

# Humans vs. Hardware: The Unique World of the NASA Human System Risk Assessment

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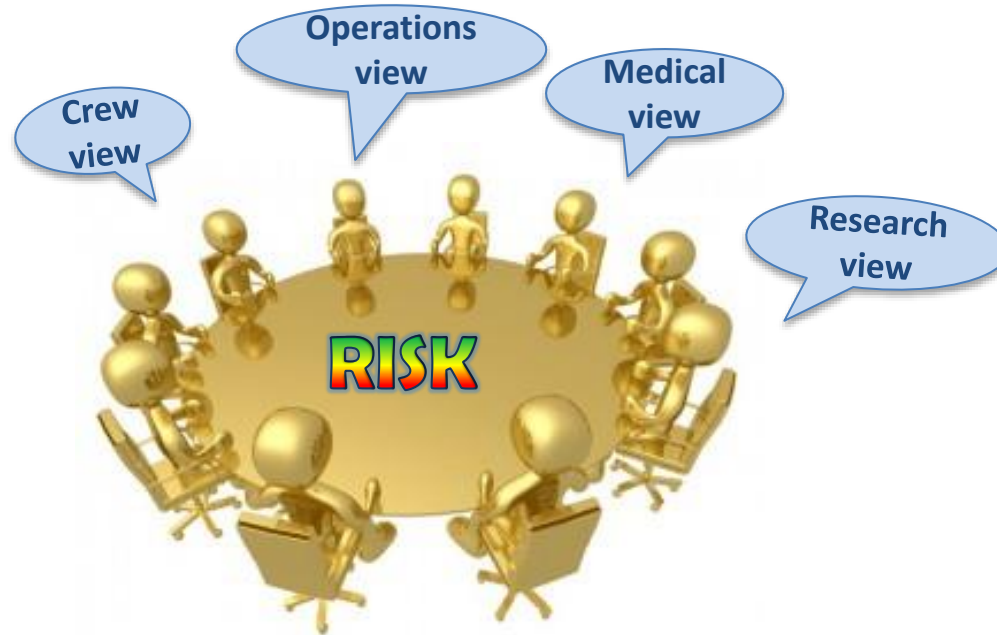
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# Background

- ❖ The process for managing NASA human system risks (health and performance) is owned by the Human System Risk Board (HSRB).



- ❖ Each of these 32 HSRB risks is assessed for its **likelihood and consequence (LxC)** scores or risk ratings using HSRB scales.

*23 of these risks define the HRP research portfolio.*

# HSRB Risk Matrix (with LxC scales)

Consequence score  
is from 1 to 4  
(y-axis)

Likelihood score is  
from 1 to 3  
(x-axis)

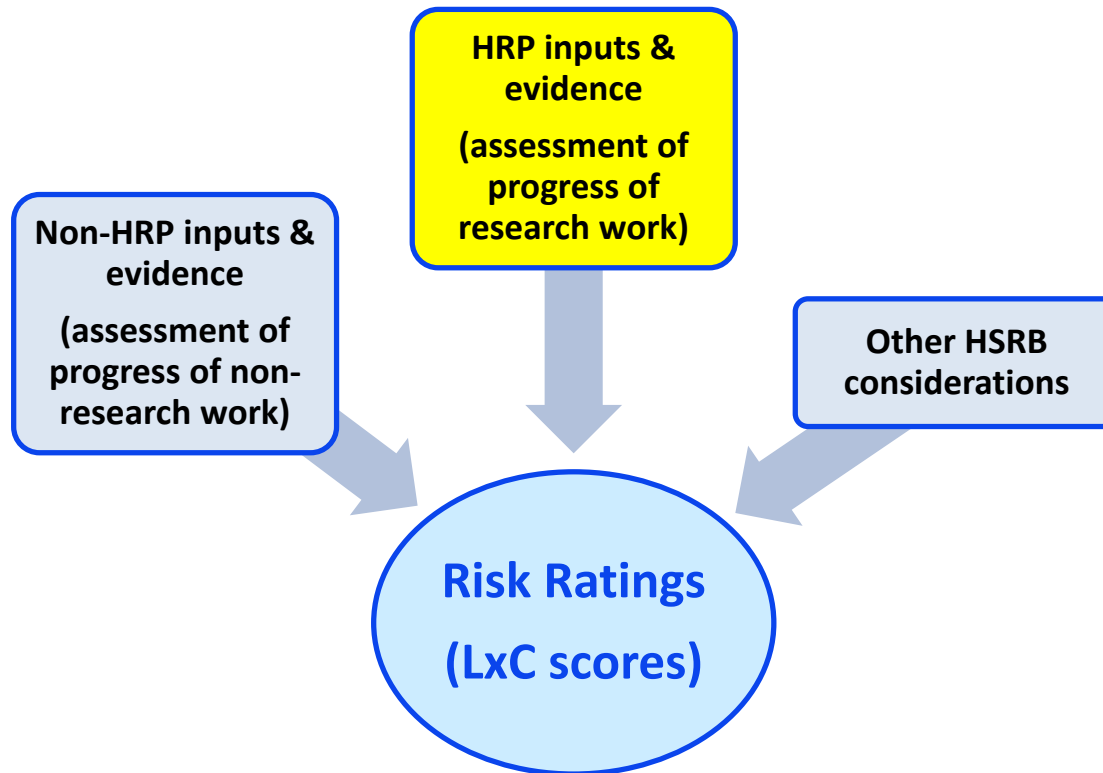
Consequence	High	1 x 4	2 x 4	3 x 4
	Medium	1 x 3	2 x 3	3 x 3
	Low	1 x 2	2 x 2	3 x 2
	Very Low	1 x 1	2 x 1	3 x 1
		Low	Medium	High
		≤0.1 %	<1 %	≥1.0%
		Likelihood		

