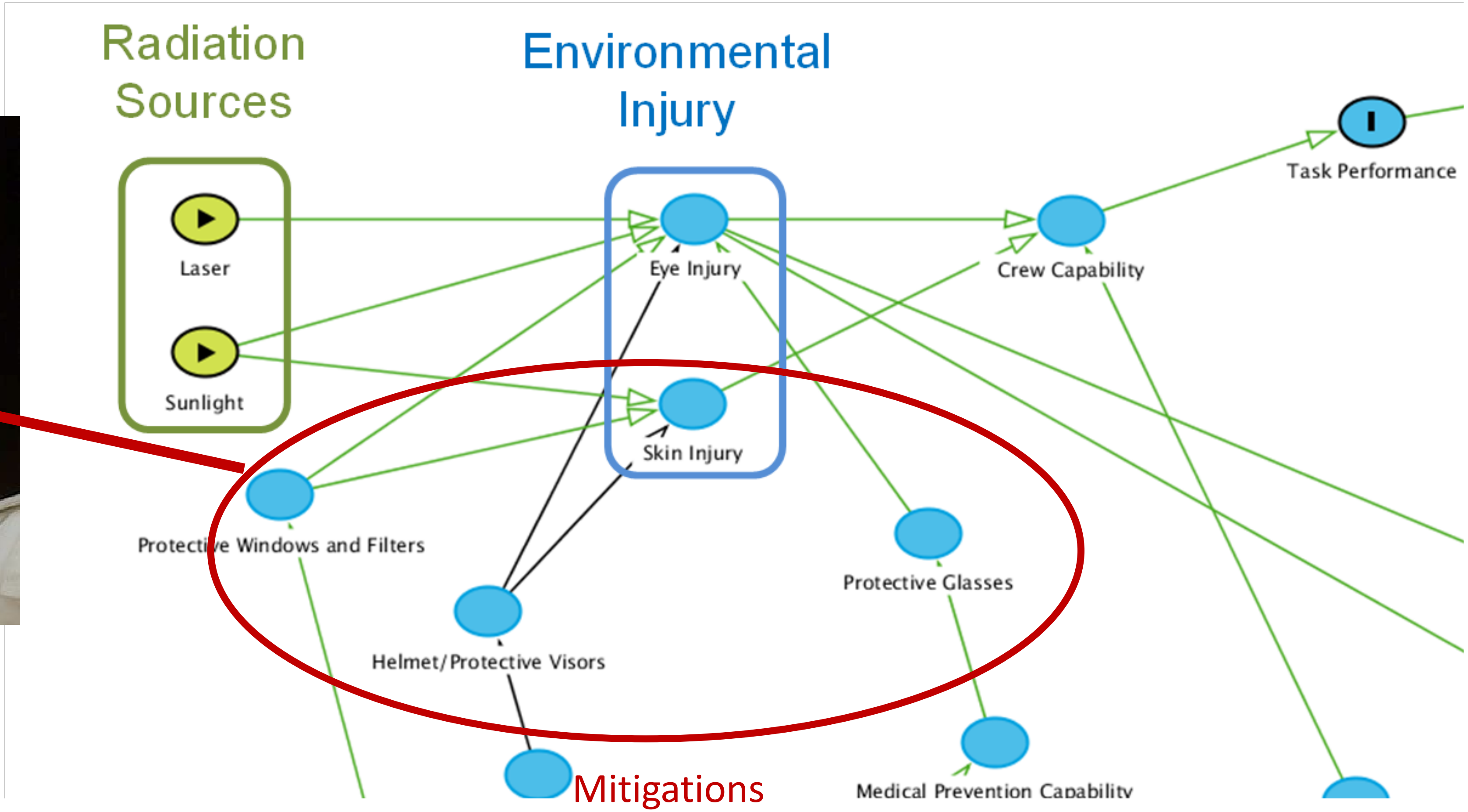


General network representation

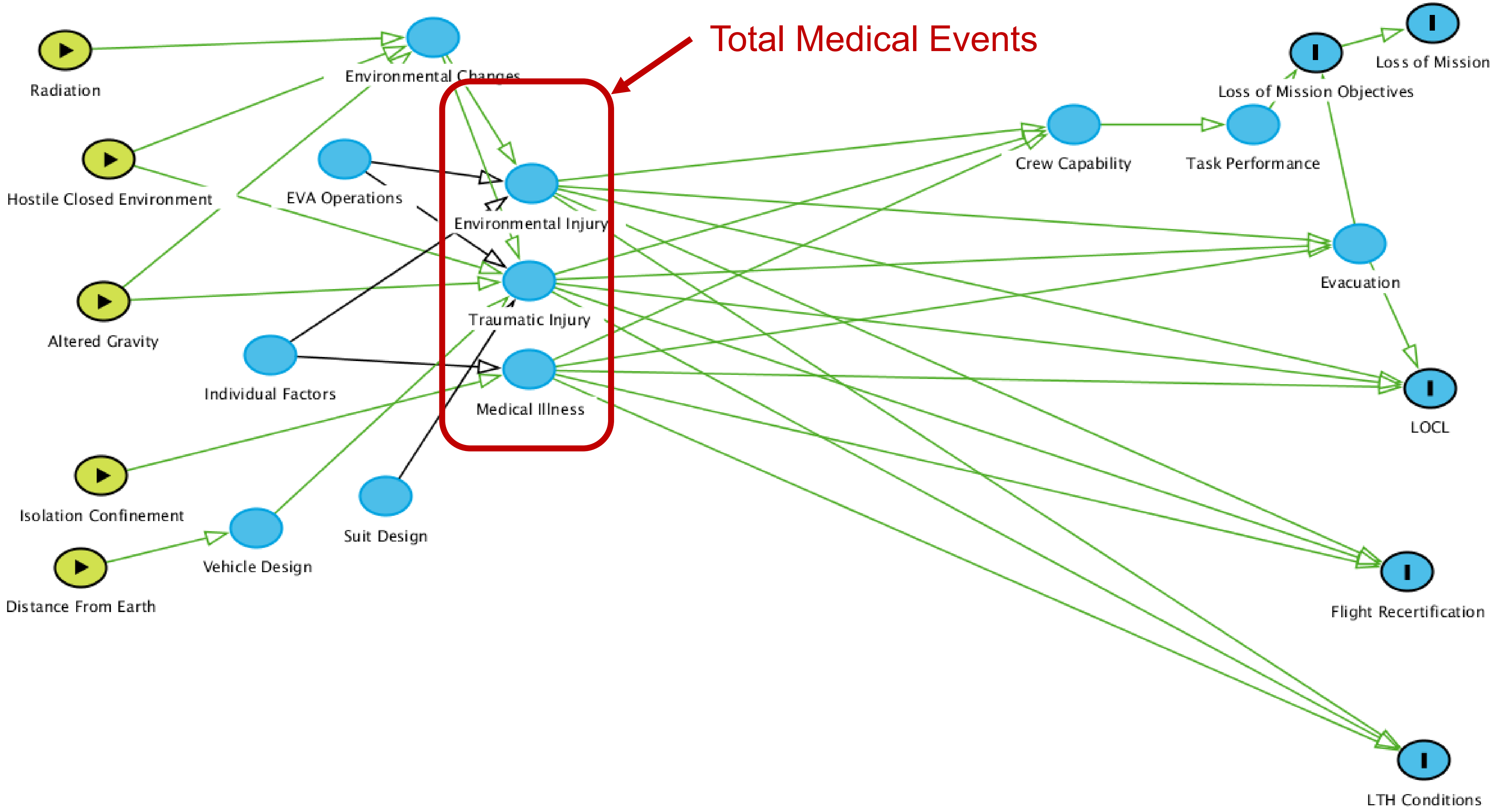
