

The background of the slide is a composite image of space. At the bottom, there is a view of Earth from space, showing blue oceans and white clouds. Above the Earth, the dark surface of the Moon is visible, showing its craters and maria. The upper portion of the image is filled with a field of stars, some of which are bright and have a starburst effect. The overall color palette is dark, with blues, greys, and whites from the celestial bodies, and various colors from the stars.

NASA's Human System Risk Management

Needs Based Implementation of Space Health Innovation

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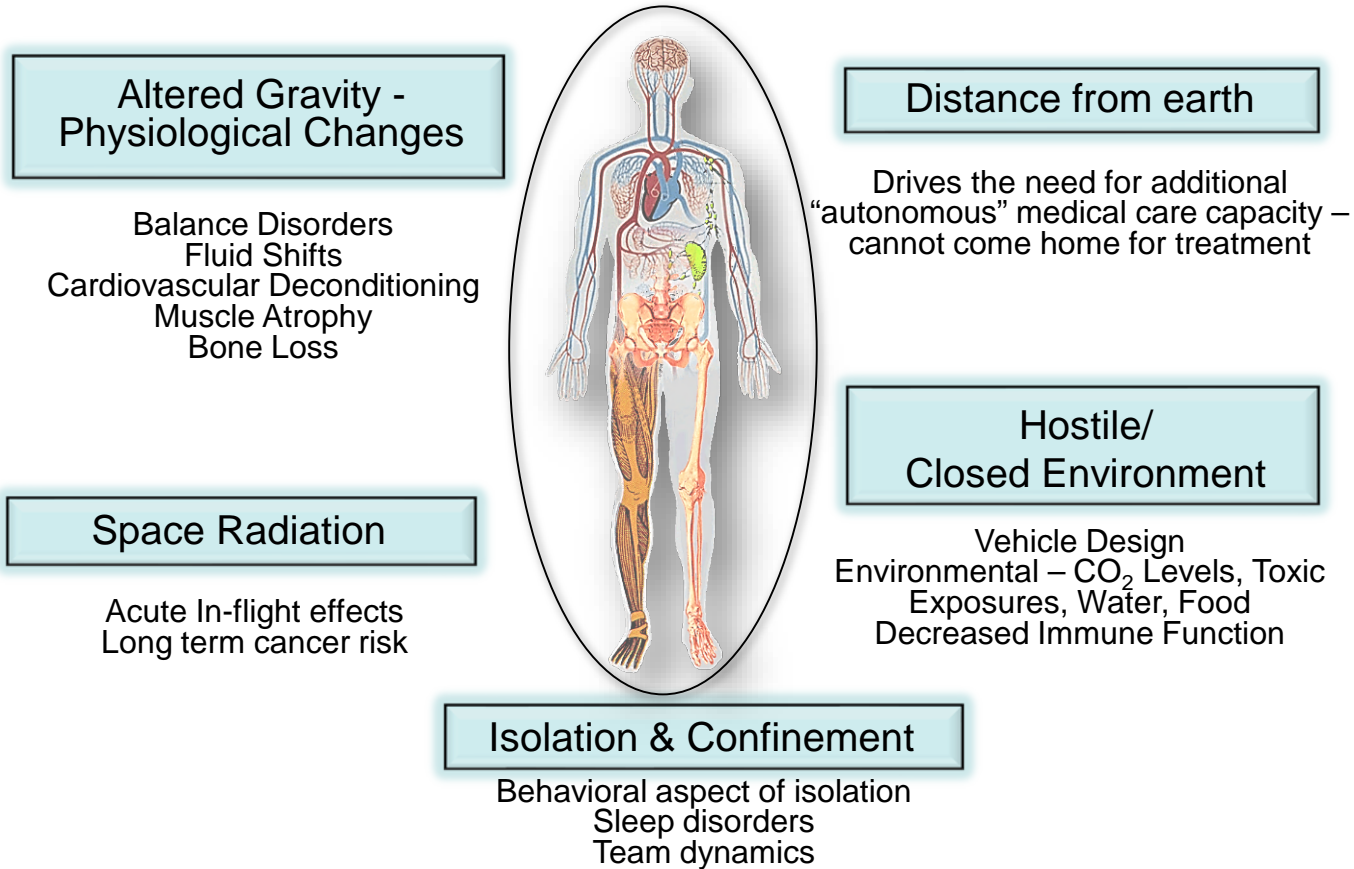
Human Systems Risk Management

NASA Johnson Space Center

- 
- ***Understand NASA's strategies for optimizing Astronaut health.***
 - ***Learn how NASA establishes Risk and Countermeasure priorities.***
 - ***Hear how promising technologies "Transition to Ops".***

The goal of this talk is to give an overview of how NASA approaches Human System Risks and how that can help inform your work as Innovators

Human System Hazards – where Risks come from



Summary of Human Risks of Spaceflight

Grouped by Hazards – 30 Human Risks

Altered Gravity Field

1. Spaceflight-Induced Intracranial Hypertension/Vision Alterations
2. Renal Stone Formation
3. Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Space Flight
4. Bone Fracture due to spaceflight Induced changes to bone
5. Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance
6. Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
7. Adverse Health Effects Due to Host-Microorganism Interactions
8. Urinary Retention
9. Orthostatic Intolerance During Re-Exposure to Gravity
10. Cardiac Rhythm Problems
11. Space Adaptation Back Pain

Concerns

1. Venous Thromboembolism

Radiation

1. Adverse Health Outcomes and Performance Decrements resulting from Space Radiation Exposure (cancer, cardio & CNS)
2. Injury from Sunlight Exposure

Distance from Earth

1. Adverse Health Outcomes & Decrements in Performance due to inflight Medical Conditions
2. Ineffective or Toxic Medications due to Long Term Storage

Isolation

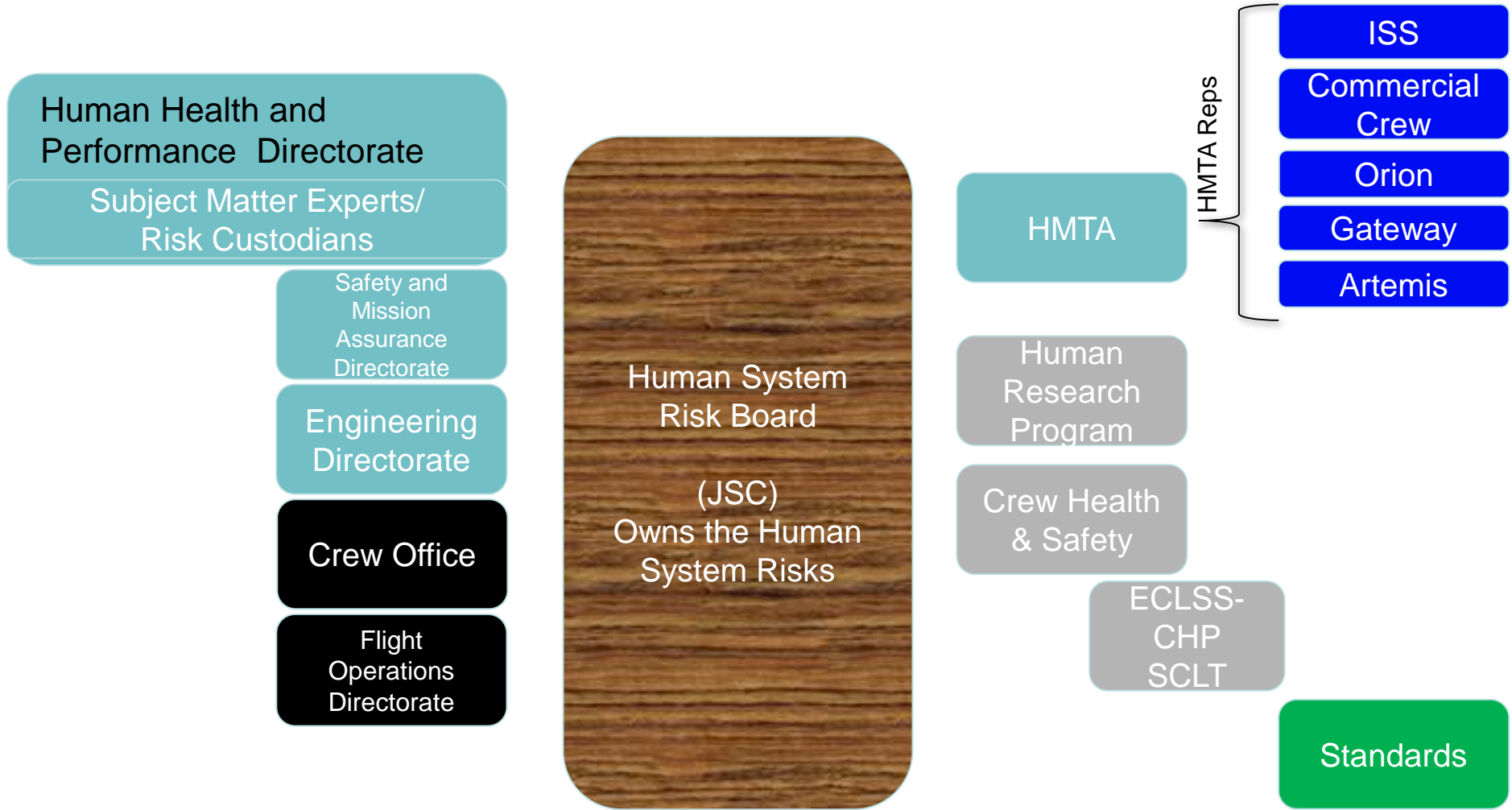
1. Adverse Cognitive or Behavioral Conditions & Psychiatric Disorders
2. Performance & Behavioral health Decrements Due to Inadequate Cooperation, Coordination, Communication, & Psychosocial Adaptation within a Team