Consequence outcomes are evaluated for two categories:

- 1) In-flight health & performance
- 2) Post-flight health

# Risk Ratings

- ❖ HRP research work produces evidence for the HSRB risk assessment process that generates risk ratings.



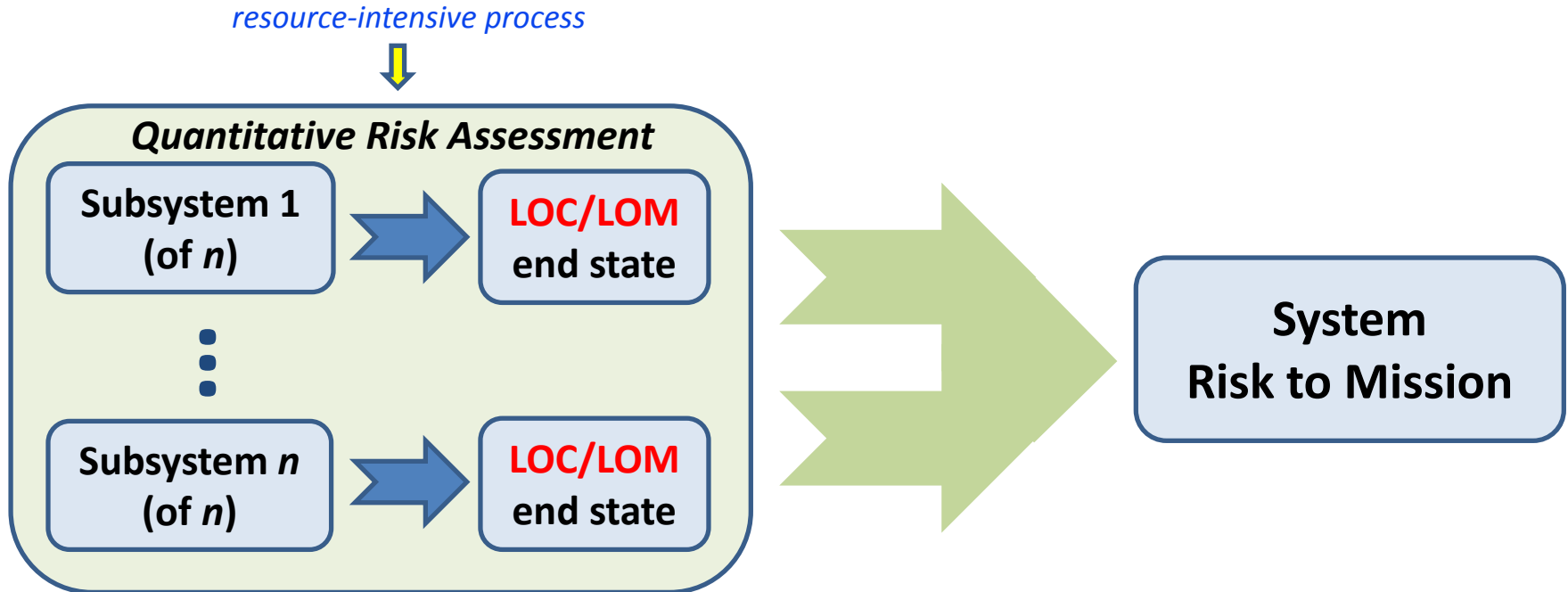
- ❖ LxC scores are helpful in determining direction of mitigation work to achieve acceptable risk levels.