DAG

Risk of Non-ionizing Radiation Exposure

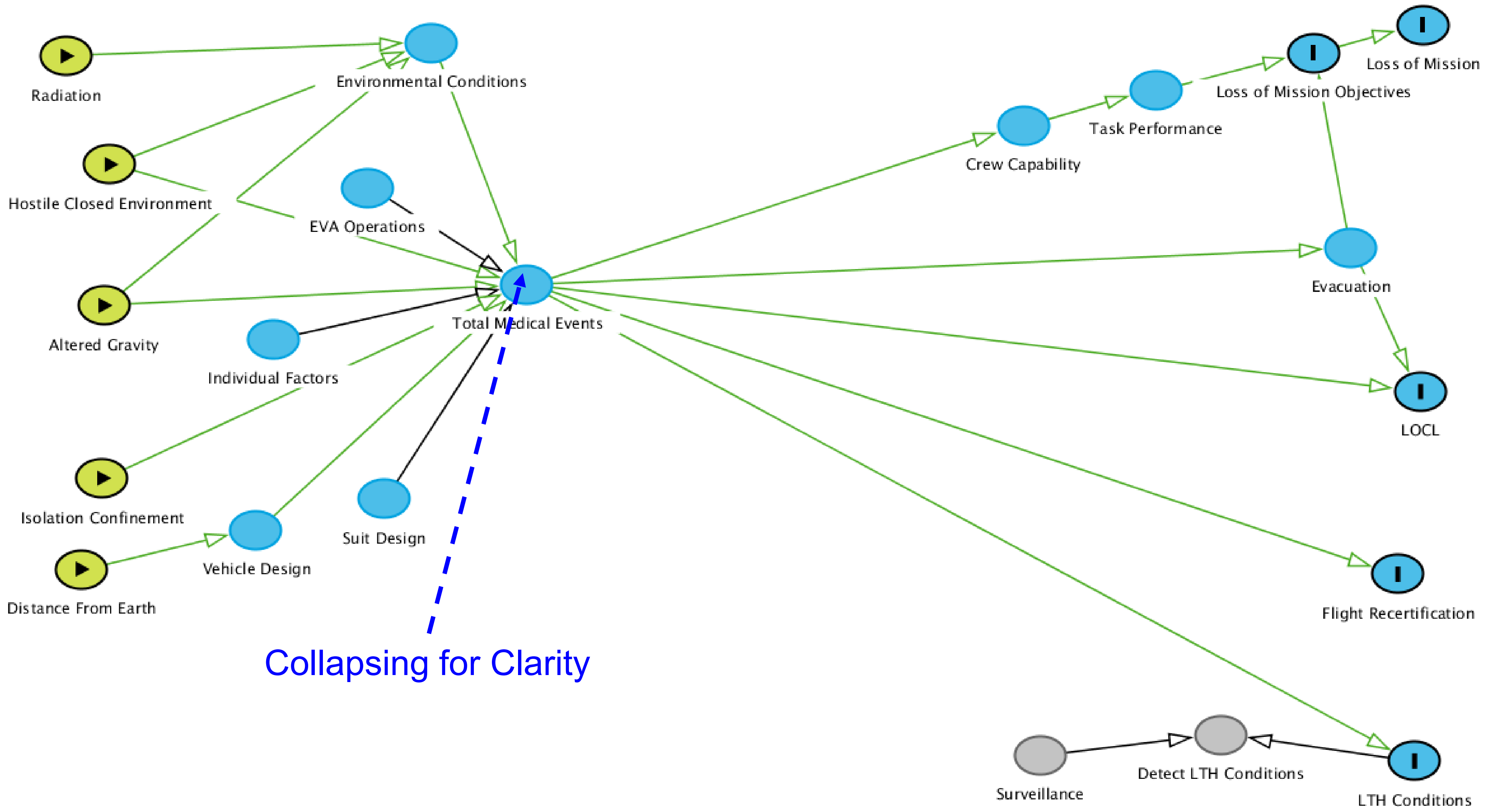