Hostile/Closed Environment-Spacecraft Design

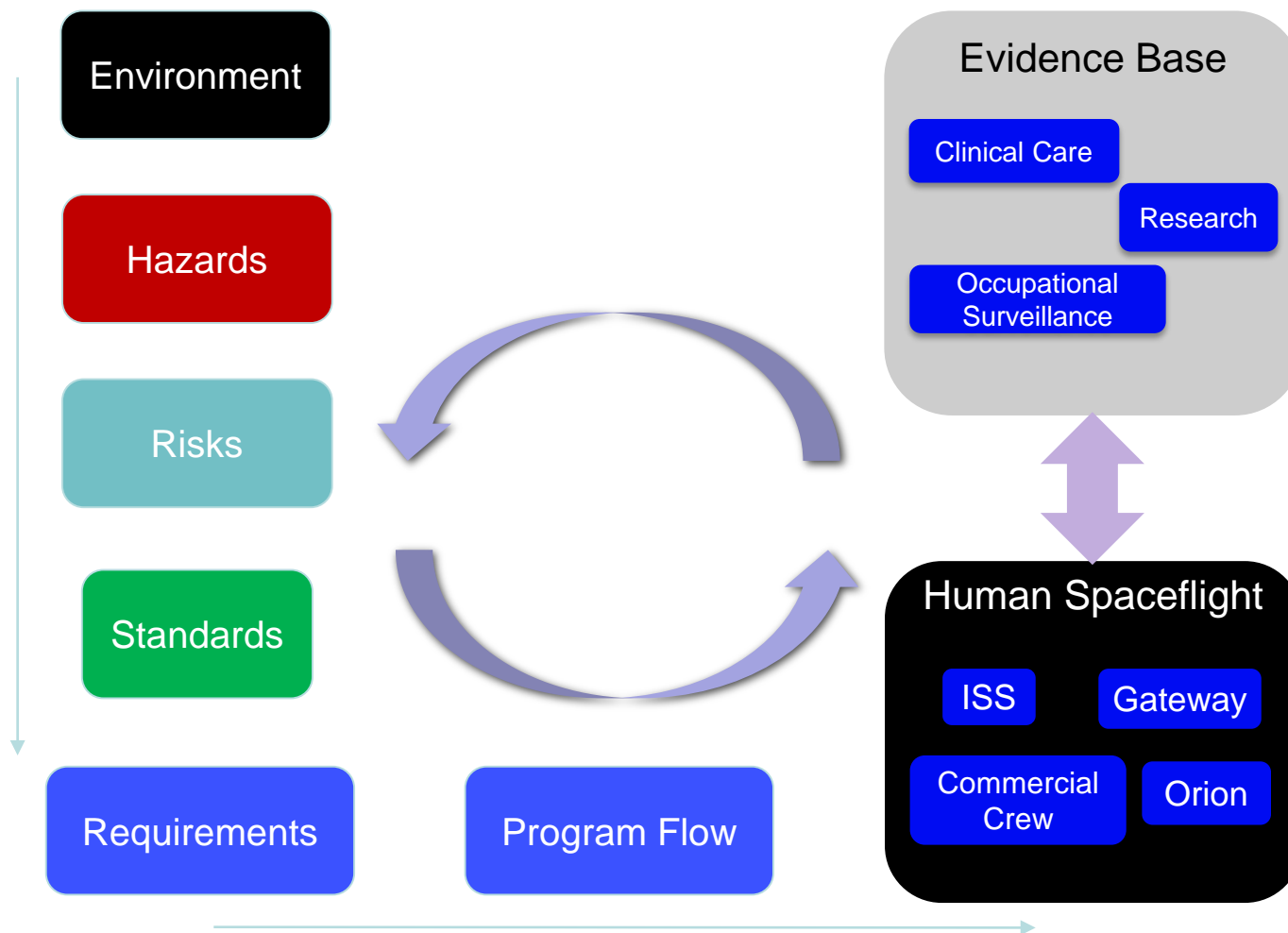
1. Acute and Chronic Carbon Dioxide Exposure
2. Performance decrement and crew illness due to inadequate food and nutrition
3. Reduced Crew Performance and of Injury Due to Inadequate Human-System Interaction Architecture (HSIA)
4. Injury from Dynamic Loads
5. Injury and Compromised Performance due to EVA Operations
6. Adverse Health & Performance Effects of Celestial Dust Exposure
7. Adverse Health Event Due to Altered Immune Response
8. Reduced Crew Health and Performance Due to Hypobaric Hypoxia
9. Performance Decrements & Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, & Work Overload
10. Decompression Sickness
11. Toxic Exposure
12. Hearing Loss Related to Spaceflight
13. Crew Health Due to Electrical Shock

Who Cares about Risk?

- Stakeholders sit at the Human System Risk Board (HSRB)
- Human System Risks are owned by Health and Medical TA



The Big Big Picture

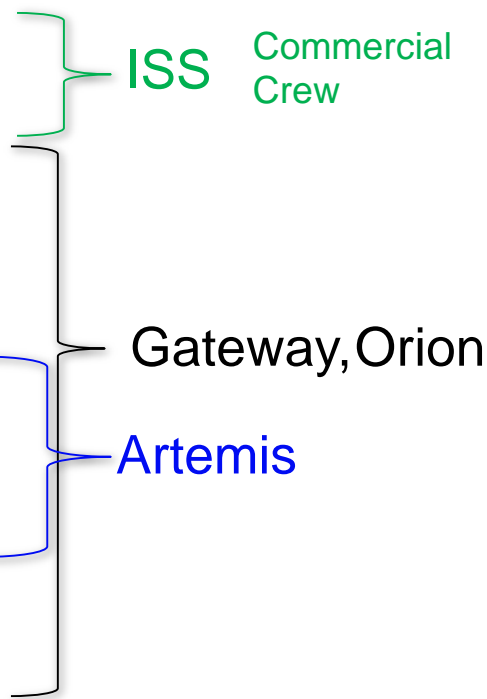


What Drives Risk in Missions?

- **Time (mission duration) and environmental exposures**
 - *Gravity Environment*
 - *Radiation Environment*
 - *Medical Conditions*
- **Distance from earth**
 - *Real-time Communications vs. store and forward communications*
 - *Time to definitive care (evacuation)*
 - *Consumables Resupply*
- **Vehicle resource constraints (mass, power, volume, data)**
- **Vehicle Habitable Volume and Capability**
- **Crew selection and assignment**
- **High Risk Activities**
- **Agency or Company Risk Tolerance**

Design Reference Missions

DRM Categories	Mission Type and Duration	Gravity Environment	Radiation Environment	Vehicle/Habitat Design	Earth Return
Low Earth Orbit	Short (<30 days)	Microgravity	LEO-Van Allen	Mid-sized volume, resupply	1 day or less
	Long (30 days to 1 year)	Microgravity	LEO-Van Allen	Mid-large optimized volume, resupply	1 day or less
Lunar Orbital	Short (<30 days)	Microgravity	Deep Space-Van Allen	Small volume, self contained, limited resupply	3-11 days
	Long (30 days to 1 year)	Microgravity	Deep space	Mid-sized, self contained, limited resupply	3-11 days
Lunar Orbital + Surface	Short (<30 days)	Microgravity & 1/6 g	Deep Space-Van Allen	Small volume, resupply	3-11 days
	Long (30 days to 1 year)	Microgravity & 1/6 g	Deep space	Mid-large optimized volume, limited resupply	3- 11 days
Mars	Preparatory (<365 days)	Microgravity	Deep Space	Midsized optimal volume, limited resupply, closed loop environment	Days-Weeks
	Planetary (365 days to 3 years)	Microgravity & 3/8 g	Deep Space-Planetary	Midsized optimal volume, no resupply, closed loop environment	Mission duration

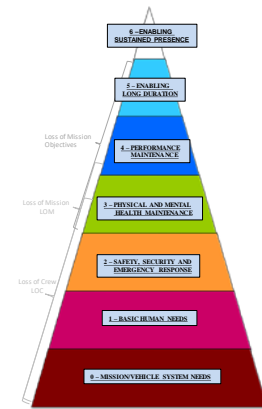


Prioritizing Risk

- Risk Color

HMTA Integrated Human System Risk Summary

- Risk Dependency and Interdependency



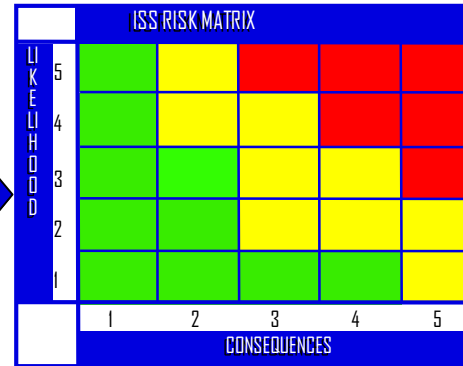
- Risk Need Date

NASA Life-Cycle Phases	Approval for Formulation			Approval for Implementation			
Project	Pre-Phase A	Phase A:	Phase B:	Phase C:	Phase D:	Phase E:	Phase F:
Life-Cycle Phases	Concept Studies	Concept & Technology Development	Preliminary Design & Technology	Final Design & Fabrication	System Assembly, Integration & Test, Launch & Checkout	Operations & Sustainment	Closeout
Project Life-Cycle Gates & Reviews	KDP A Δ MCR	LKDP B ▲ SR/DR	Comp KDP C ▲ PDR	KDP D ▲ CDR	KDP E ▲ SIR	KDP F ▲ ORR	FRR

What are the top risks?
It depends on all these factors as well as the mission you are concerned with.