# Traditional Engineering Risk Assessment

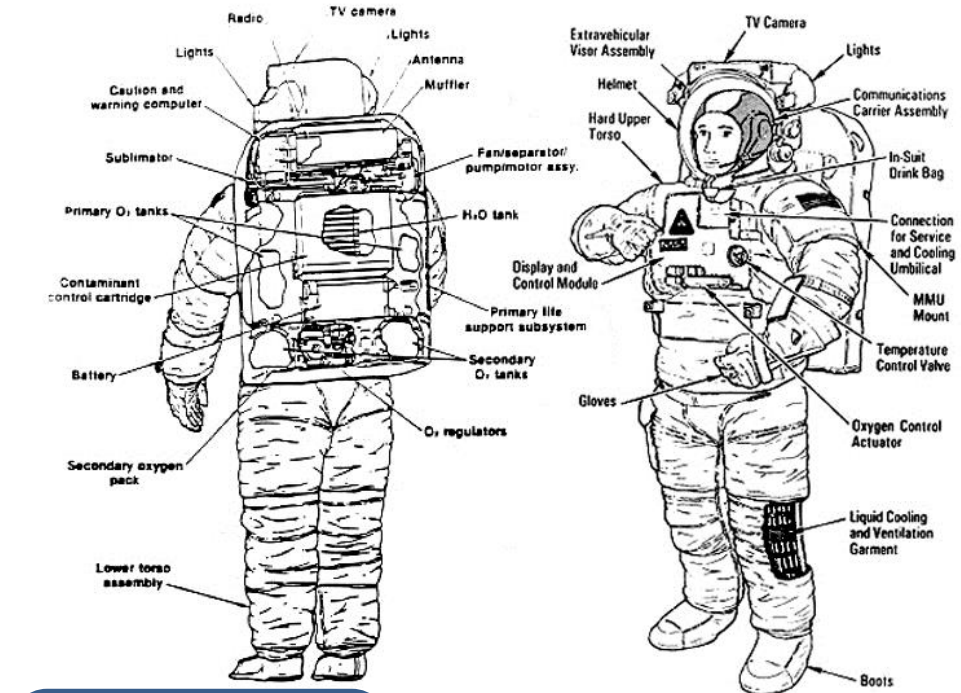
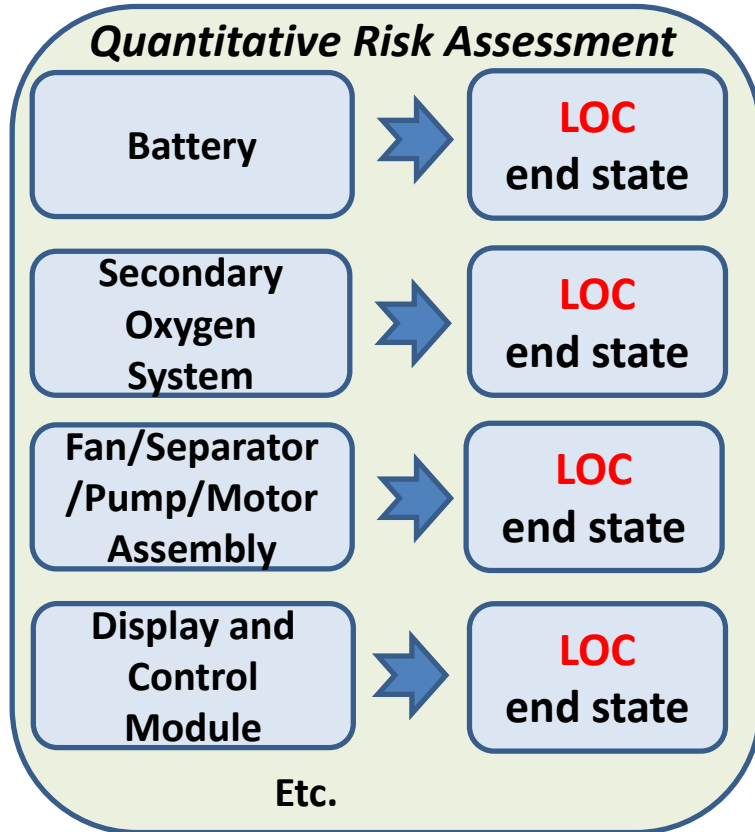
- ❖ A lot of NASA engineering systems use quantitative risk methods (e.g. ISS, Shuttle).
- ❖ The approach is generally based on an aggregate of quantitative assessments at the subsystem level.

