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

Wilma Anton

Wyle-Johnson Space Center

Maria Havenhill

Glenn Research Center

Eric Overton

Glenn Research Center

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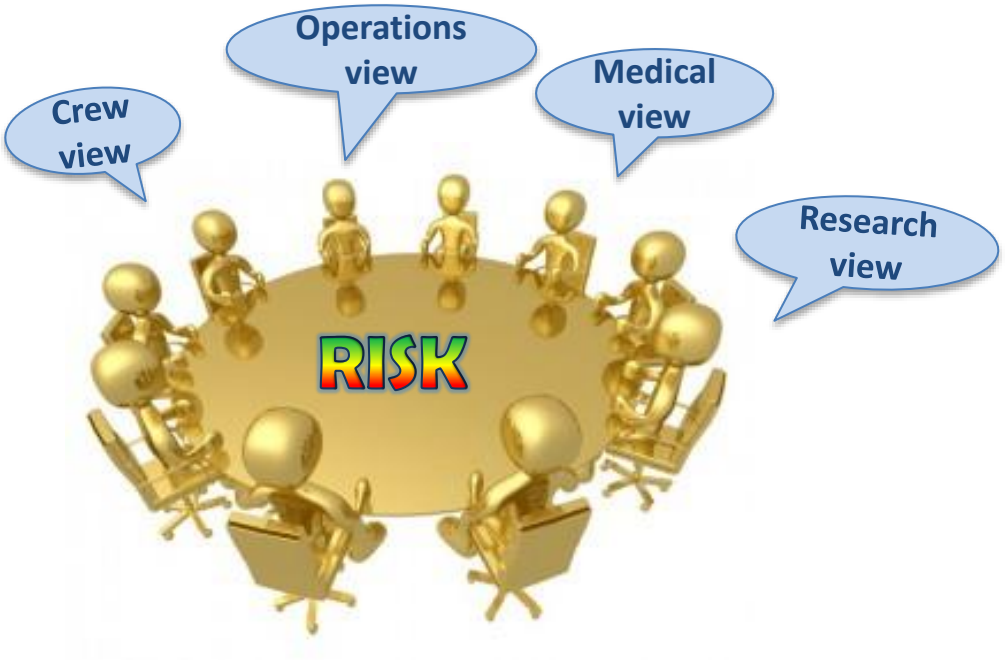
Background

- 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)

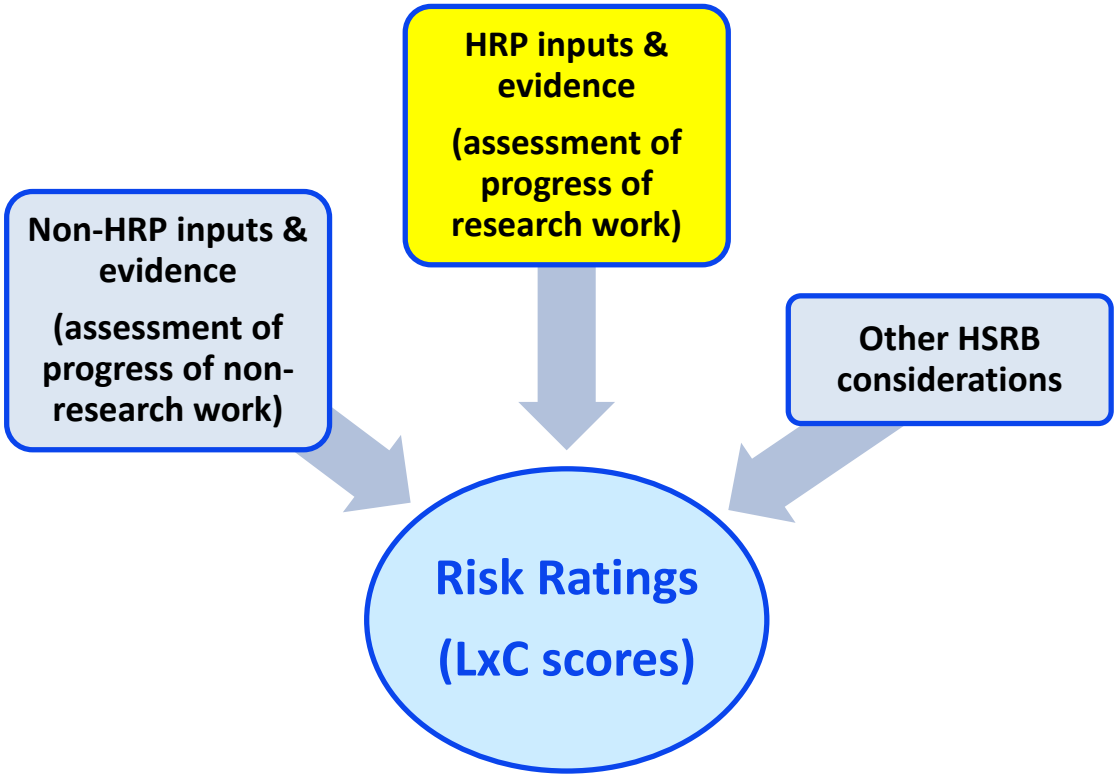
Consequence outcomes are evaluated for two categories:

