

# Human System Risk at NASA

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# Conflicts of Interest Disclosure

1. Assistant Professor of Emergency Medicine, Baylor College of Medicine
2. Assistant Professor of Space Medicine, Center for Space Medicine
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4. Assistant Director, Human Systems Risk Management, NASA

I have financial interests in the above entities.

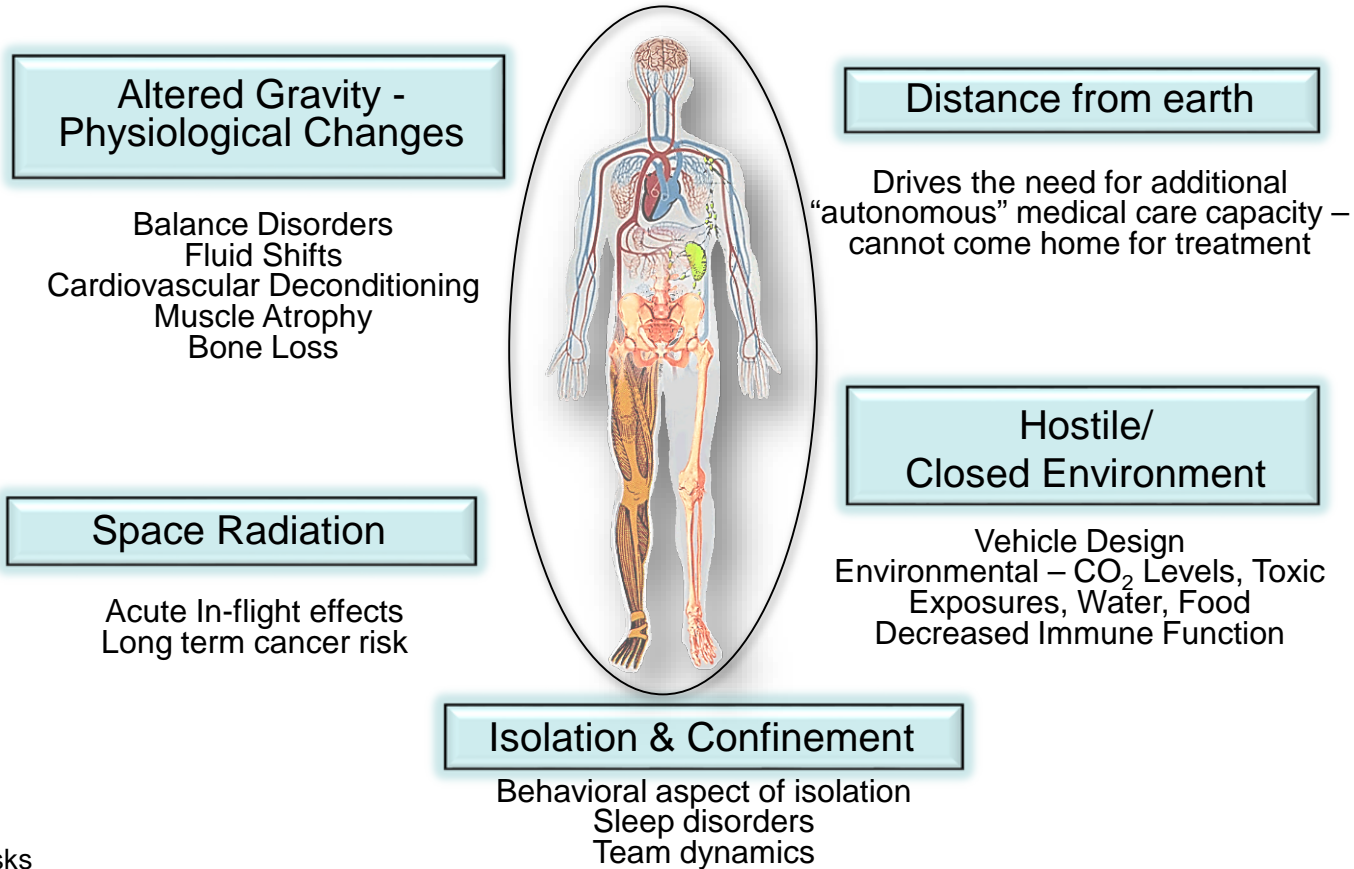
The opinions shared here are my own and not necessarily reflective of the above institutions.