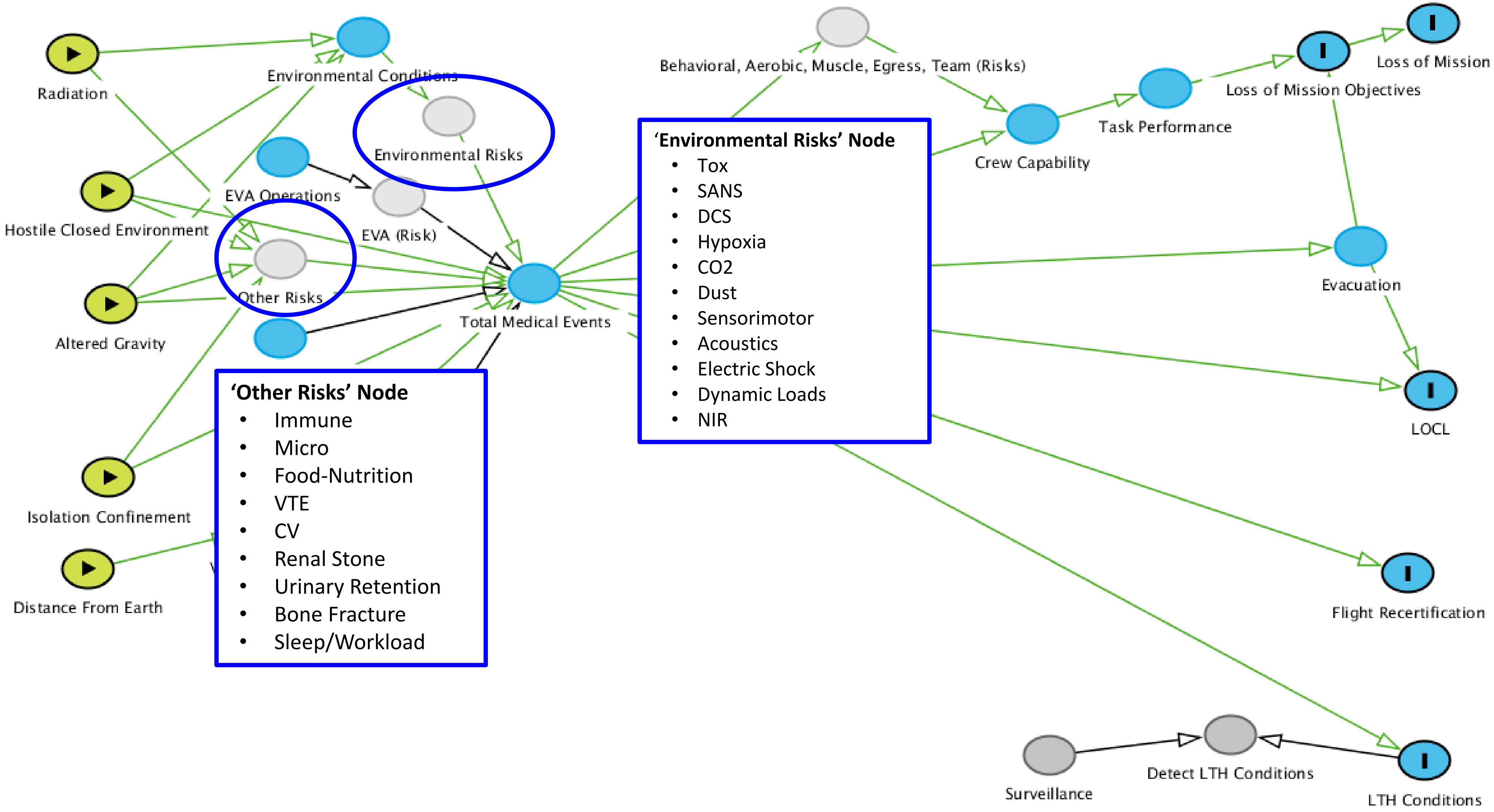
What about a more complicated Risk?