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.

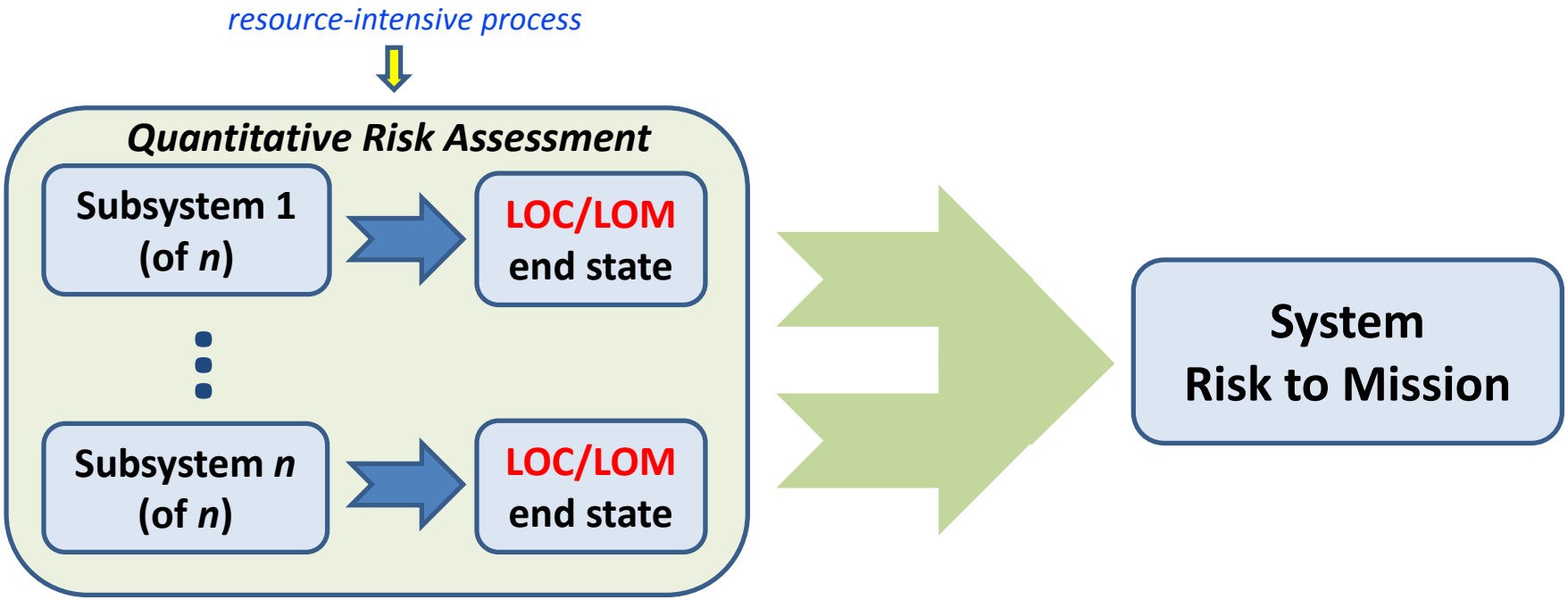
Traditional Engineering Risk Assessment

- 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



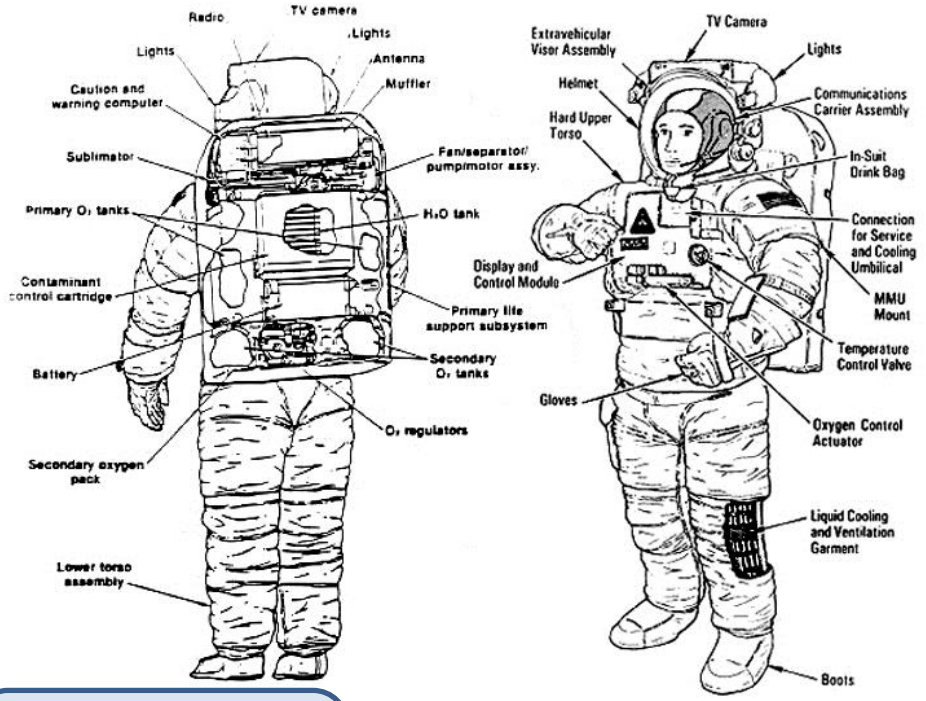
Example of a Traditional Engineering Risk Assessment

Quantitative Risk Assessment

Battery	LOC end state
Secondary Oxygen System	LOC end state
Fan/Separator /Pump/Motor Assembly	LOC end state
Display and Control Module	LOC end state

Etc.