$$\sum_{\text{subsystem} = 1}^n = \text{SYSTEM}$$

# Traditional Engineering Risk Assessment



# Example of a Traditional Engineering Risk Assessment



**ISS Suit\*  
Malfunction  
Risk to Crew**



*\*ISS Program recently kicked off a more traditional Probabilistic Risk Assessment (PRA) for the Extravehicular Mobility Unit (EMU).*

# Aspects of Traditional Engineering Systems

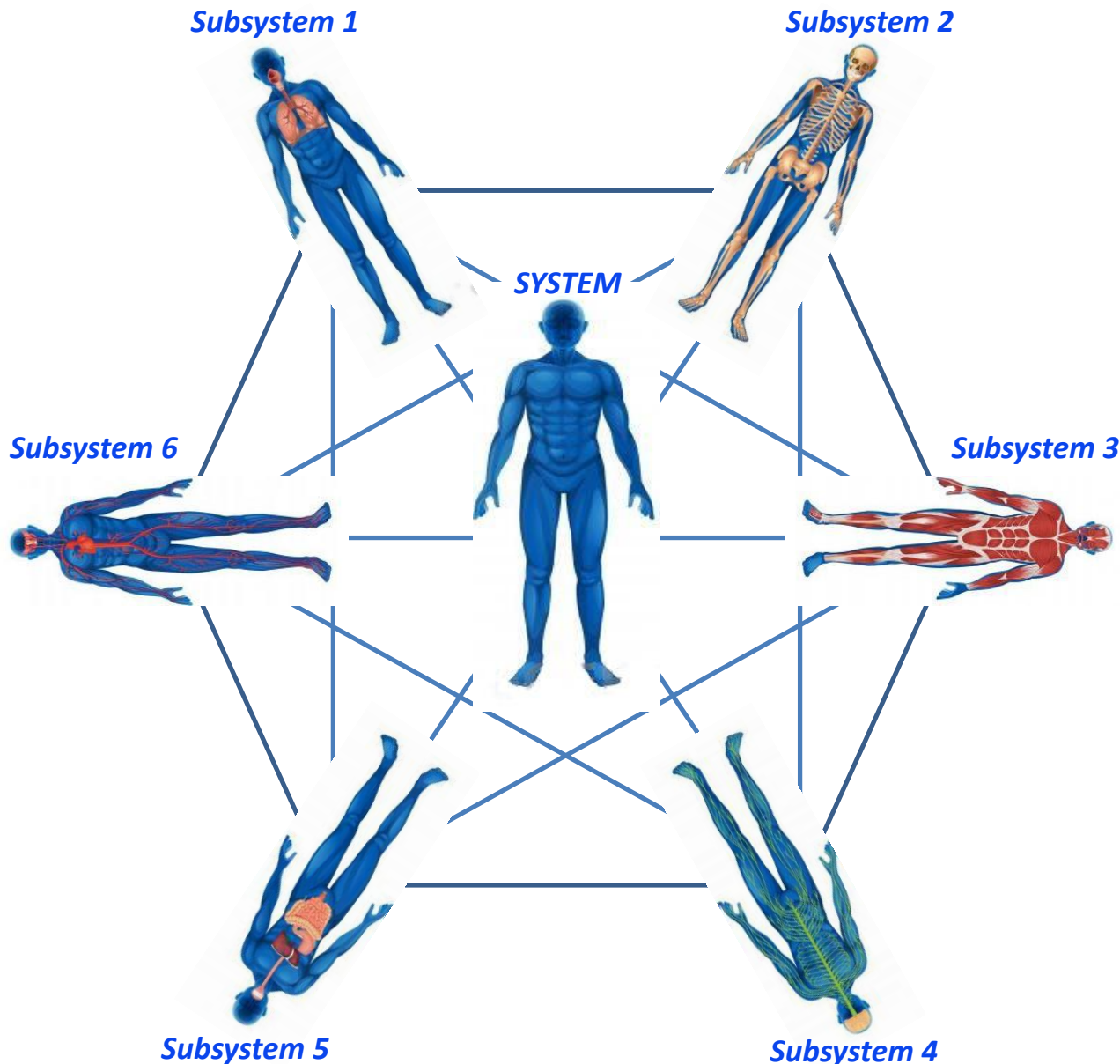
- ❖ Can be evaluated on a subsystem, subassembly, or component level.
  - Interfaces are concretely defined.
- ❖ Can be replicated into identical units with same behavior and response.
  - Can (almost) eliminate element of chance or variance.
  - Allows for multiple forms of design verification.
- ❖ Can be subjected to destructive testing.