Medical Risk DAG – Easier to view



Medical Risk DAG - Other Risk Interactions



'Other Risks' Node
- Immune
- Micro
- Food-Nutrition
- VTE
- CV
- Renal Stone
- Urinary Retention
- Bone Fracture
- Sleep/Workload

'Environmental Risks' Node
- Tox
- SANS
- DCS
- Hypoxia
- CO2
- Dust
- Sensorimotor
- Acoustics
- Electric Shock
- Dynamic Loads
- NIR

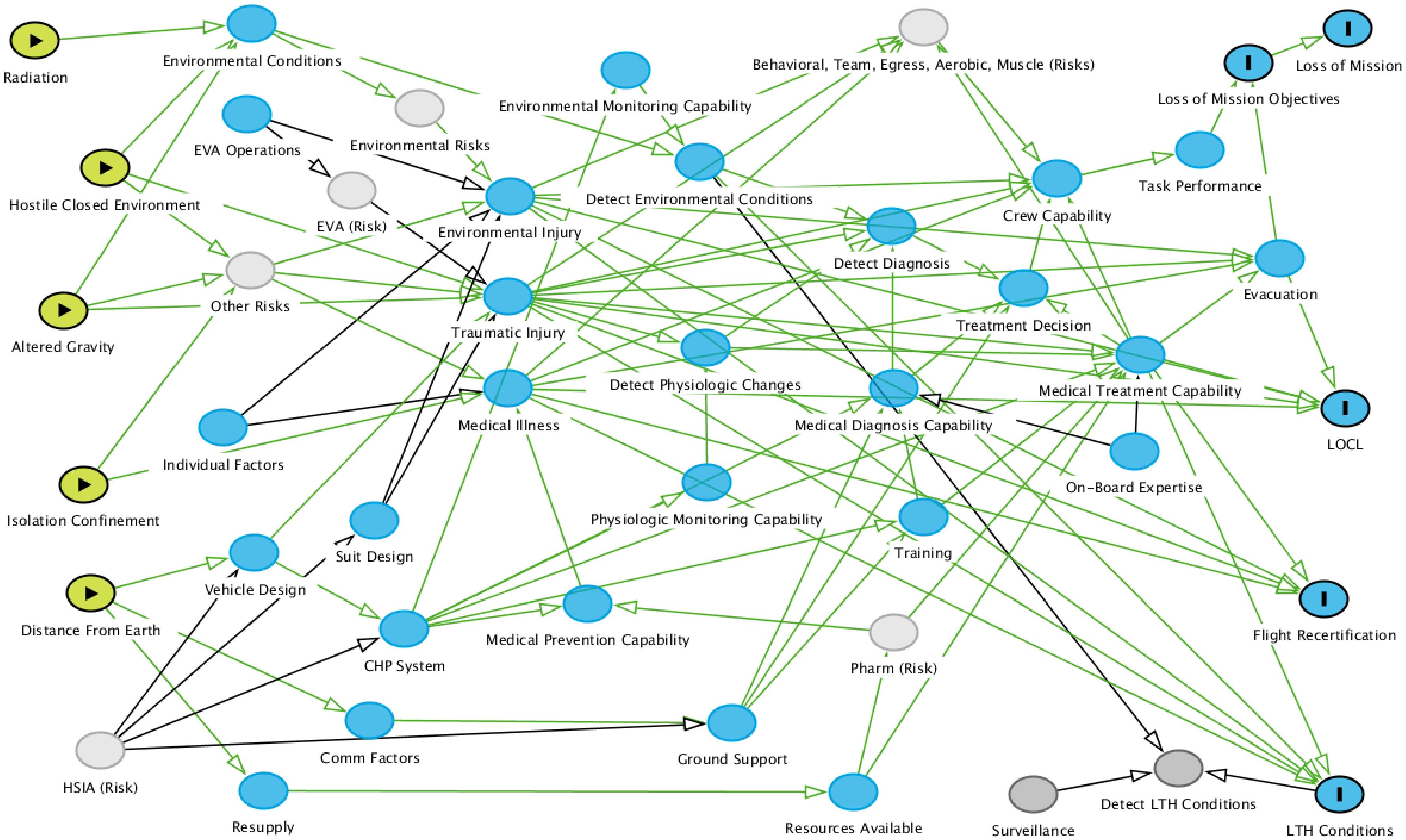
Risk Complexity

How do we identify where to most effectively mitigate all of this risk?