ISS Suit* Malfunction Risk to Crew



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

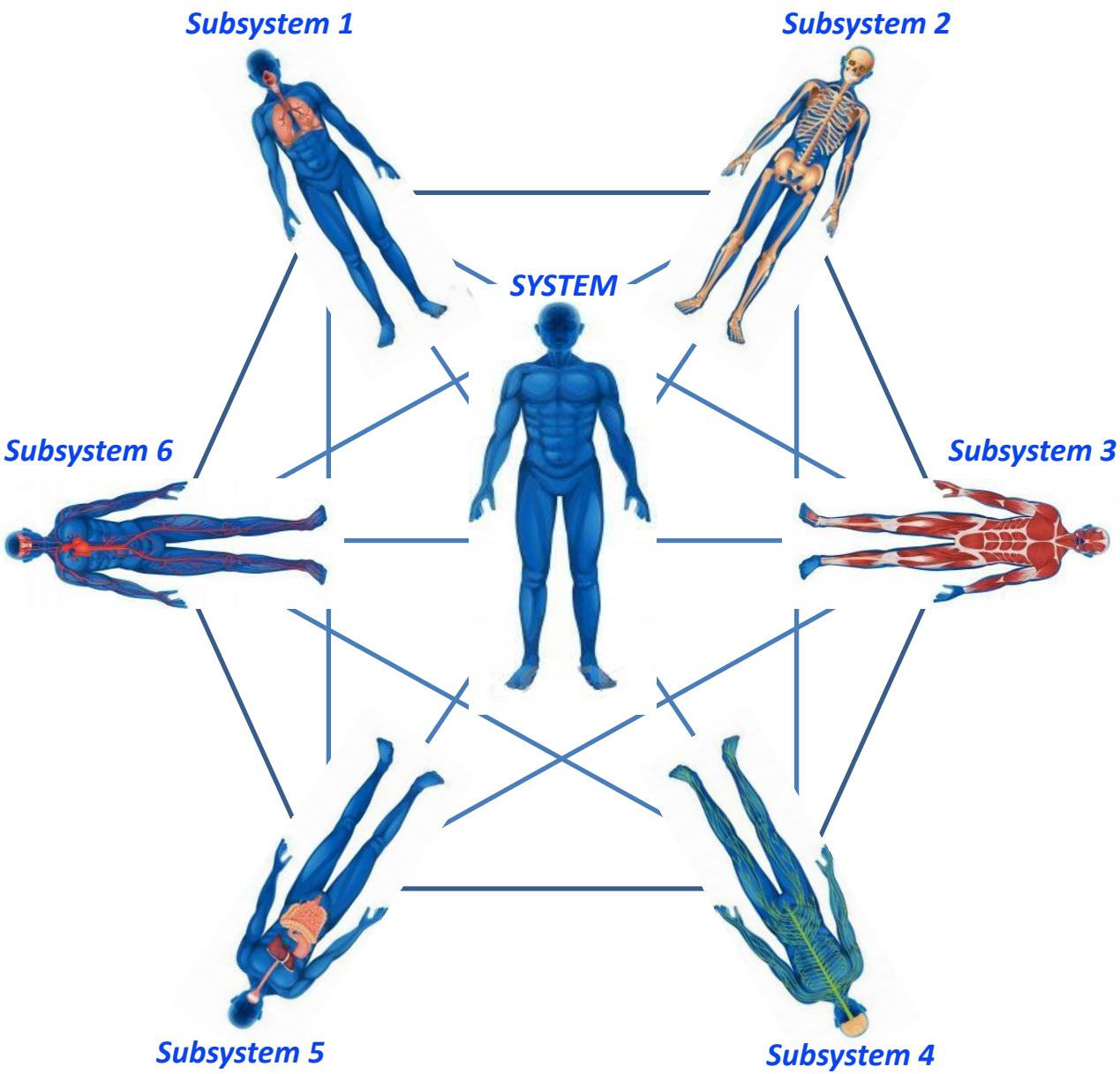
Aspects of Traditional Engineering Systems

- 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.