Communicating with Spaceflight Programs

Likelihood Rating		
5	Very Likely	Expected to happen in the life of the program Controls are missing or insufficient
4	Likely	Likely to happen in the life of the program Controls have significant limitations or uncertainty
3	Possible	Could happen in the life of the program Controls exist, with some limitations or uncertainty
2	Unlikely	Unlikely to happen in the life of the program Controls have minor limitations or uncertainty
1	Highly Unlikely	Extremely remote possibility that it will happen in the life of the program Strong controls in place



Mitigation	
Red	High - Implement new process(es) or change baseline plan(s)
Yellow	Medium - Aggressively manage; consider alternative process
Green	Low - Manage within normal processes; monitor

Consequence Rating	1	2	3	4	5
Mission Success / Operational Performance (Technical)	Minor impact to mission objectives Nominal Execution of Mission Minor reduction in performance Minor impact to design or operating margins	Failure to meet any single mission objective Operating in a degraded state Moderate reduction in performance Can handle within design or operating margins Damage to non-critical system, element, ground facility, function, or emergency system	Significant impact to mission objectives Operational Workarounds available Significant reduction in performance Significant loss of design or operating margin Loss of any non-critical system, element, ground facility, or function Loss of emergency system	Loss of multiple mission objectives Major increase in flight operations timelines or complexity Major degradation in performance Loss of all design or operating margin Damage to critical system, element, ground facility, or function Planned De-Crewing	Loss of entire mission No alternatives exist Loss of ISS or any critical system, element, major ground facility or function ISS in a condition which prevents rendezvous/docking operations Emergency Evacuation
Safety	Minor injury or illness with no medical attention required	Injury or illness with medical attention required	Significant or long-term injury, illness, incapacitation or impairment Non-disabling injury	Permanent injury, impairment or incapacitation	Loss of Life Disabling injury
Cost - Score by cost of mitigating risk	Minimal impact (<\$100K) or 0 < cost impact ≤ 2.5% increase	Moderate impact (\$100K up to \$1M) or 2.5% < cost impact ≤ 5% increase	Significant impact (\$1M up to \$10M) or 5% < cost impact ≤ 7.5% increase	Major impact (\$10M up to \$50M) Or 7.5% < cost impact ≤ 10% increase	Major impact (> \$50M) Or Cost impact > 10% increase
Schedule	Minor impact to project schedule	Can handle with schedule reserve, no impact to key project milestone or critical path	Project milestone slip No impact to Program critical path	Impact to Program milestone and/or Program critical path	Cannot meet program critical path milestone(s)

Note: Risk management is a communication system where a *qualitative* score can help in understanding a risk. This score is a *qualitative* guide for determining a likelihood and consequence for a risk. Significant resources should not be spent scoring a risk. Score is relative to the risk's highest consequence and likelihood.

Defining Human System Risks

Consequence

Mission Health and Performance (OPS)

Death or permanently disabling injury to one or more crew (LOC)
OR
Severe reduction of performance that results in loss of most mission objectives (LOM)

Significant injury, illness, or incapacitation – may affect personal safety
OR
Significant reduction in performance results in the loss of some mission objectives

Minor injury/illness that is self-limiting
OR
Minor impact to performance and operations- requires additional resources (time, consumables)

Temporary discomfort
OR
Insignificant impact to performance and operations - no additional resources required

Consequence

Long Term Health (post mission) (LTH)

Unknown and improbable return to baseline (requires drastic intervention surgery & therapy)
OR
Major impact on quality of life (permanent reduced function, premature death)

Return to near baseline requires extended medical intervention w/ known clinical methods/technologies (pharmaceuticals, etc.)
OR
Moderate impact on quality of life

Return to baseline values within 1 year with nominal intervention (time, exercise, nutrition, lenses)
OR
Negligible effect on quality of life

Return to baseline values within 3 months with limited intervention
OR
No effect on the quality of life

High	1 x 4	2 x 4	3 x 4
	1 x 3	2 x 3	3 x 3
	1 x 2	2 x 2	3 x 2
	1 x 1	2 x 1	3 x 1
Medium	1 x 3	2 x 3	3 x 3
	1 x 2	2 x 2	3 x 2
	1 x 1	2 x 1	3 x 1
	1 x 1	2 x 1	3 x 1
Low	1 x 2	2 x 2	3 x 2
	1 x 1	2 x 1	3 x 1
	1 x 1	2 x 1	3 x 1
	1 x 1	2 x 1	3 x 1
Very Low	1 x 1	2 x 1	3 x 1
	1 x 1	2 x 1	3 x 1
	1 x 1	2 x 1	3 x 1
	1 x 1	2 x 1	3 x 1

Low Medium High
≤0.1% <1% ≥1.0%

Likelihood

CM = Countermeasure
LOC = Loss of Crew
LOM = Loss of Mission

Quality of Life is defined as impact on day to day physical and mental functional capability and/or lifetime loss of years

Big Picture of Risks?

HMTA Integrated Human System Risk Summary

Human Spaceflight Risk	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Vult/Habitation	Deep Space Journey/Habitation	Planetary Vult/Habitation	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Vult/Habitation	Deep Space Journey/Habitation	Planetary Vult/Habitation
	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years
Small Spacecraft	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inflight Medical Conditions	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation
Vision Alterations	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inadequate Human System Architecture	Accepted with Monitoring	Accepted with Monitoring	+ Standard Refinement, May Require Mitigation	Requires Mitigation	Standard Refinement, May Require Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Cardiac Rhythm Problems	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
Cognitive or Behavioral Conditions	Accepted with Monitoring	Requires Mitigation	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation
Space Radiation Exposure	Accepted	Accepted	Accepted	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with PEs	Accepted with PEs	Accepted with PEs	Requires Mitigation	Requires Mitigation	Requires Mitigation
Carbon Dioxide Exposure	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Inadequate Food and Nutrition	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Requires Mitigation
Ineffective or Toxic Medications	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
SVA Operations	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation
Psychosocial Adaptation within a Team	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring
Bone Fracture	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Optimize
Injury from Dynamic Loads	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Requires Mitigation
Hypobaric Hypoxia	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with Monitoring	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data
Sleep Loss	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Toxic Exposure	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring	Accepted with Monitoring
Altered Immune Response	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Host-Microorganism Interactions	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Sensorimotor Alterations	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Standard Refinement	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Reduced Muscle Mass/Strength	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Reduced Aerobic Capacity	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation

HMTA Integrated Human System Risk Summary

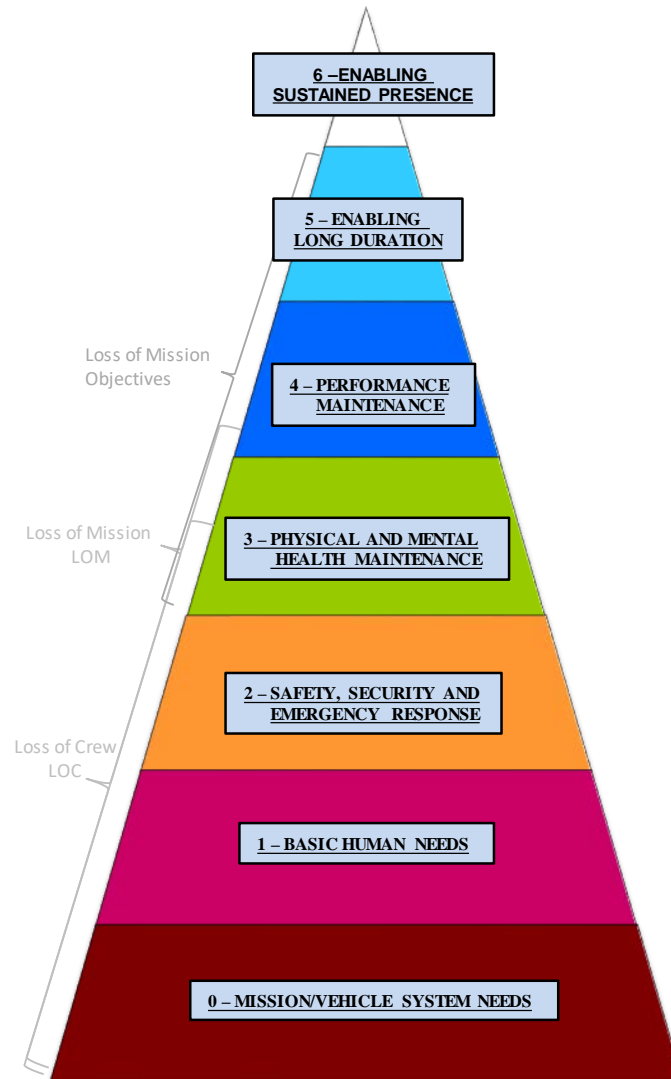
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	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years
Maximal Load Related to Spaceflight	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
Injury from Sudden Exposure	Accepted / Low Probability	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Electrical Shock	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Urinary Retention	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Pericardial Effusion	Accepted	Accepted	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Orthostatic Intolerance	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Back Pain	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	N/A	N/A	N/A	N/A	N/A	N/A
Cerebral Duct Exposure	N/A	N/A	TBD	Accepted	TBD	TBD	N/A	N/A	TBD	Accepted	TBD	TBD
CLOSED - Intervertebral Disc Damage	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Big Picture of Risks?