What happens when we integrate this risk with other risks?

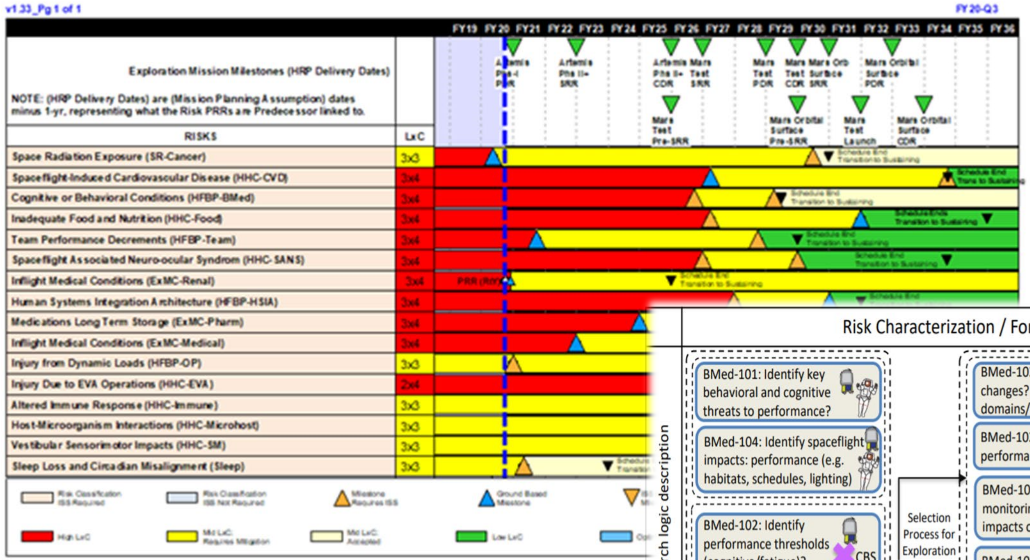
Advanced modelling techniques needed

Expanded evidence base

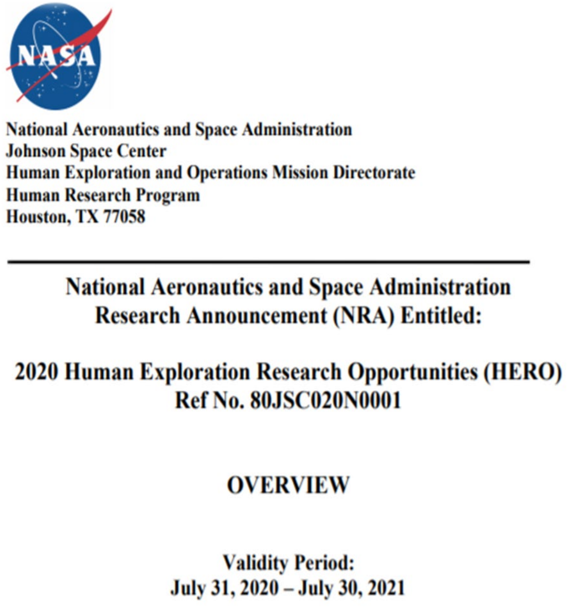


Human Research Program as a Risk Stakeholder

- **HRP relies on HSRB's risk posture and evidence assessment as inputs to inform its research planning and development of the following:**
  - Path to Risk Reduction



  - Solicitation topics



National Aeronautics and Space Administration
Johnson Space Center
Human Exploration and Operations Mission Directorate
Human Research Program
Houston, TX 77058