# In contrast...

Human systems and human system risks have unique issues that are difficult to address using methods nominally used for traditional hardware and software systems...

# Uniqueness of the Human System



- ❖ Human physiology is so complicated – hundreds of complex feedback loops so connectivity between subsystems is difficult to fully understand or model.

# Uniqueness of the Human System

- ❖ Hard to predict precise physiological impacts of spaceflight hazards and effectiveness of countermeasures because...
  - Human systems can't be designed identically like engineering systems can.



Source: theafrolounge.com

# Uniqueness of the Human System

- Human systems have the exceptional ability to heal and repair themselves at differing rates.



vs.



# Uniqueness of the Human System

- Various factors impact individual responses.



*2013 Astronaut Class*

# Uniqueness of the Human System

- ❖ Human systems can't be tested to failure to generate useful data points –



Source: truthalerts.com

i.e. we remain uncertain about human threshold break points and susceptibility thresholds.

# Other Constraints for Human System Risk Assessment

- ❖ Limited spaceflight data to support risks - astronaut population is small within 55 years of spaceflight history.
- ❖ Data collection protocols different over time – no consistency in spaceflight data.
  - Need epidemiological expertise to analyze data.
- ❖ We rely on broader body of evidence from terrestrial sources from which we can only make inferences about human spaceflight risks.
  - E.g., terrestrial population clinical data, analog data, ground experiments

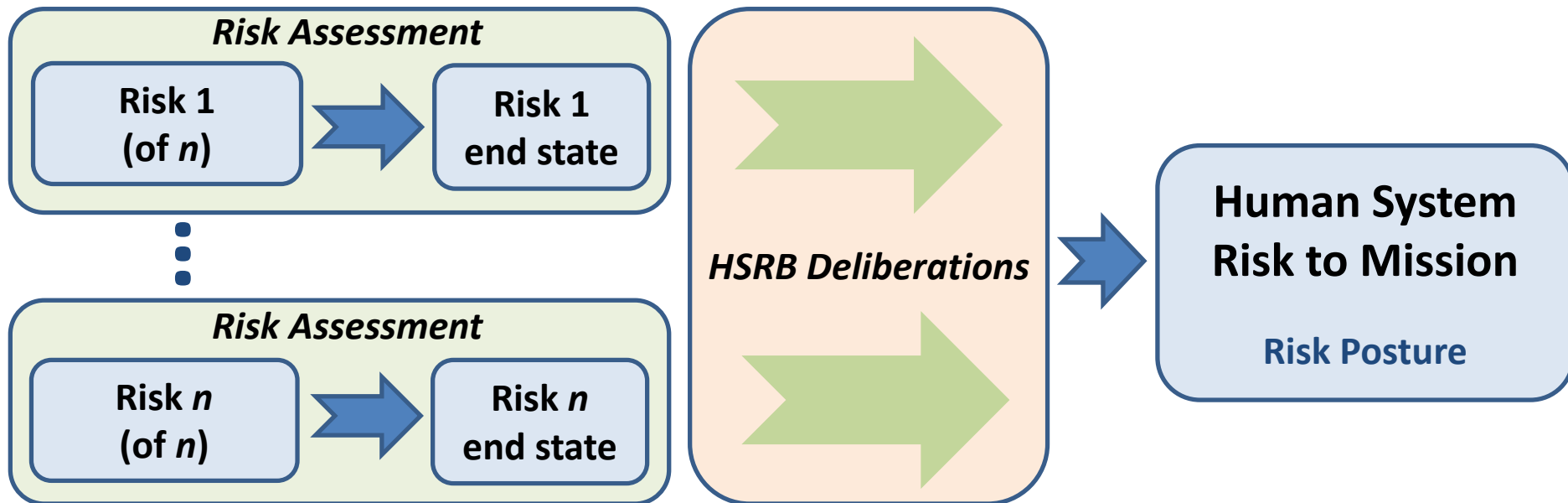
# Human System Risk Assessment

- ❖ For human system risks, NASA primarily uses qualitative risk methods.
  - Each risk represents only **an aspect of a subsystem** of the human body 'system' so parts do not necessarily sum up to the whole.

Each subsystem is too broad to cover only one health/performance risk.



# Human System Risk Assessment



# How are the unique issues addressed?

HSRB doesn't use any systematic approach but considers the complexity of the human system and integration of risks...