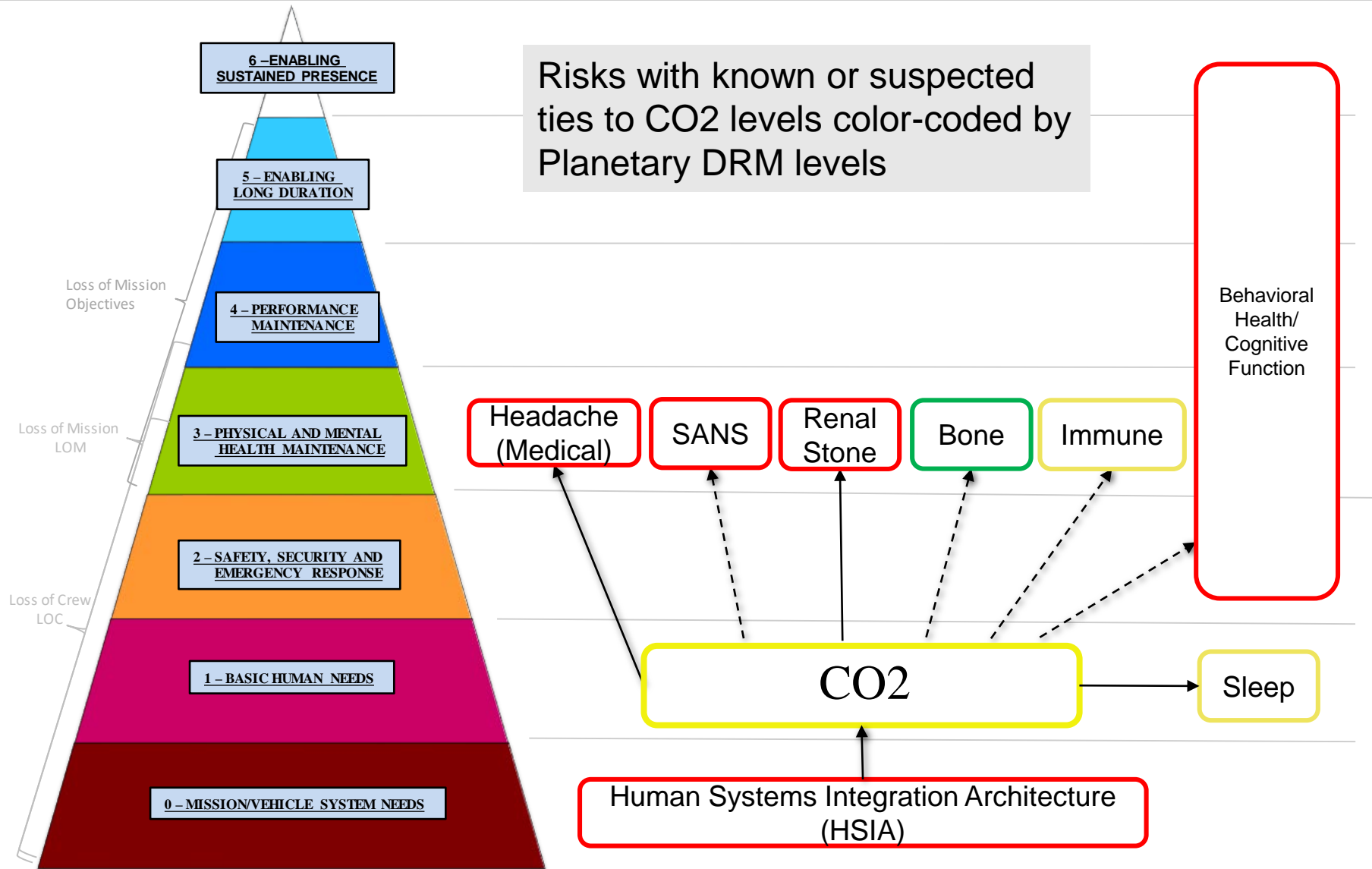
DRM Categories Details	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
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Inflight Medical Conditions	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation
Vision Alterations	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inadequate Human Systems Integration Architecture	Accepted with Monitoring	Accepted with Monitoring	+Standard Refinement; May Require Mitigation	Requires Mitigation	Standard Refinement; May Require Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Cardiac Rhythm Problems	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
Cognitive or Behavioral Conditions	Accepted with Monitoring	Requires Mitigation	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation
Space Radiation Exposure	Accepted	Accepted	Accepted	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with PELs	Accepted with PELs	Accepted with PELs	Requires Mitigation	Requires Mitigation	Requires Mitigation
Carbon Dioxide Exposure	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Inadequate Food and Nutrition	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Requires Mitigation
Ineffective or Toxic Medications	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
EVA Operations	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation
Psychosocial Adaptation within a Team	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring

Objectives Hierarchy

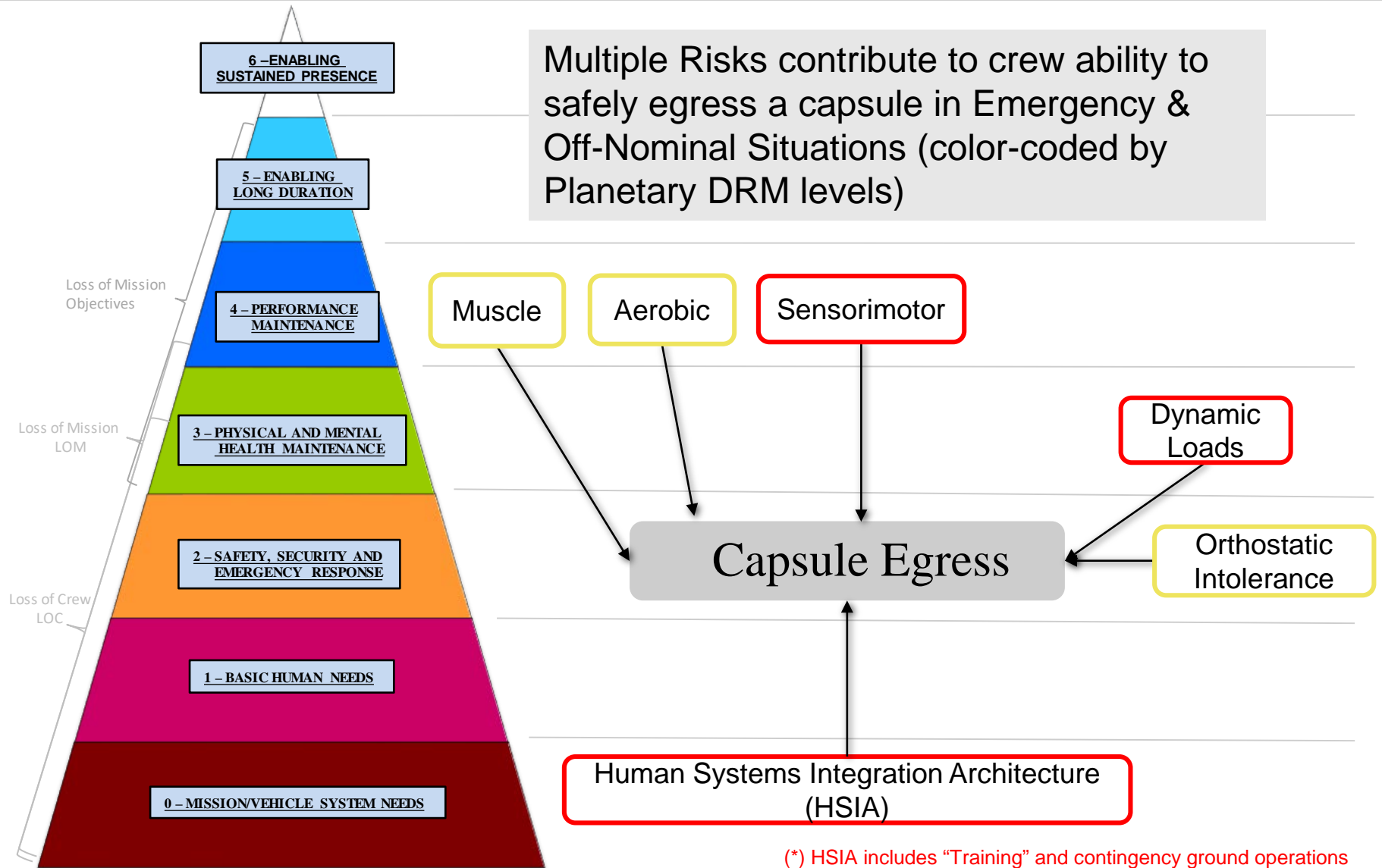
Risks in fundamental categories should be prioritized higher than those in dependent categories