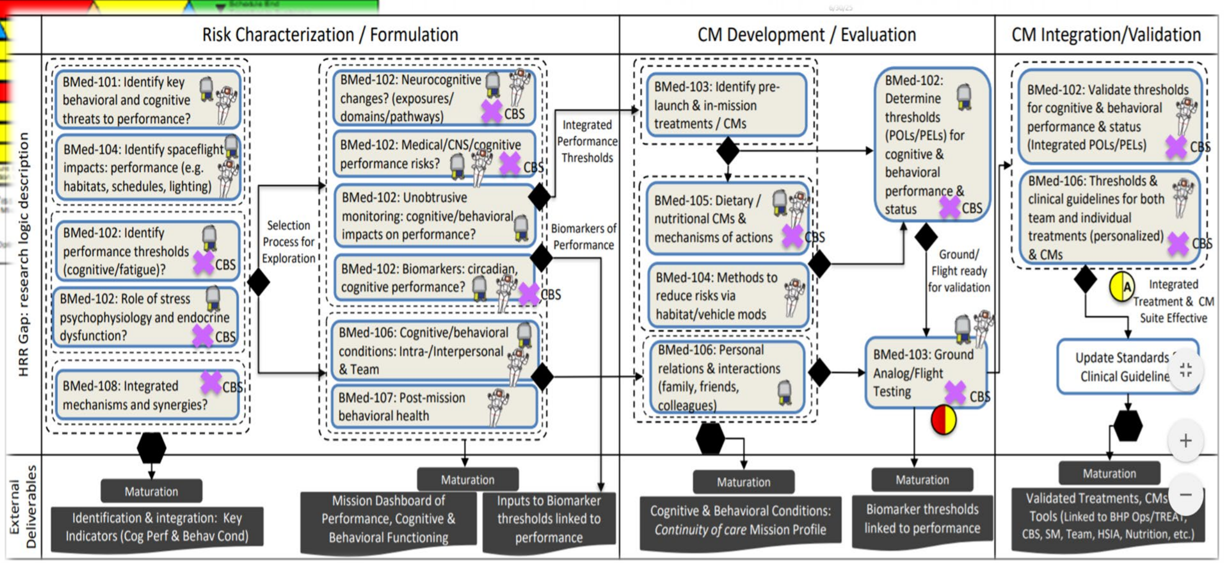
National Aeronautics and Space Administration
Research Announcement (NRA) Entitled:

2020 Human Exploration Research Opportunities (HERO)
Ref No. 80JSC020N0001

OVERVIEW

Validity Period:
July 31, 2020 – July 30, 2021

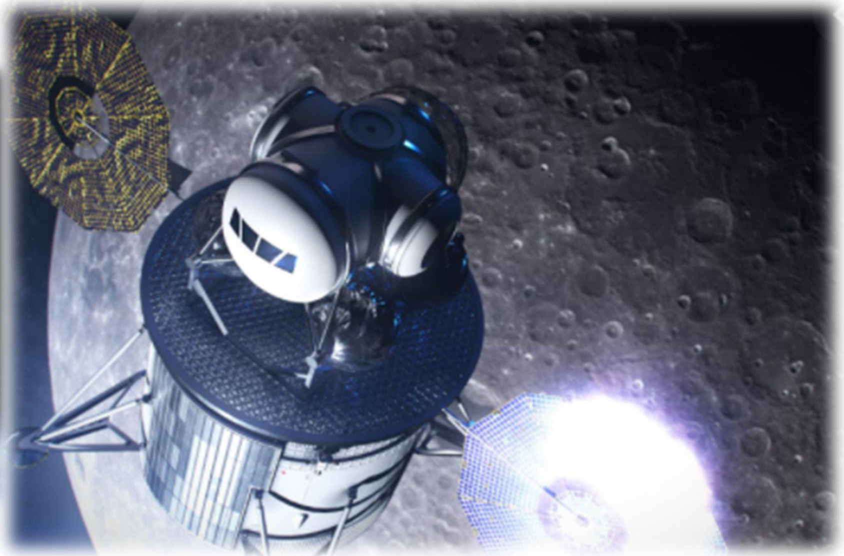
  - Deliverables

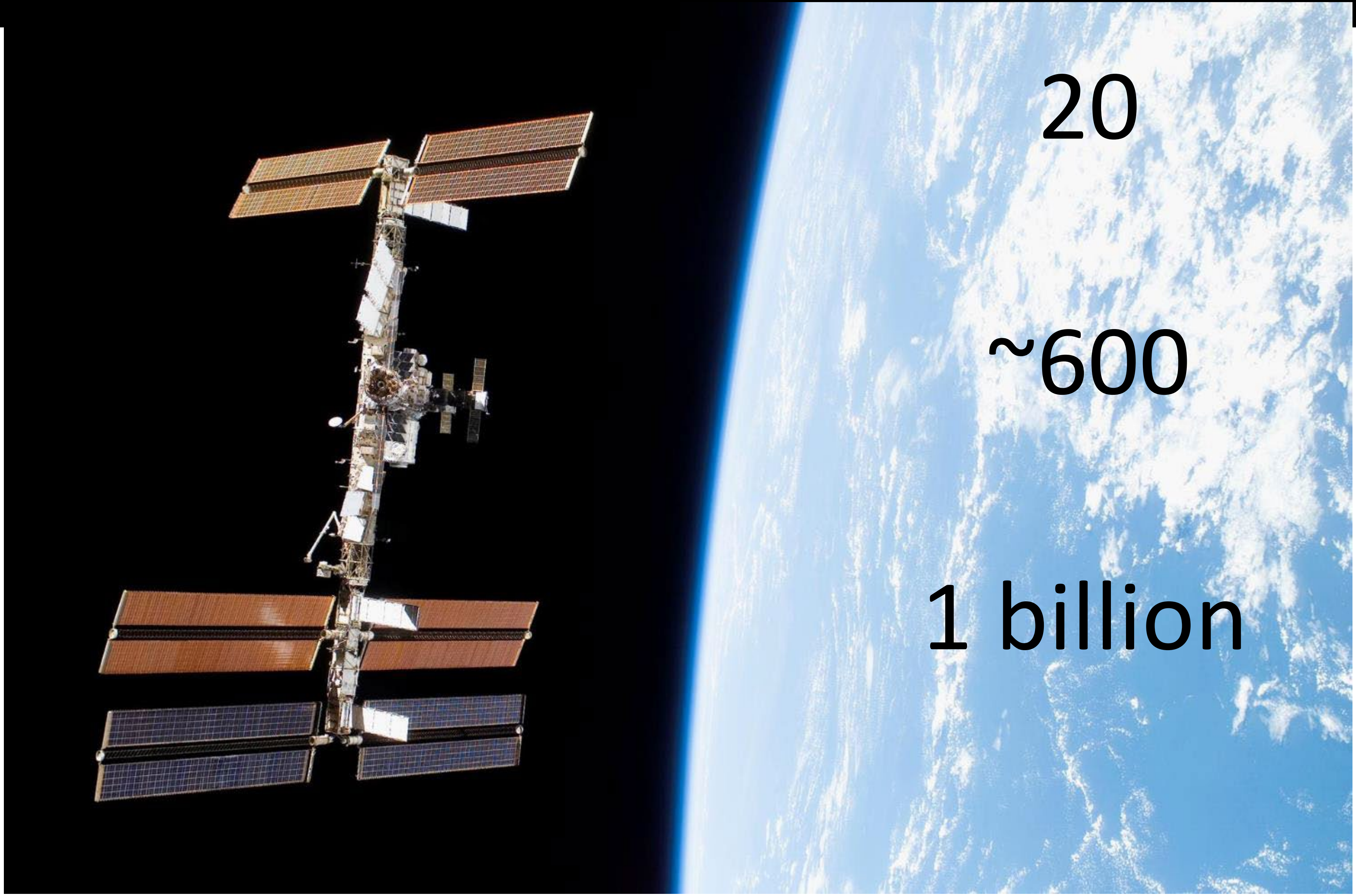


Other HSRB Risk Stakeholders

- **HSRB risk mitigation targets are used by other stakeholders in**
  - Informing Strategic Capability Leadership Team (SCLT) Roadmaps
  - Improving the elements of the astronaut occupational health program
  - Integrating with the Flight Operations Directorate and Safety and Mission Assurance Directorate for risk discussions with Programs and the Human Exploration and Operations Directorate

- **Human spaceflight programs consider HSRB risk posture recommendations in the development of their program requirements and design systems.**




20
~600
1 billion

Q&A?

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BACK UP

Differences between Human System and Artemis Risks

Human System Risks

- **Independent of specific spaceflight programs**
  - Focused around DRM categories, loosely defined by destination, operating environment, and expected duration
- **Risk contributors are hazards of the spaceflight environment**
  - How do the inherent challenges of spaceflight impact the human?
- **Often mitigated by refined characterization, countermeasure development, or updated standards**
  - Do we understand the problem?
  - Does an implementable solution exist?
- **The Human System Risk Board evaluates risks across the breadth of expected future human spaceflight programs [Mars = long pole]**

Artemis Risks

- **Tied to a specific Program or mission**
  - Focused on specific mission parameters, durations, vehicles, and vehicle systems available for a given mission
- **Risk contributors are the technical limitations of the hardware, vehicle, or operations.**
  - How are the mission parameters or vehicle design impacting the human?
- **Often mitigated technically, while balancing safety, schedule, cost, and vehicle performance**
  - Is the solution implemented?
- **The Human Health and Performance Control Board evaluates programmatic health and performance risks for established human spaceflight programs**

HSRB Risk Likelihood x Consequence Matrix

LIKELIHOOD RATING	In-Mission	Flight Recertification	Long Term Health
5 Very High	More likely to happen than not during the mission or probability (P) >10%	Very likely to happen. Controls are insufficient or P> 10%	Likelihood is very high OR >10% excess risk
4 High	Likelihood is during the mission or 1%<P≤10%	Likely to happen. Controls have significant limitations or uncertainties or 1%<P≤ 10%	Likelihood is high OR 6-10% excess risk
3 Moderate	May happen during the mission or 0.1%<P≤1%	Not likely to happen. Controls exist with some limitations or uncertainties or 0.1%<P≤1%	Likelihood is moderate OR 3-6% excess risk
2 Low	Unlikely to happen during the mission or .01%<P≤0.1%	Not expected to happen. Controls have minor limitations or uncertainties or 0.01%<P≤0.1%	Likelihood is low OR 1-3% excess risk
1 Very Low	Nearly certain to not occur in-mission or P≤0.01%	Extremely remote possibility that it will happen. Strong controls in place or P≤0.01%	Likelihood is very low OR < 1% excess risk

L x C Matrix

LIKELIHOOD					
5	10	16	20	23	25
4	7	13	18	22	24
3	4	9	15	19	21
2	2	6	11	14	17
1	1	3	5	8	12
	1	2	3	4	5

CONSEQUENCE

Time frame
Expected Need for Mitigation

Near	0 < 2 Years
Mid	2-7 Years
Far	> 7 Years

Risk Score Card values are constant across all risks and prioritize consequence over likelihood.