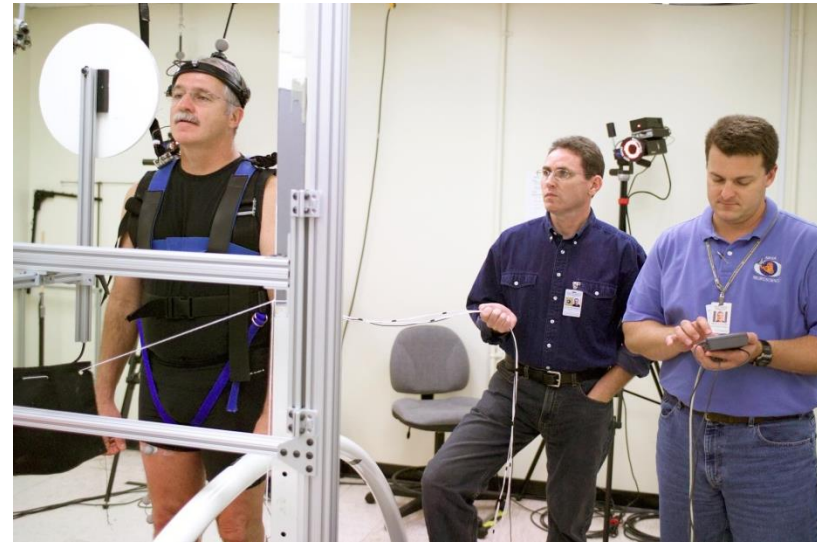
- ❖ In describing risks to properly assess LxC...e.g,
  - *How do possible virulence changes in microorganisms (**Microhost Risk**) interact with potential changes in the immune system that would be manifested in clinical outcomes (**Immune Risk**)?*
  - *How does fatigue (**Sleep Risk**) impact crew performance during critical tasks (**Task Risk and Human-Robotics Risk**)?*

# How are the unique issues addressed?

- ❖ ...And in directing work to different entities to ultimately lower LxC...e.g.,
  - Could work for a risk create or exacerbate another risk?



*Do fluid shift control devices (for **Visual Impairment Risk**) negatively impact neuro-vestibular issues (**Sensorimotor Risk**)?*



# How are the unique issues addressed?

- Could work for a risk partially mitigate another risk?

*To what extent do exercise countermeasures (for **Muscle Risk**) lead to...*



*stronger bones?  
(**Bone Risk**)*

Source: patriothealthreport.com



*healthier minds?  
(**Behavioral Risk**)*

Source: businesswolf.org



*lower risk of  
radiation illness?  
(**Radiation Risk**)*

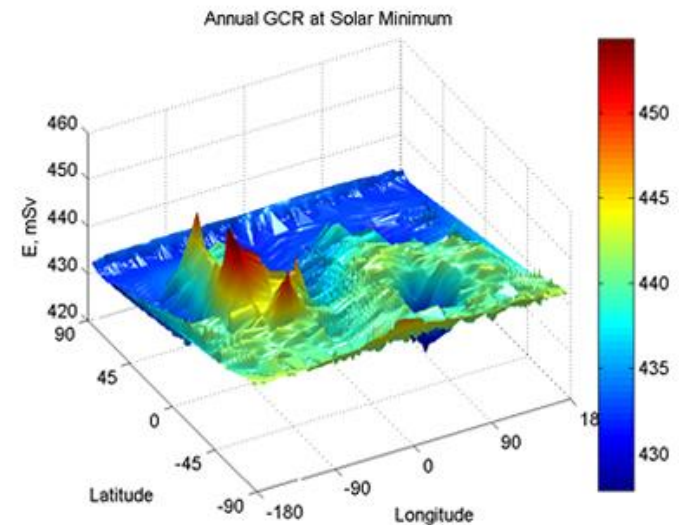
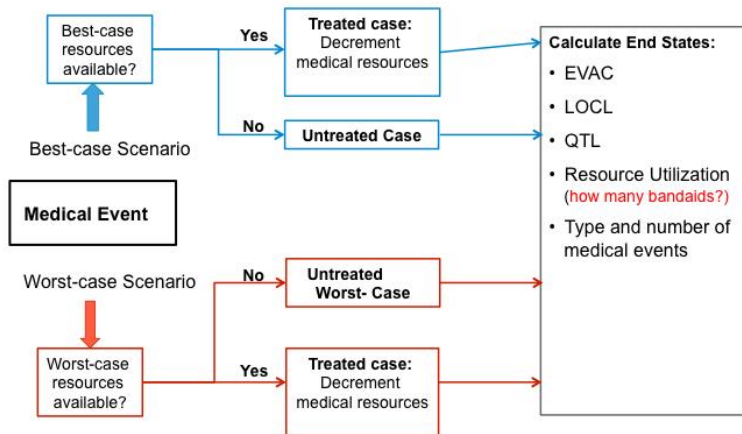


Source: i.kinja-img.com

# How are the unique issues addressed?

- ❖ HSRB is flexible with risk assessment approaches to use on the best available evidence –
  - Quantitative models when available – e.g. HRP medical system model, HRP radiation risk models

## Integrated Medical Model



# How are the unique issues addressed?

- Subject Matter Expert opinion – flight surgeons, scientists and engineers...