Risk Dependency



Risk Interdependency – Operational Endpoints



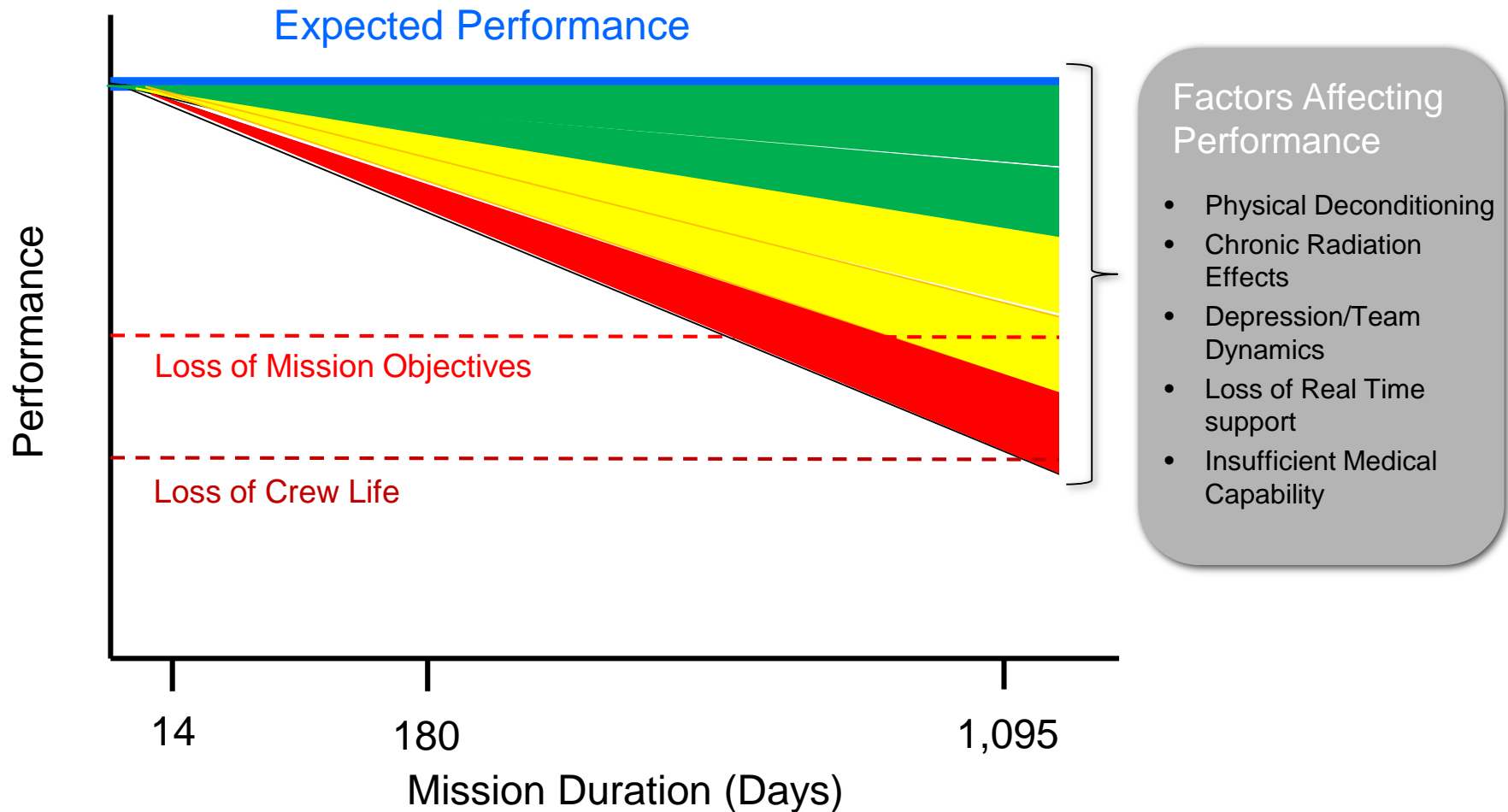
Capsule Egress



Capsule Egress

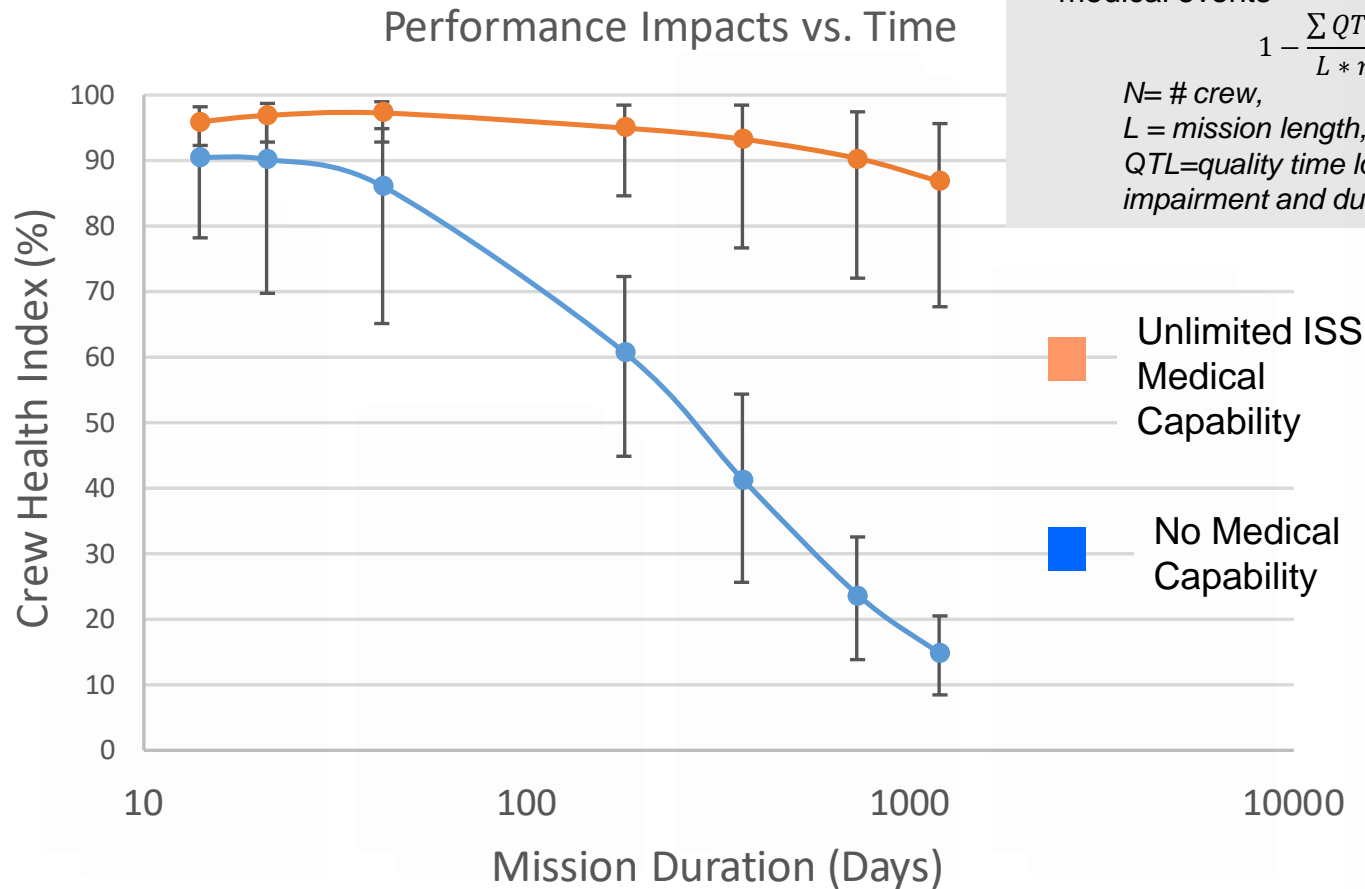


Risks to Health & Human Performance won't occur in isolation



Where are the red lines and when will we hit them?