# The goal of this talk is to give an overview of how NASA approaches Human System Risks and how that relates to your work as researchers

Expect an overview of the following:

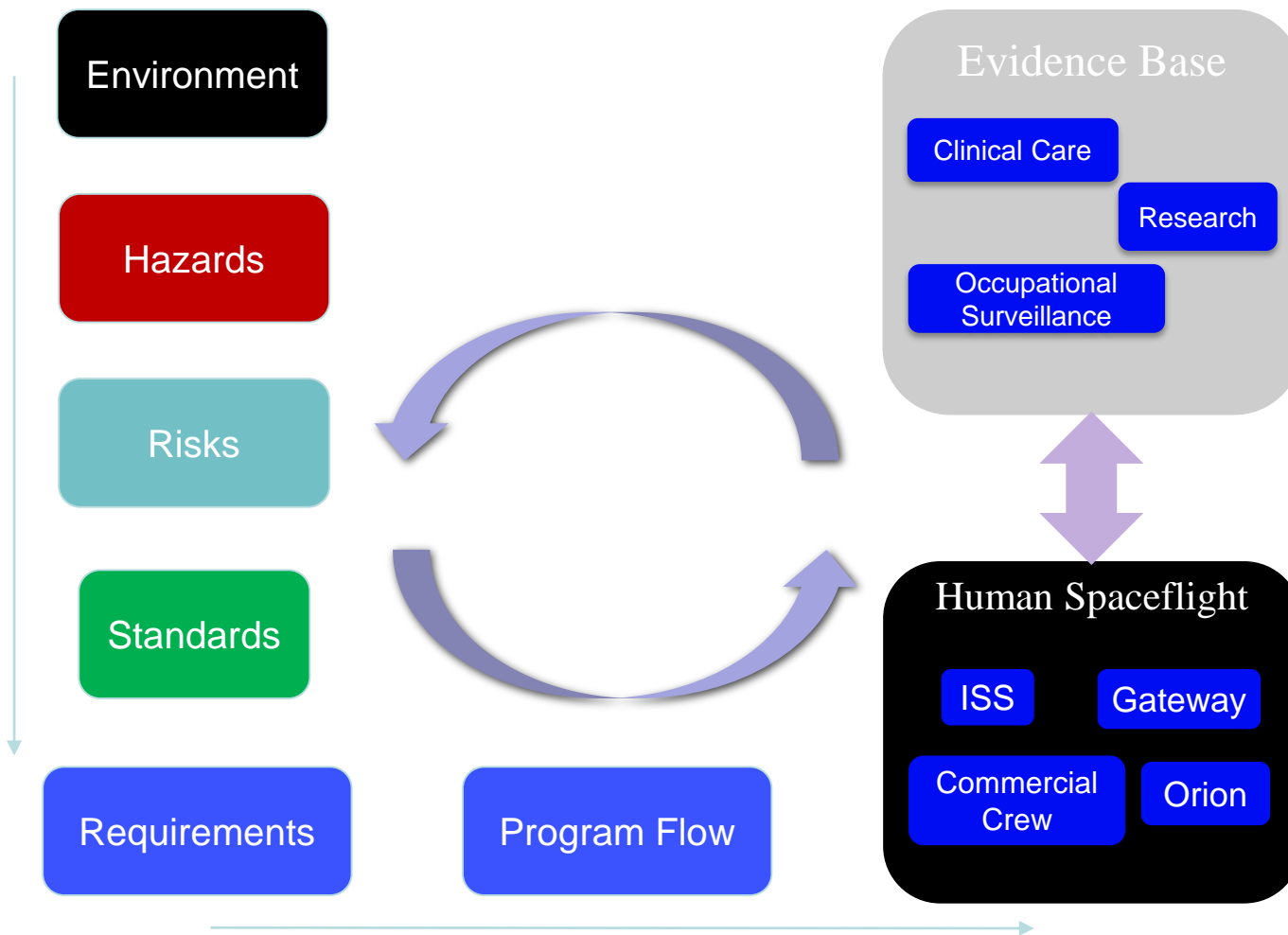
- **Big Big Picture**
- **Stakeholders**
- **Defining Likelihood and Consequences**
- **Prioritizing Risks**
- **Relationship between Risks and Programs**
- **Integrating Between Risks**
- **Risk Stacking**
- **How do we burn down Risk? (OR why does your research matter?)**