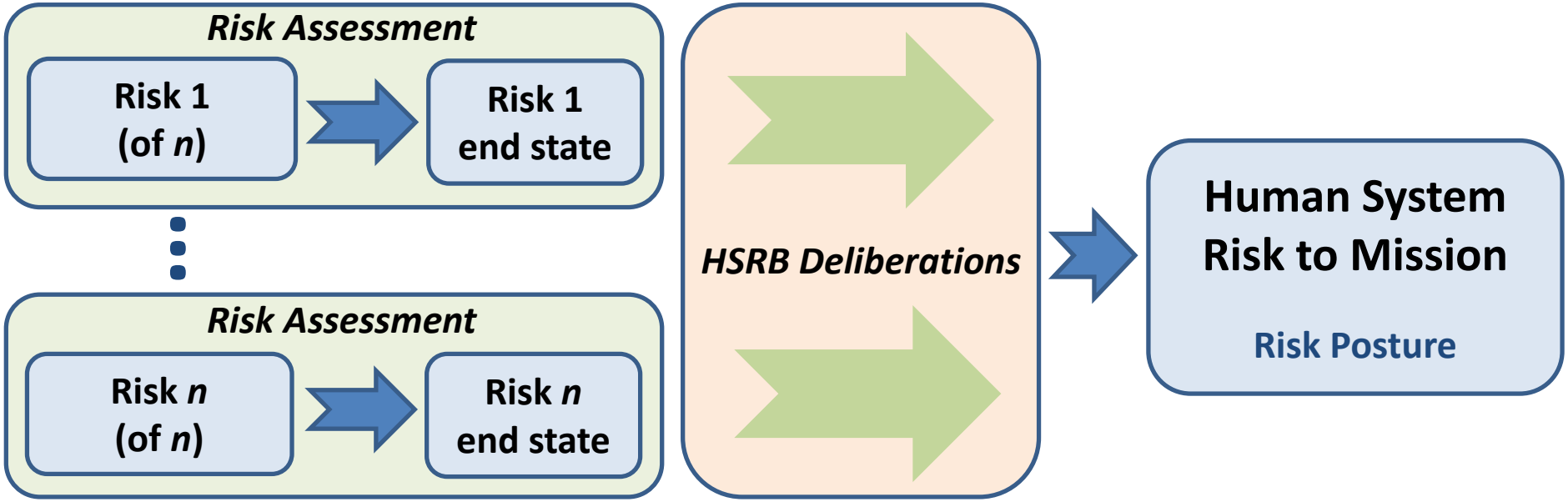
- We rely on broader body of evidence from terrestrial sources from which we can only make inferences about human spaceflight risks.
  - E.g., terrestrial population clinical data, analog data, ground experiments

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?

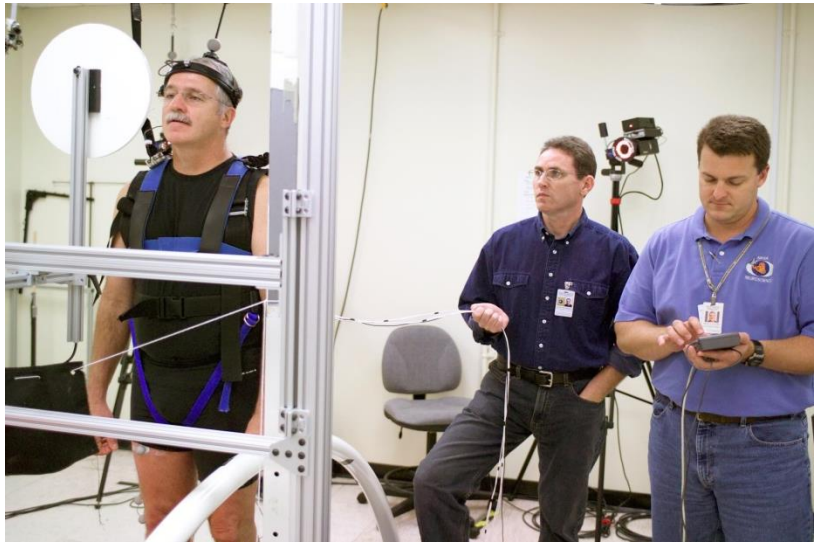
HSRB doesn't use any systematic approach but considers the complexity of the human system and integration of risks…

- 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…*

Source: patriothealthreport.com

stronger bones?
(Bone Risk)