Expected Performance Impacts



CHI Definition: Proportion of mission time *not* lost to medical events

$$1 - \frac{\sum QTL}{L * n} = CHI$$

$N = \#$ crew,

$L =$ mission length,

$QTL =$ quality time lost; is a function of functional impairment and duration

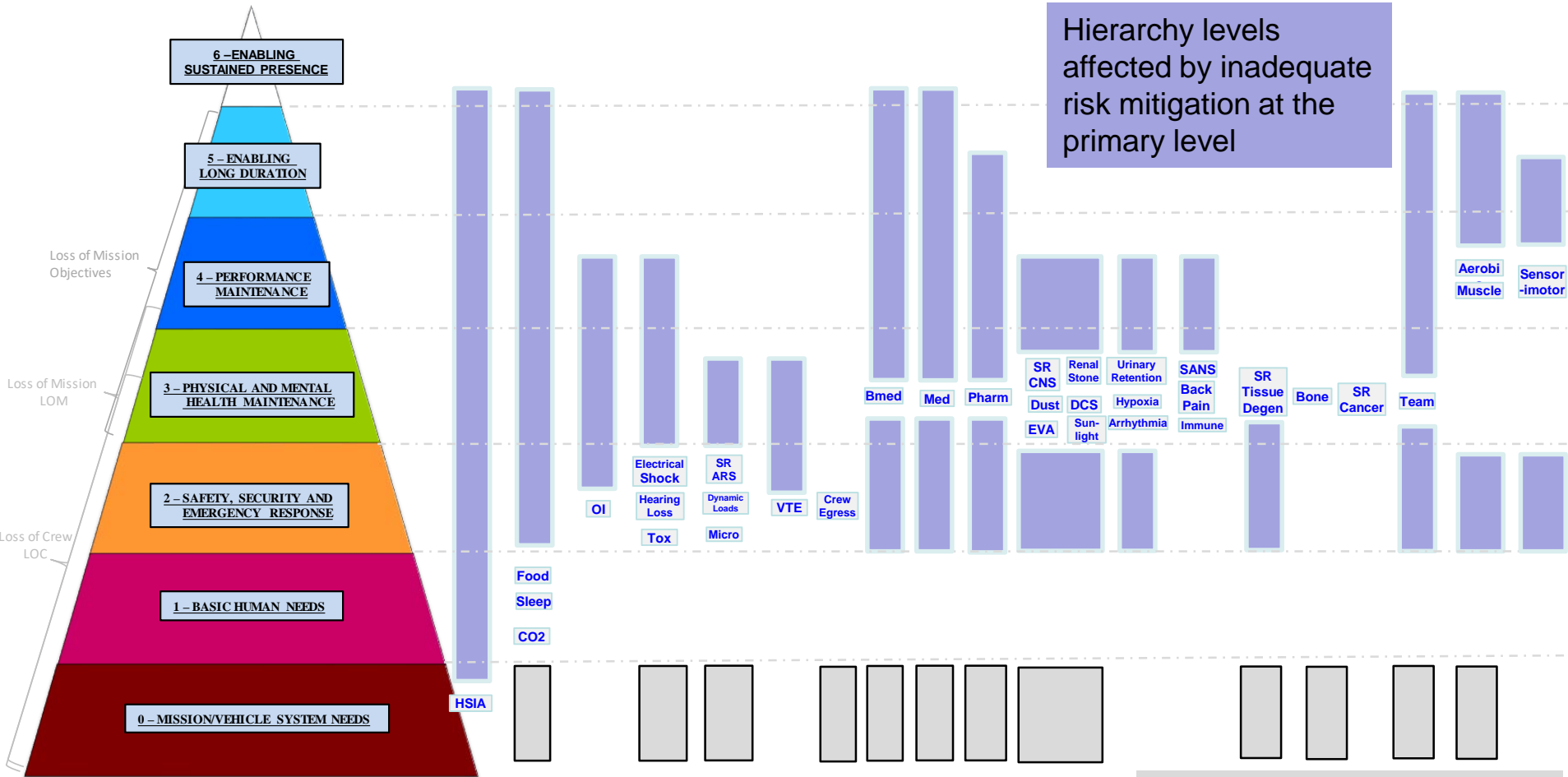
Unlimited ISS
Medical
Capability

No Medical
Capability

Be aware: there are a lot of caveats in these PRA calculations

IMM Run S-20180531-405, 100,000 simulations

Risk Dependency



HIERARCHY CATEGORIES FOR A GIVEN MISSION

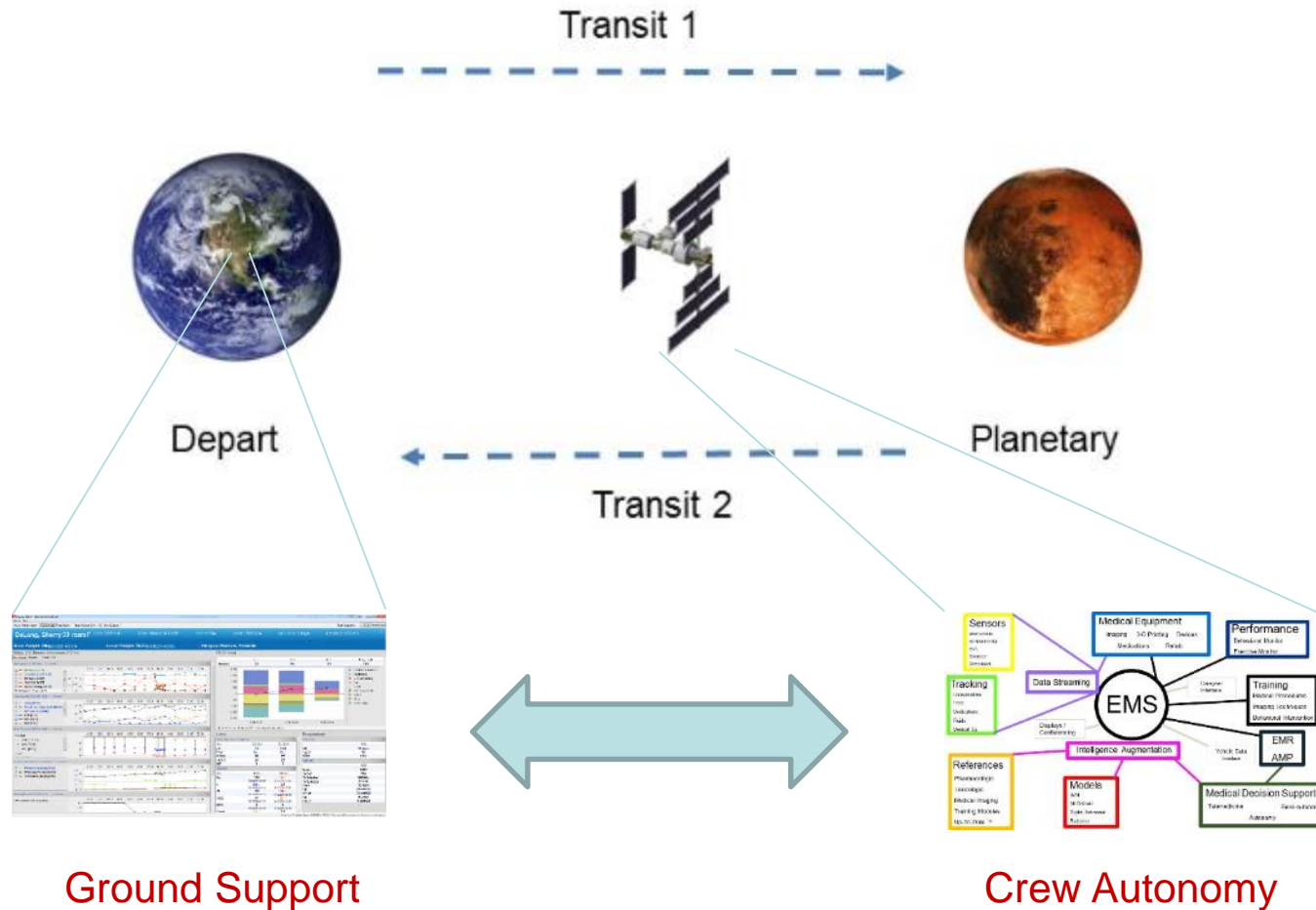
Risk Primary Placement

- Hierarchy levels affected by inadequate risk mitigation at the primary level
- Early inputs to system design requirements needed to enable risk mitigation at the primary level

Formal Criteria for primary category and secondary categories are defined in the Risk Management Plan

Early inputs to system design requirements needed to enable risk mitigation at the primary level

Keeping Track of all this requires a System



Move Knowledge, Not People

Crew Health and Performance System Must...

- **Protect from environmental hazards**

- Radiation protection
- Noise, vibration, CO₂, etc.



- **Keep healthy crew well**

- Exercise
- Other physiological countermeasures
- Food
- Behavioral health



- **Prevent, diagnose, treat, manage long-term health care**

- Data system
 - Medical Data Capture
 - Medical Training
- Medical devices
- Medical supplies

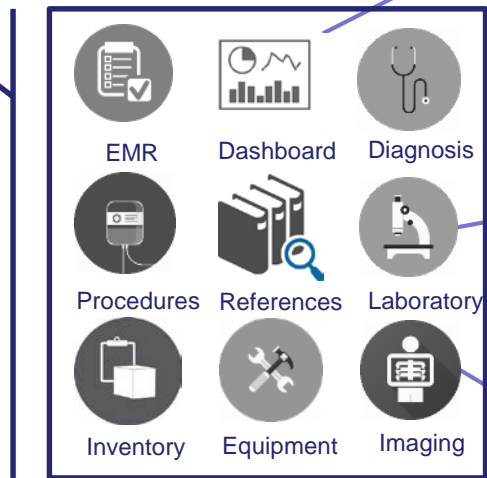
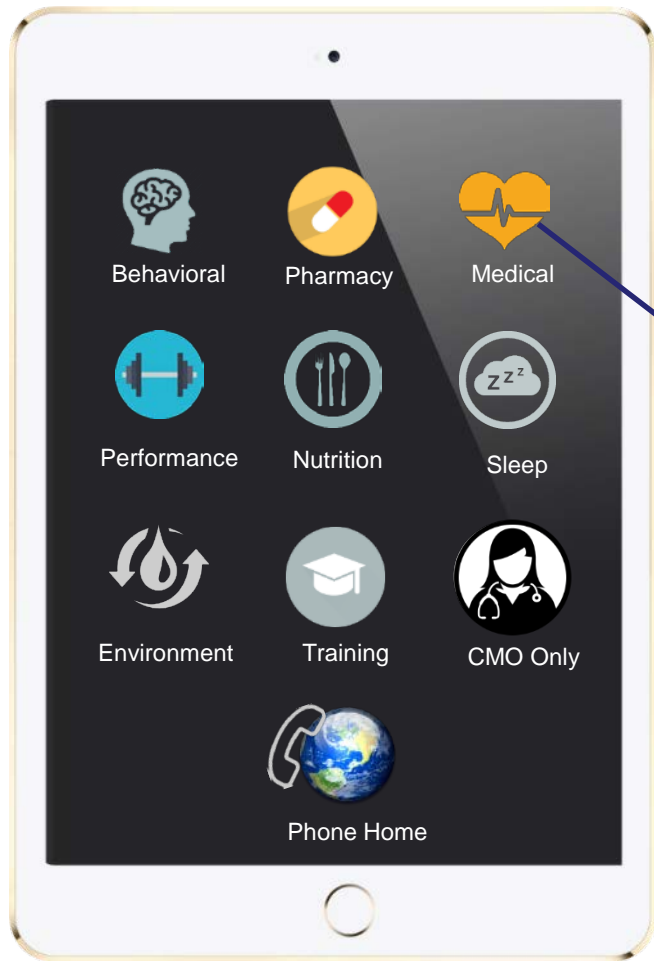