# Human System Hazards – where Risks come from



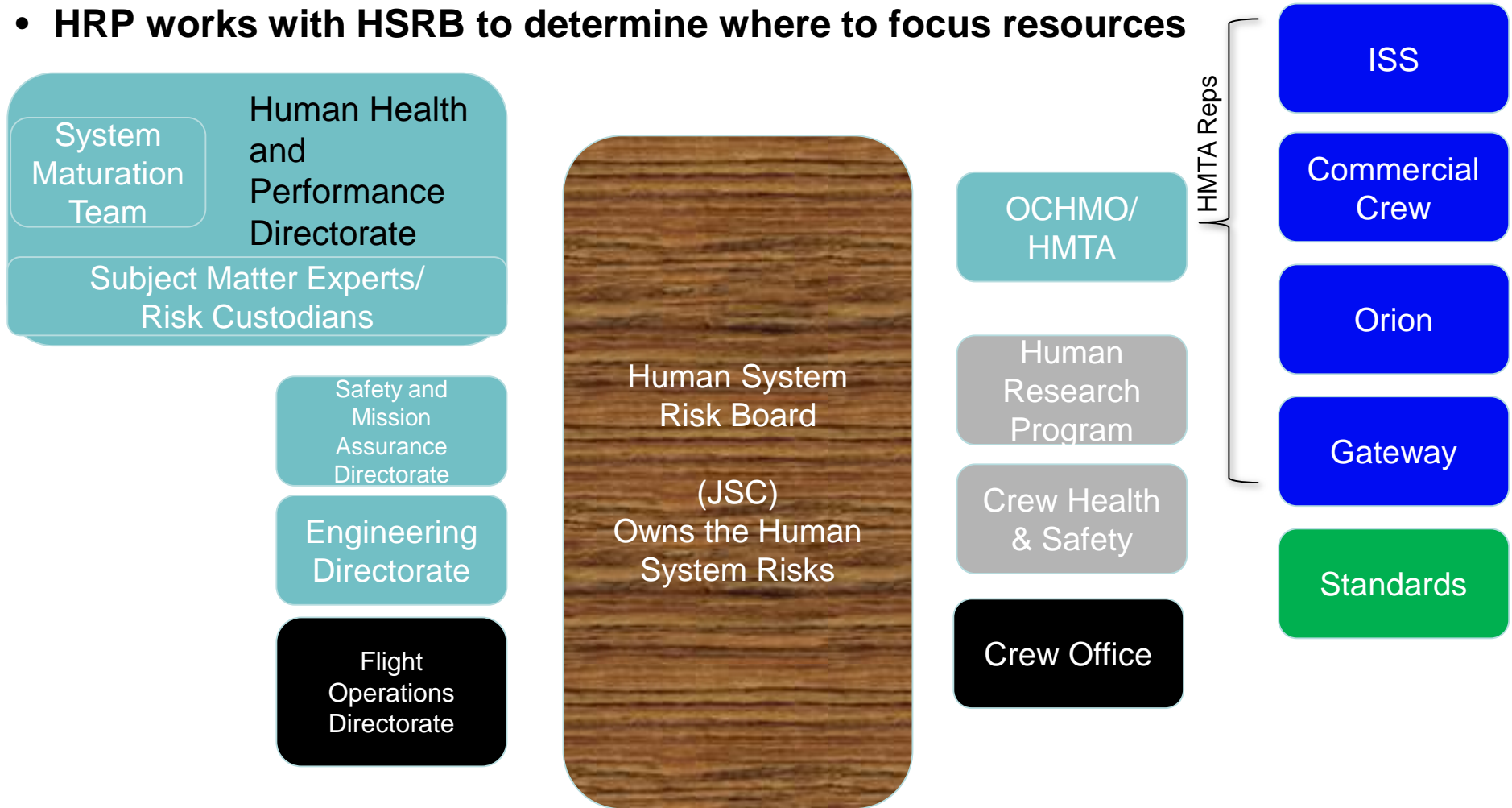
Human System Risks

# The Big Big Picture



# Who Cares about Risk?

- Stakeholders sit at the HSRB table
- Human System Risks are owned by HMTA
- HRP works with HSRB to determine where to focus resources



# Human System Risks – Likelihood vs Consequence

## 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			
Low			
Very Low			

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?

Human Spaceflight Risks	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ 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
Renal Stone Formation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inflight Medical	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation

Human Spaceflight Risks	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
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Renal Stone Formation	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
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
Inadequate Food and Nutrition	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	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
Inadequate Human-System Interaction Design	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Standard Refinement, May Require Mitigation	Standard Refinement, May Require Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

Unpredicted Effects of Medication	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA



# How do we relate Risks to Programs?

Operation Assessment Health and Performance Risks	Nominal Operations						Off Nominal/Emergency Conditions					
	ISS	Soyuz	SpaceX	Boeing	Orion	Gateway	ISS	Soyuz	SpaceX	Boeing	Orion	Gateway
Inflight Medical Care System											Limited ALS	Limited ALS
SANS			Seat Inclination									
Renal Stone Formation												
Radiation Exposure					Deep Space	Deep Space				Deep Space	Deep Space	
Altered Immune Response												
Urinary Retention												
Sleep Loss			Thruster Firings									
Space Adaptation Back Pain												
Cardiovascular Disease/Cardiac Rhythm												
Behavioral Conditions												
Team Dynamics												
Ineffective Medications - Long Term Storage												
Food Supply, inadequate nutrition												
Muscle Loss			Water Landing	Water Landing	Water Landing			Water Landing	Water Landing	Water Landing		
Sensorimotor Alterations			Water Landing	Water Landing	Water Landing			Water Landing	Water Landing	Water Landing		
Aerobic Capacity			Water Landing	Water Landing	Water Landing			Water Landing	Water Landing	Water Landing		
Orthostatic Intolerance			Water Landing	Water Landing	Water Landing			Water Landing	Water Landing	Water Landing		
Bone Fracture			Water Landing	Water Landing	Water Landing			Water Landing	Water Landing	Water Landing		
Injury from Dynamic Loads												
Host Microorganism Interaction												
Toxic Exposure												
Acute and Chronic Carbon Dioxide Exposure						2 mmHg			Emergency Scenarios	Emergency Scenarios		
Hypoxia												
Lunar (Celestial) Dust Exposure	N/A	N/A	N/A	N/A	TBD		N/A	N/A	N/A	N/A	TBD	
EVA/LEA - suit design									Suit PSI	Suit PSI		
Decompression Sickness									Suit PSI	Suit PSI		
Human Centric Design			Time on back	Time on back	Time on back	Limited NHV			Hatch Design	Hatch Design	Hatch Design	
Injury from Sunlight Exposure												
Hearing Loss Related to Spaceflight												
Risk of electrical shock												