CONSEQUENCES		1	2	3	4	5
IN MISSION	Crew Health Impact	Temporary discomfort	Minor injury/illness that can be dealt with by crew without ground support, minor crew discomfort	Significant injury/illness or incapacitation that requires diagnosis and/or treatment support from ground, may affect personal safety	Critical injury/illness of one crew member requiring extended medical intervention and support, may result in temporary disability	Death or permanently disabling injury/illness affecting one or more crewmember (LOCL/LOC)
	OR					
	Mission Objectives Impact	Insignificant impact to crew performance and operations – no additional resources required	Minor impact to crew performance and operations – requires additional resources (time, consumables)	Significant reduction in crew performance, threatens loss of a mission objective	Severe reduction of crew performance that results in loss of multiple mission objectives	Loss of mission due to crew performance reductions or loss of crew
FLIGHT RECERT	Crew Flight Recertification Status	Immediate flight recertification status	Flight recertification status within 3 months with limited intervention	Flight recertification status within 1 year with nominal intervention or restricted flight status	Flight recertification status requires extended medical intervention and takes > 1 year	Unable to be Recertified for Flight Status, premature career end
LONG TERM HEALTH	Health Outcomes	Career related short term self-resolving medical conditions	Career related medical conditions manageable with outpatient medical treatments	Treatable career related medical condition that requires hospitalization for management	Chronic career related medical condition requiring intermittent hospitalization or nursing care	Career related premature death or permanent disability requiring institutionalization
	OR					
	Quality of Life	No impact on quality of life OR independence in activities of daily living	Minor, short-term impact on quality of life OR rare support required for activities of daily living	Moderate long-term impact on quality of life OR may require some time-limited support for activities of daily living	Major long-term impact on quality of life OR requires intermittent support for activities of daily living	Chronic debilitating impact on quality of life OR requires continuous support for activities of daily living

Assumptions for Long Term Health Risk Matrix:

•Long Term Health extends from the end of the post mission time period and covers an astronaut's lifetime.
•Conditions considered within the LTH Risk Matrix are those that 1) are related to the astronaut career, 2) are beyond those expected as part of natural aging, and 3) include acute, chronic and latent conditions.
•Quality of Life is defined as impact on day-to-day physical and mental functional capability and/or lifetime loss of years

Design Reference Missions

DRM Categories	Mission Type and Duration	Gravity Environment	Radiation Environment	Vehicle/Habitat Design	Distance from Earth		EVA
					Evacuation	Communication	Frequency
Low Earth Orbit	Short (<30 days)	Microgravity	LEO-Van Allen (<5-15 mGy)	Mid-sized volume, resupply	1 day or less	Real time	1-4 EVAs
	Long (30 days-1 year)	Microgravity	LEO-Van Allen (5-150 mGy)	Mid-large optimized volume, resupply	1 day or less	Real time	1-10 EVAs
Lunar Orbital	Short (<30 days)	Microgravity	Deep Space-Van Allen (15-20 mGy)	Small volume, self contained, resupply	3 – 11 days	Real time	Contingency EVA only or very few EVA
	Long (30 days-1 year)	Microgravity	Deep Space (175-220 mGy)	Mid-sized volume, self contained, limited resupply	3 – 11 days	Real time	Contingency EVA only or very few EVA
Lunar Orbital + Surface	Short (<30 days)	Microgravity & 1/6g	Deep Space-Van Allen (15-20 mGy)	Small volume, resupply	3 – 11 days	Real time	5 EVAs, some back to back
	Long (30 days-1 year)	Microgravity & 1/6g	Deep Space (100-120 mGy)	Mid-large sized optimized volume, limited resupply	3 – 11 days	Real time	3-4 EVA per week, 20-24 EVA hrs. per week
Mars	Preparatory (<1year)	Microgravity	Deep Space (175-220 mGy)	Midsized optimal volume, limited resupply, closed loop environment	Days – weeks	Controlled - Delayed	Contingency EVA only or very few EVA
	Mars Planetary* (730-1224 days)	Microgravity & 3/8g	Deep Space – Planetary (300-450 mGy)	Midsized optimal volume, no resupply, closed loop environment	Mission duration	No real time	2 crew x 8-hour EVA x 20 EVA days

*Based on memo - HEO-DM-1002 HEO Systems Engineering and Integration (SE&I) Decision Memo on Mars Mission Duration Guidance for Human Risk Assessment and Research Planning Purposes