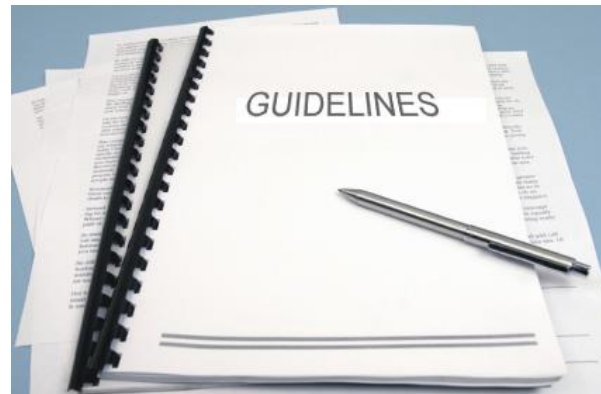


Source: kamaladevi.com

- Combination of approaches - semi-quantitative

# How are the unique issues addressed?

- ❖ Assumptions and rationale for judgments are documented.
  - For consistency, LxC analyses use only the applicable existing countermeasures and standards for exploration missions.
  - Guidelines for risk assessment and applicable rules-of-thumb are being developed.



Source: [asset-tilburg.nl](http://asset-tilburg.nl)



Source: [atleastihaveabrain.files.wordpress.com](http://atleastihaveabrain.files.wordpress.com)

# How are the unique issues addressed?

What about HRP?

- ❖ HRP tracks shared tasks and gaps in research plans among the risks and across Elements