Minimal Impact to Crew Health and Performance. Standards and requirements generally being met

Noticeable impact to Crew Health and Performance. Standards and requirements not being met.

Significant Impact to Crew Health and Performance. Standards and requirements not being met

# Example Risk Matrix from Exploration Systems Directorate

- Minor Injury – Based on Soyuz
- Moderate Injury Scenario – expect Orion to have harder landings

LIKELIHOOD RATING	
<b>5</b> Very High	Qualitative: Nearly certain to occur. Controls have little or no effect. Quantitative: $10^{-1} < P$ (for risks with primary consequence on Human Safety - Personnel) or $P > 50\%$ (for risks with primary consequence on Cost, Schedule, or Performance).
<b>4</b> High	Qualitative: Highly likely to occur. Controls have significant uncertainties. Quantitative: $10^{-2} < P \leq 10^{-1}$ (for risks with primary consequence on Human Safety-Personnel) or $33\% < P \leq 50\%$ (for risks with primary consequence on Cost, Schedule or Performance)
<b>3</b> Moderate	Qualitative: May occur. Controls exist with some uncertainties. Quantitative: $10^{-3} < P \leq 10^{-2}$ (for risks with primary consequence on Human Safety-Personnel) or $10\% < P \leq 33\%$ (for risks with primary consequence on Cost, Schedule, or Performance)
<b>2</b> Low	Qualitative: Not likely to occur. Controls have minor limitations/uncertainties. Quantitative: $10^{-4} < P \leq 10^{-3}$ (for risks with primary consequence on Human Safety-Personnel) or $1\% < P \leq 10\%$ (for risks with primary consequence on Cost, Schedule, or Performance)
<b>1</b> Very Low	Qualitative: Very unlikely to occur. Strong Controls in Place. Quantitative: $P \leq 10^{-5}$ (for risks with primary consequence on Human Safety-Personnel) or $P \leq 1\%$ (for risks with primary consequence on Cost, Schedule, or Performance).

ESD Risk Score Card						
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						
<b>Timeframe</b> To Initiate Handling Strategy						
Near	0 to 3 months					
Mid	3 to 9 months					
Far	> 9 months					

CONSEQUENCES		1	2	3	4	5
SAFETY	Personnel	Minor injury not requiring first-aid treatment, minor crew discomfort	Injury requiring first-aid treatment, moderate crew discomfort	Injury, illness or incapacitation requiring emergency or hospitalization treatment	Severe injury or illness requiring extended hospital/Medical treatment	Loss of life or permanently disabling injury
	Facilities, equipment, assets	Minor damage or non-essential flight assets	Minor damage to Program Critical assets, Major damage to non-essential assets	Minor damage to flight/Ground assets, Major damage to Program critical assets, or loss of non-essential assets	Loss of mission, Major damage to Flight/Ground Assets; doesn't meet criteria for catastrophic hazard, or Loss of Program Critical Asset	Loss of Flight/Ground Assets or Loss of vehicle prior to completing its mission
	Environmental	Negligible OSHA/EPA violation – non reportable	Minor reportable OSHA/EPA violation	Moderate OSHA/EPA violation which requires immediate remediation	Major OSHA/EPA violation causing temporary stoppage	Serious or repeat OSHA/EPA violations resulting in action terminating Program
PERFORMANCE	Requirements	Negligible impact to requirements/design margins	Minor impact to requirements/design margins	Moderate impact to requirements/design	Major impact to requirements/design margins	Technical goals not achievable with existing engineering capabilities/technologies
	Operations	Negligible impact to mission operations	Minor impact to operations – workarounds available	Moderate impact to operations – workarounds available	Failure to achieve major mission objectives	Contingency Abort
	Supportability	Temporary usage loss or LOCM of non-flight critical asset	Permanent usage loss or LOCM of non-flight critical asset	Temporary usage loss or LOCM of major element(s) of flight vehicle or ground facility	Permanent usage loss or LOCM of major element(s) of flight vehicle or ground facility	Inability to support further flight operations
COST		≤\$100K	>\$100K but ≤\$1M	>\$1M but ≤\$10M	>\$10M but ≤\$100M	>\$100M
SCHEDULE		Negligible schedule impact	Minor overall schedule impact (no impact to critical path)	≤1 month impact to critical path/milestones	>1 and ≤6 month impact to critical path/milestones	>6 month impact to critical path/milestones or possible Program cancellation