- **Support crew to accomplish mission tasks**

- Procedures
- Training
- User interfaces



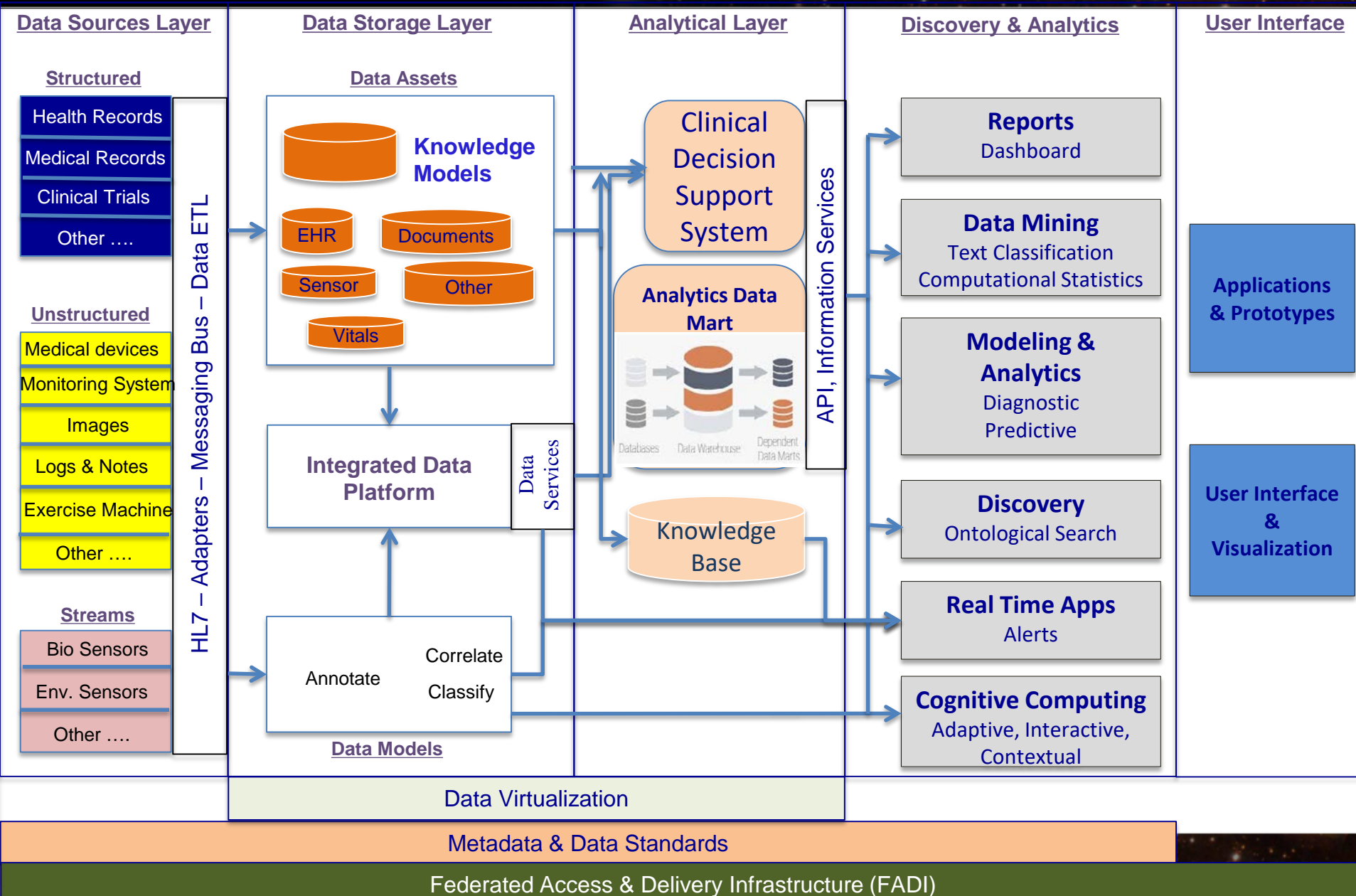
A Crew Health and Performance System



Medical



ExMC Data Architecture (ARC)

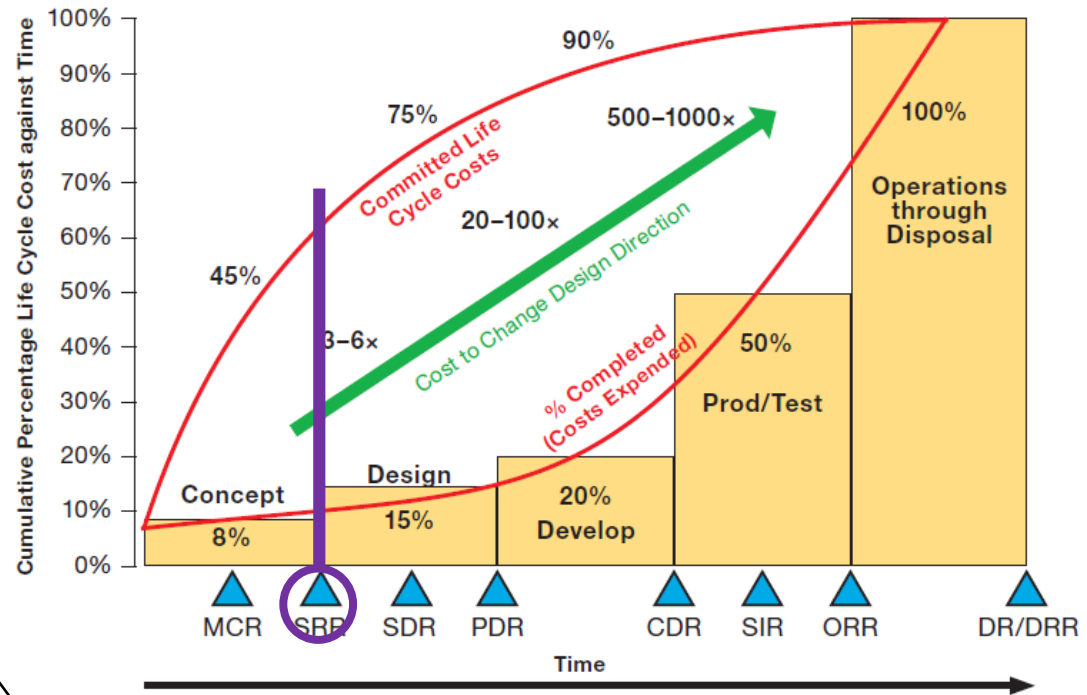


Understanding Level 0

Risk mitigation that affects Level 0 must be considered early in the vehicle engineering life cycle to avoid incurring cost and schedule penalties later

Examples of known risk mitigations dependent on ear vehicle design consideration

- Bone, Muscle, Aerobic* – Exercise Systems
- Sleep* – Crew Quarters, Environment Control
- Food & Nutrition, Pharm* – Food System, Refrigeration
- CO2* - Environment Control, Monitors
- HSIA* – System Maintainability, Repairability, Net Habitable Volume, Displays, Hardware and Software, Decision Support, Autonomy
- Dynamic Loads* – Monitoring, Seat and Restraint Design
- Radiation* – Shielding and Reconfigurable Mass, Monitors
- Dust* – Filtration and Particulate Exclusion
- DCS, Hypobaric Hypoxia* – Vehicle/Hab atmosphere

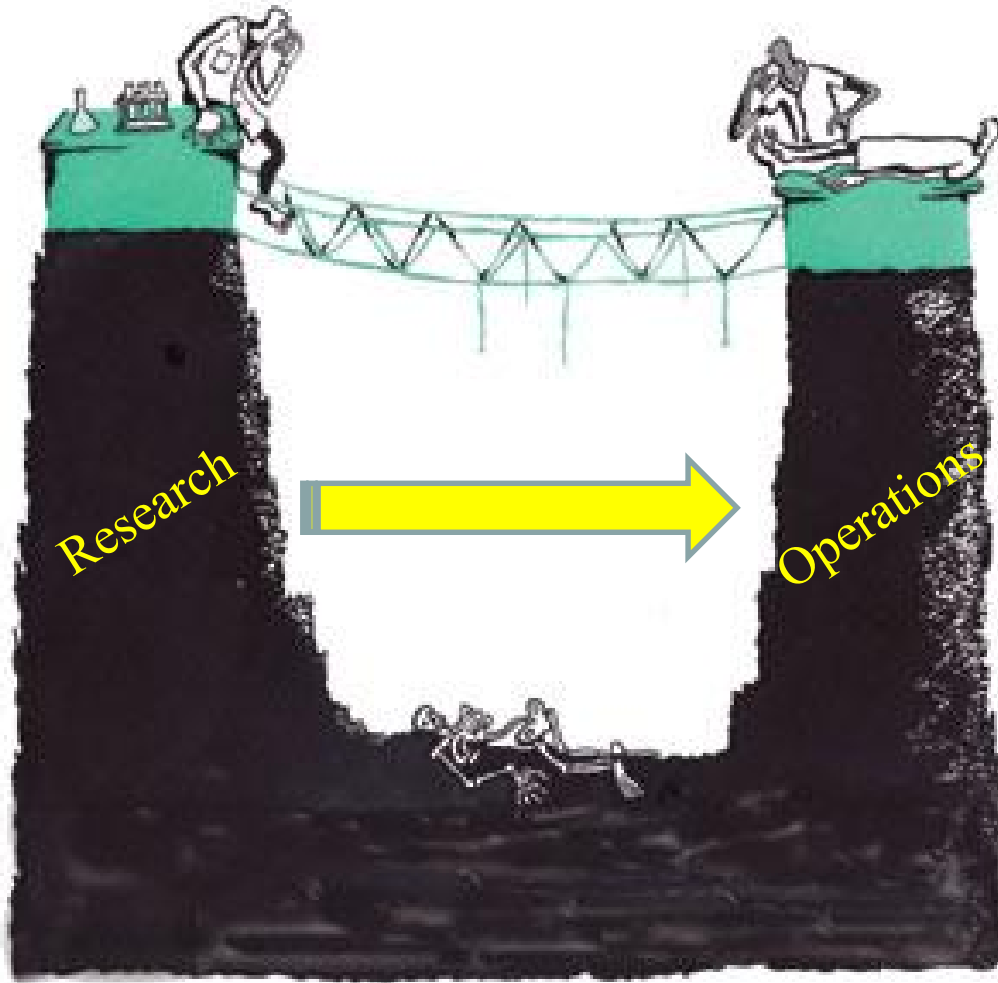


MCR	Mission Concept Review	CDR	Critical Design Review
SRR	System Requirements Review	SIR	System Integration Review
SDR	System Definition Review	ORR	Operational Readiness Review
PDR	Preliminary Design Review	DR/DRR	Decommissioning/Disposal Readiness Review

Adapted from INCOSE-TP-2003-002-04, 2015

FIGURE 9.1. Lifecycle costs are locked in early on in the life cycle.