## HRP Human Research Roadmap

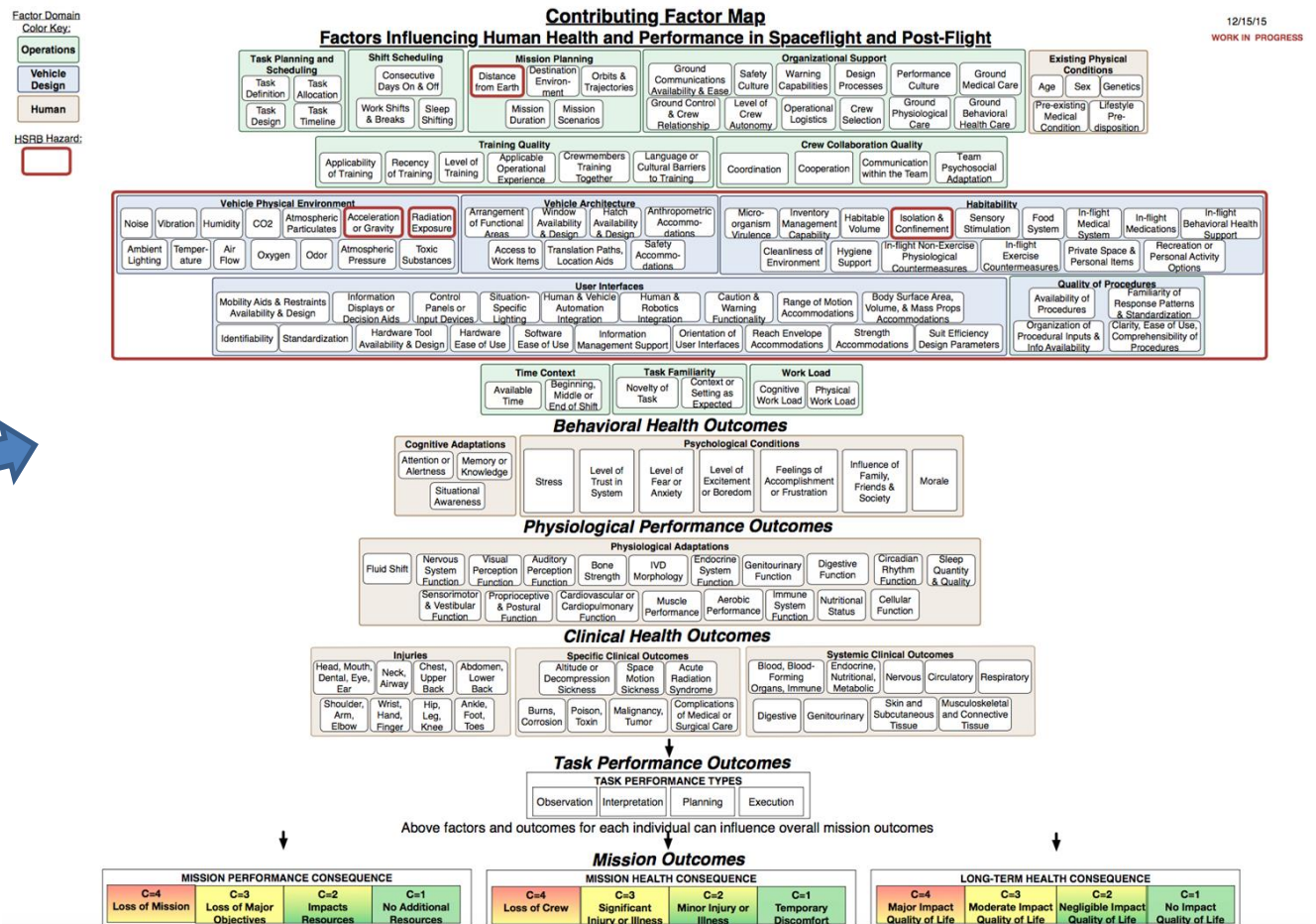
<http://humanresearchroadmap.nasa.gov/>





# How are the unique issues addressed?

- ❖ HRP uses a taxonomy framework to develop insights on potential integration points between risks.

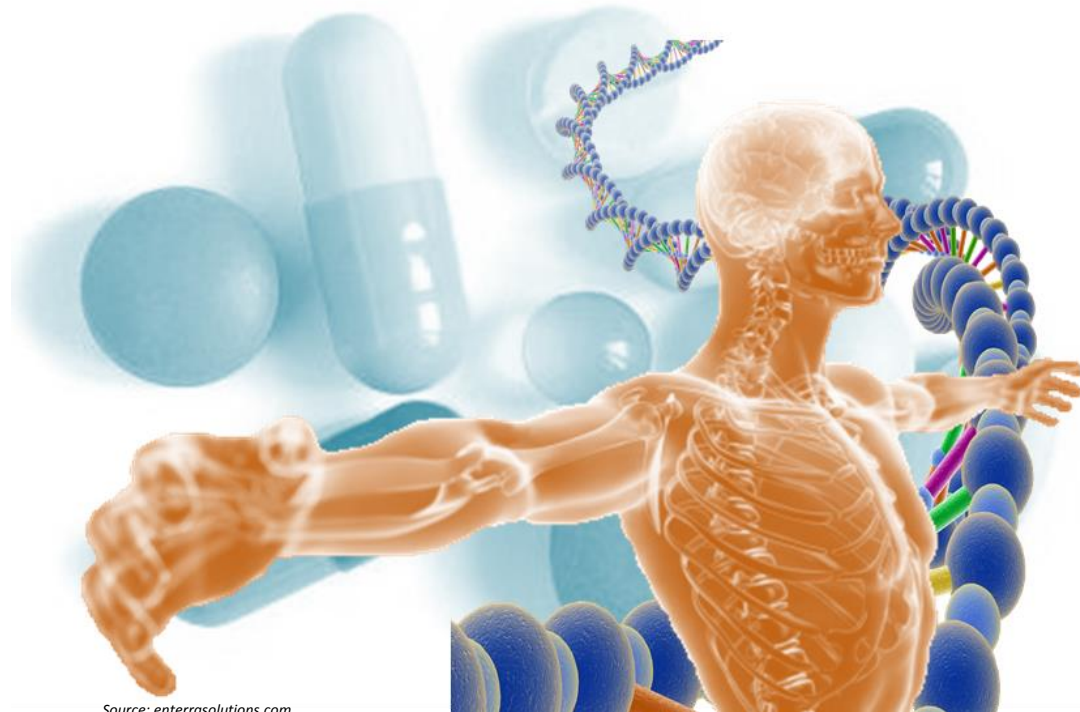


Taxonomy for human system variables



# How are the unique issues addressed?

- ❖ HRP is exploring genomics research to understand individual variation and potentially develop personalized countermeasures.



# Conclusions

- ❖ The general approach for quantitative risk assessments of engineering systems at NASA is difficult to apply to human system risks.
- ❖ HSRB considers how the complexity of human systems and unique nature of these risks impact LxC assessment.
- ❖ HRP incorporates these same considerations in the design of research plans and in its research management framework.

*The HRP Risk Team supports the HSRB in improvements to and execution of the risk assessment process (and the risk management process in general).*

# THANK YOU!

*HRP Risk Team  
(and HSRB Support)*

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