# Translating Program and HMTA Risk Posture Updates

Health and Performance Risks	Nominal Operations					Off Nominal/Emergency Conditions						
	ISS	Soyuz	SpaceX	Boeing	Orion	Gateway	ISS	Soyuz	SpaceX	Boeing	Orion	Gateway
Inflight Medical Care System										Limited ALS	Limited ALS	
SANS			Seat Inclination									
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## Commercial Crew (ISS)

5	1 5	1 0	6	3	1
4	1 9	1 4	9	5	2
3	2 2	1 8	1 3	8	4
2	2 4	2 1	1 7	1 2	7
1	2 5	2 3	2 0	1 6	1 1
	1	2	3	4	5

Likelihood

Consequence

## Orion (Gateway)

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

## HMTA

High	1 x 4	2 x 4	3 x 4	High
Medium	1 x 3	2 x 3	3 x 3	Medium
Low	1 x 2	2 x 2	3 x 2	Low
Very Low	1 x 1	2 x 1	3 x 1	Very Low
	Low ≤0.1%	Medium <1%	High ≥1.0%	

Likelihood

Soyuz  
ISS

# Prioritize by Color?

Human Spaceflight Risks	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
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# NASA Human System Risk Relationships

**Prioritize by Foundation?**

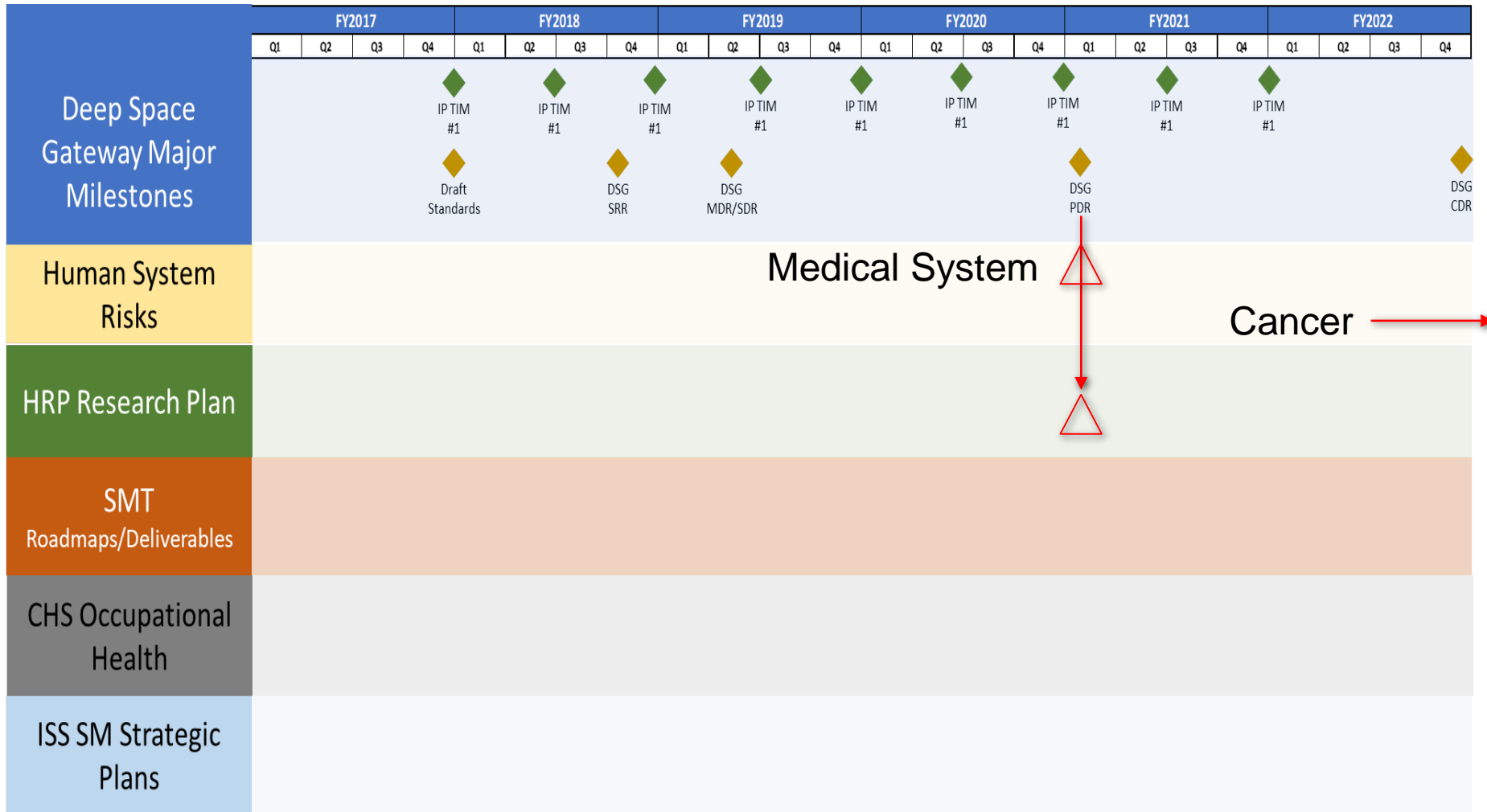
Risks are distributed across the entire pyramid. Foundational Risks can affect higher level risk posture.