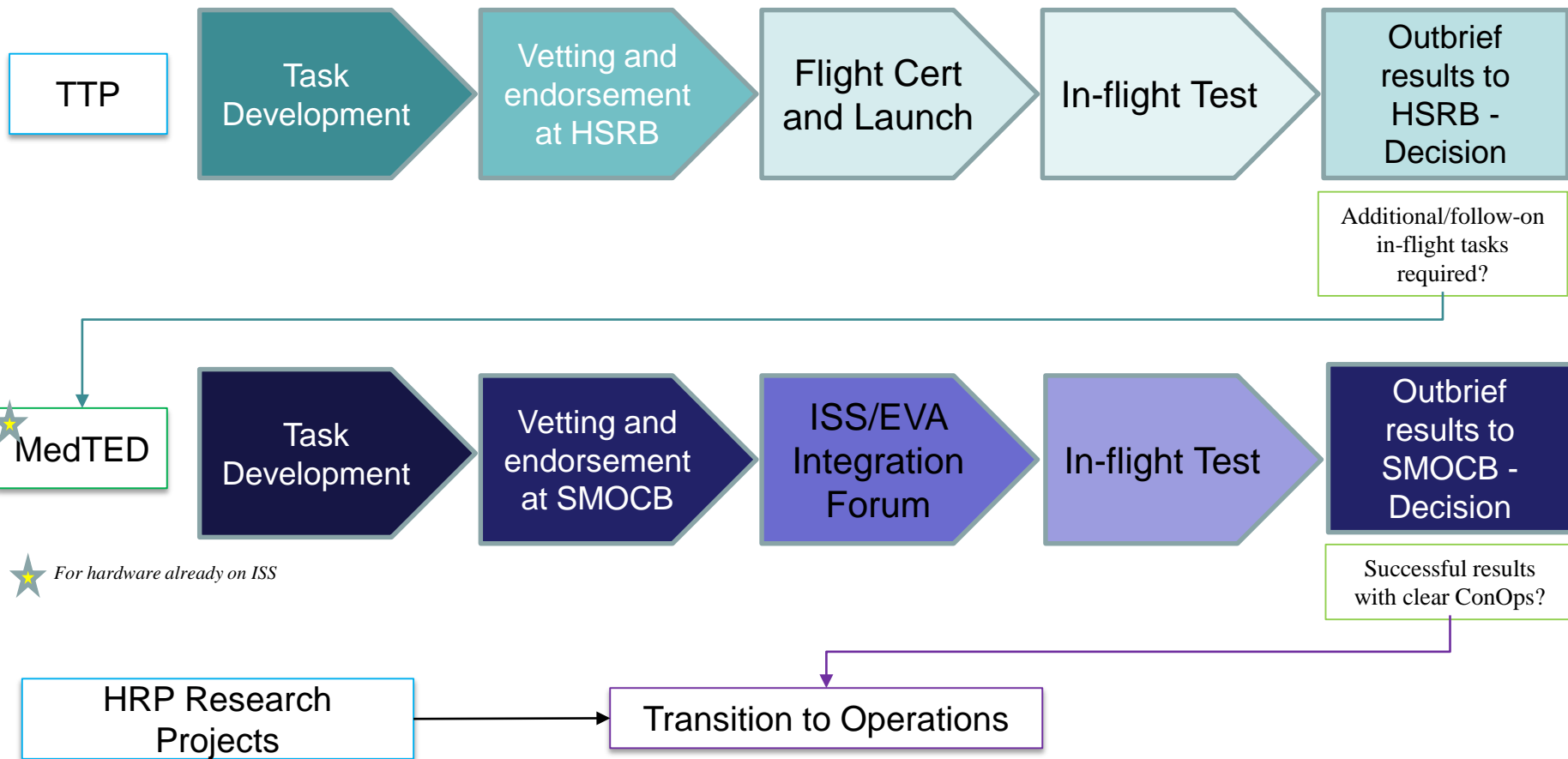
Bench to Floating Bedside?



“A chasm has opened up between biomedical researchers and the patients who need their discoveries.” ~NIH in Nature 453, 840-842 (2008)

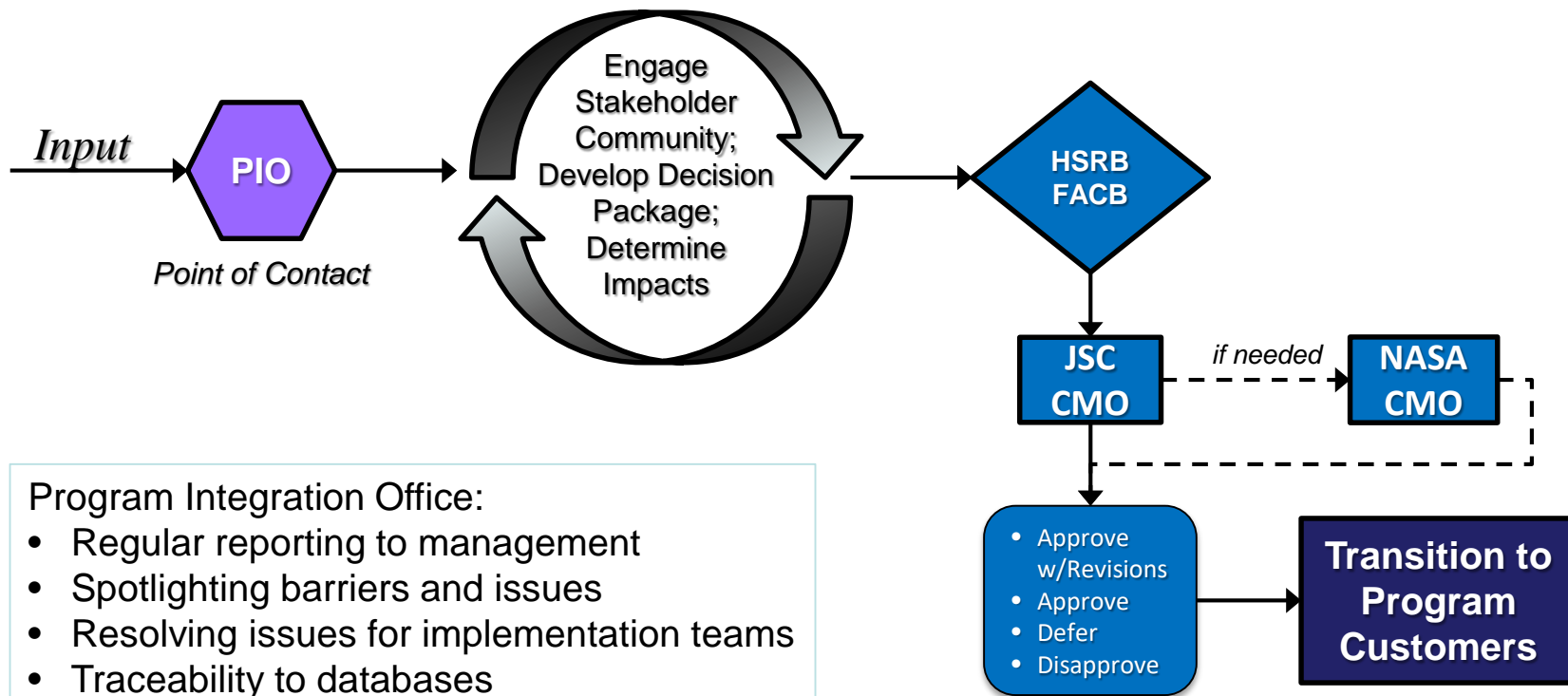
Getting Technology Up There

Flow from TTP to MedTED to TtO



★ For hardware already on ISS

- TtO – Transition to Operations is a pathway to assess the effectiveness and operational readiness of medical research and technology products and deliverables to move into operations



Program Integration Office:

- Regular reporting to management
- Spotlighting barriers and issues
- Resolving issues for implementation teams
- Traceability to databases
- Community engagement

How do we Burn Down Risk?

High value research accomplishes one or more of the following:

- **Characterize or Understand the Risk**
- **Prevent Risk scenarios from occurring (Hazard Control)**
- **Reduce the consequence of Risk scenarios**
- **Improve System Resilience**
- **Inform appropriate acceptance of Risk**

AND strives to provide solutions that fit