Loss of Crew  
LOC

Loss of Mission  
LOM

# Prioritize by Need Date?



# Prioritizing Risk

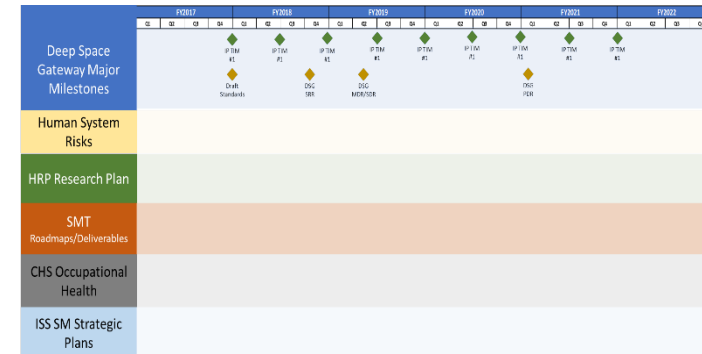
- Risk Color

Human Spaceflight Risks	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
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Inadequate Human-System Interaction Design	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Standard Requirement May Require Mitigation	Standard Requirement May Require Mitigation	Standard Requirement May Require Mitigation	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	

- Risk Category

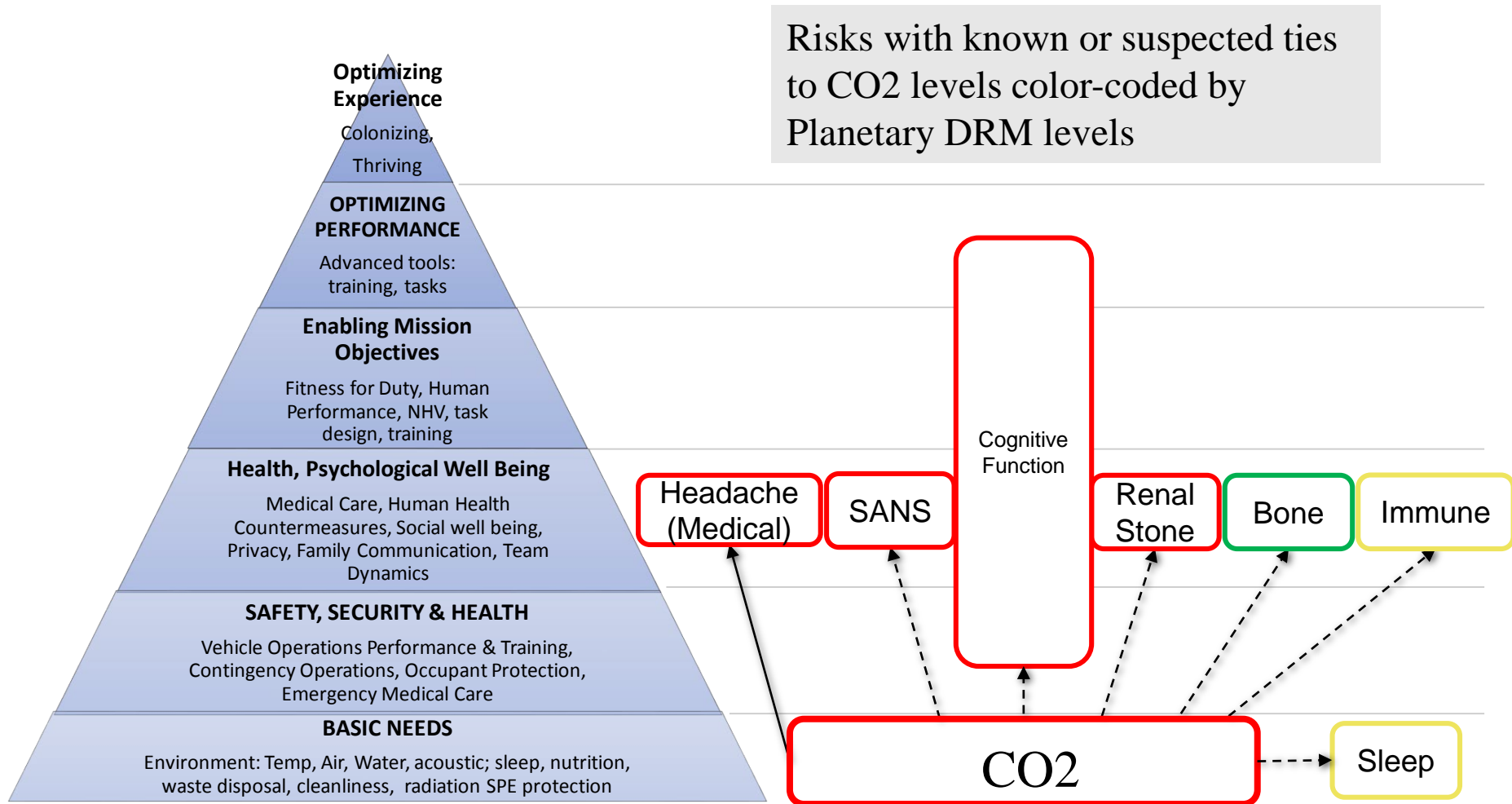


- Risk Need Date



When you ask what are the top Risks, it depends on all these factors as well as the mission you are concerned with.

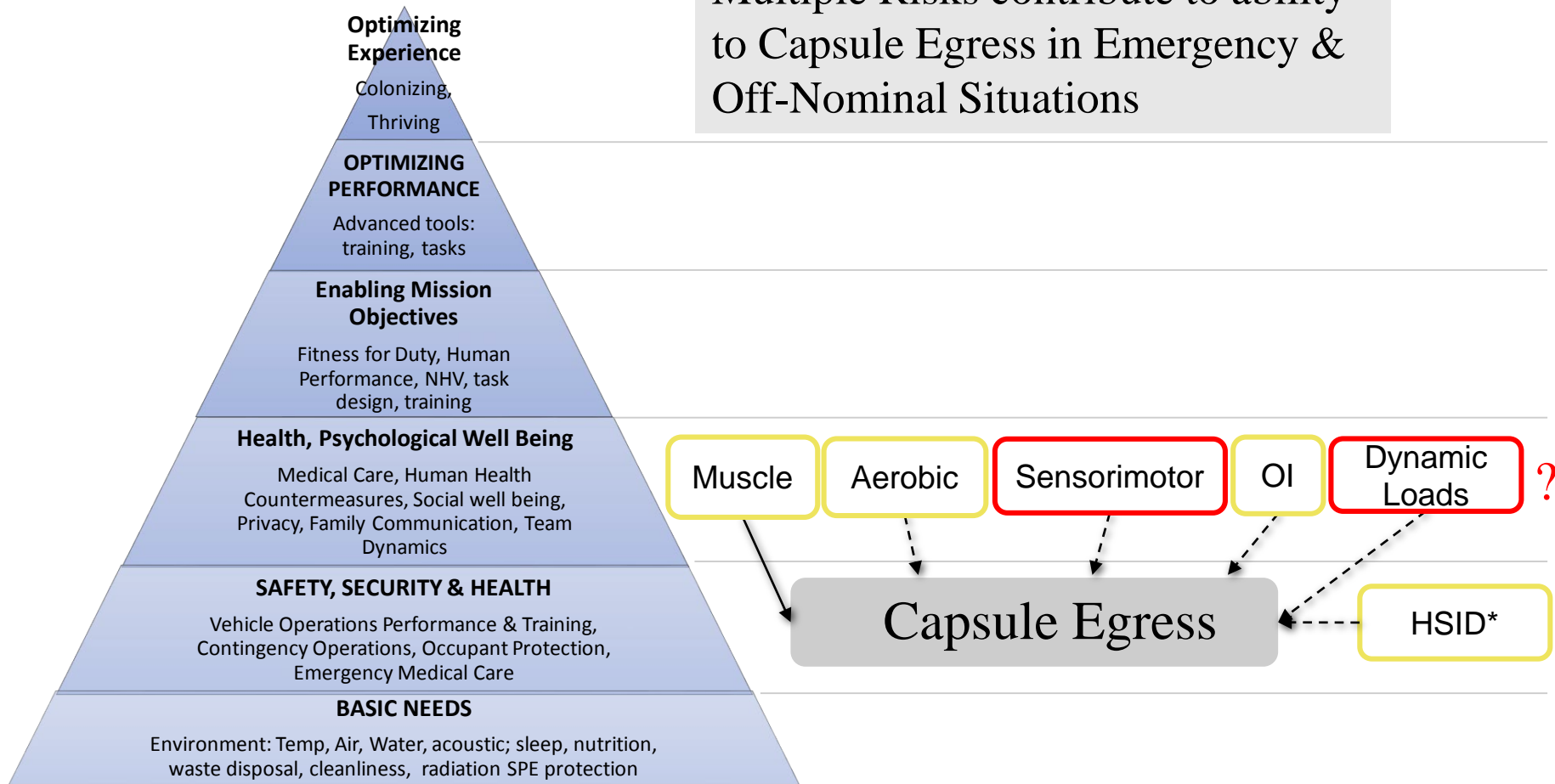
# Integrating Between Risks – Foundational vs. Dependent





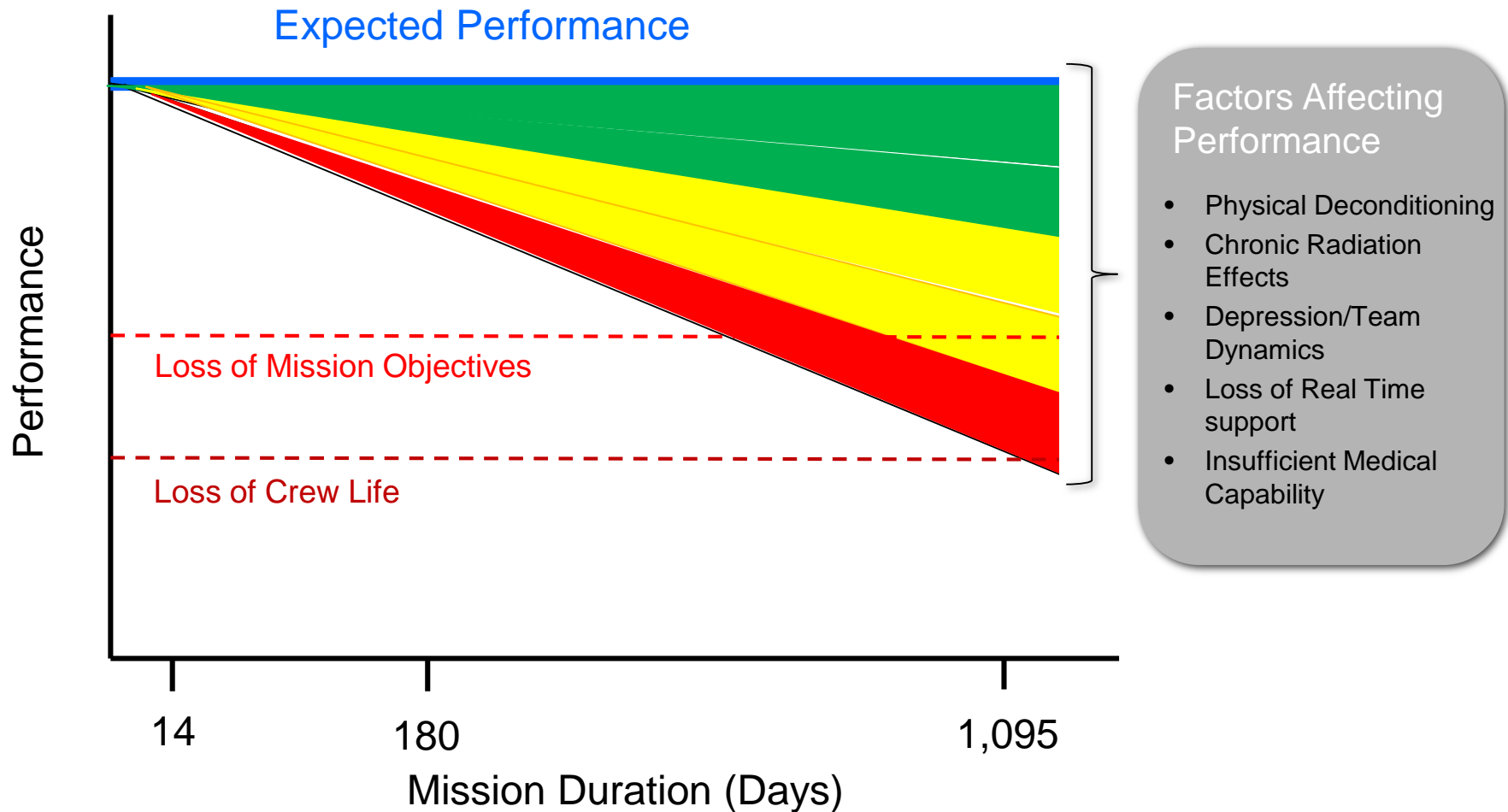
# Integrating Between Risks – Operational Endpoints

Multiple Risks contribute to ability to Capsule Egress in Emergency & Off-Nominal Situations



(\*) HSID includes "Training" and contingency ground operations

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



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

# 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)**
- **Consequence Reduction (Risk Mitigation)**
- **Improve Margin**
- **Acceptance of Risk Levels**

Explanations can be found in  
the Risk Custodian Handbook



# Backup