Source: businesswolf.org

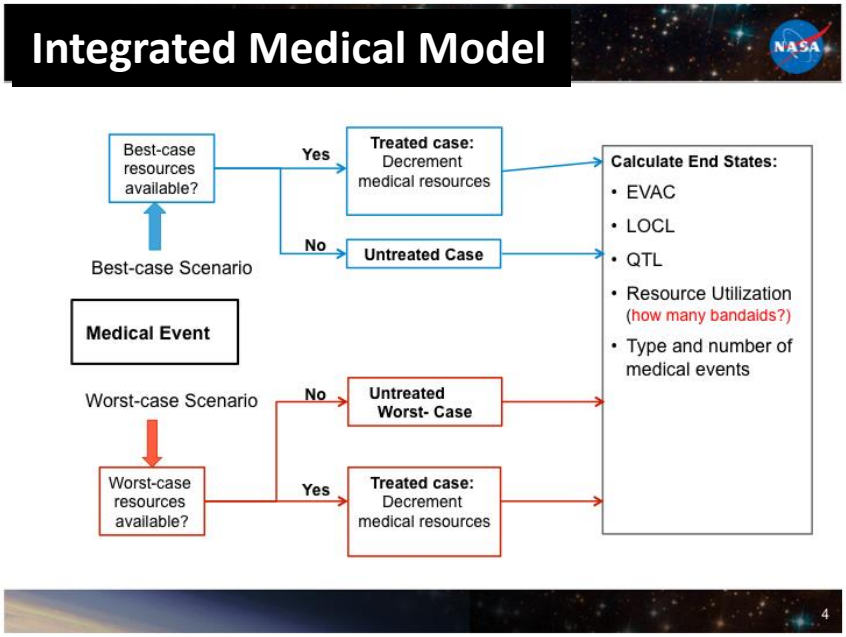
healthier minds?
(Behavioral Risk)

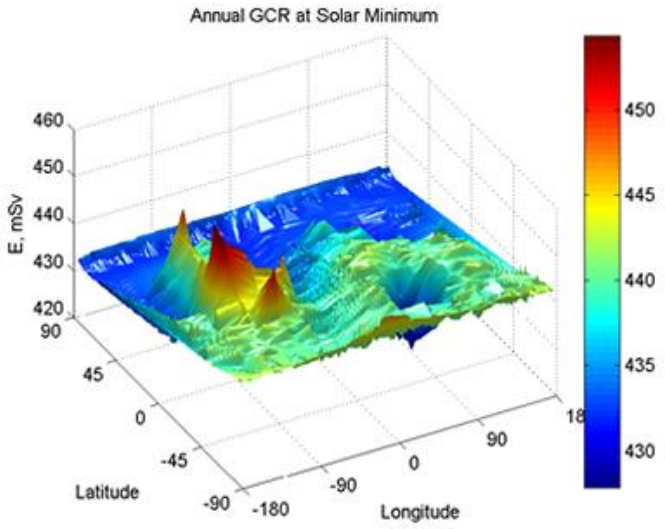
Source: i.kinja-img.com

lower risk of radiation illness?
(Radiation Risk)

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





How are the unique issues addressed?

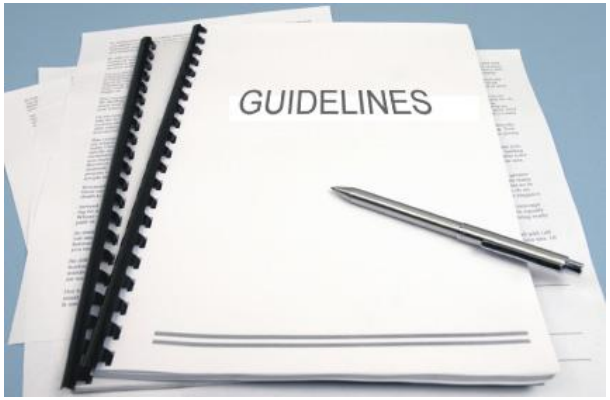
- Subject Matter Expert opinion – flight surgeons, scientists and engineers…

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

Source: 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

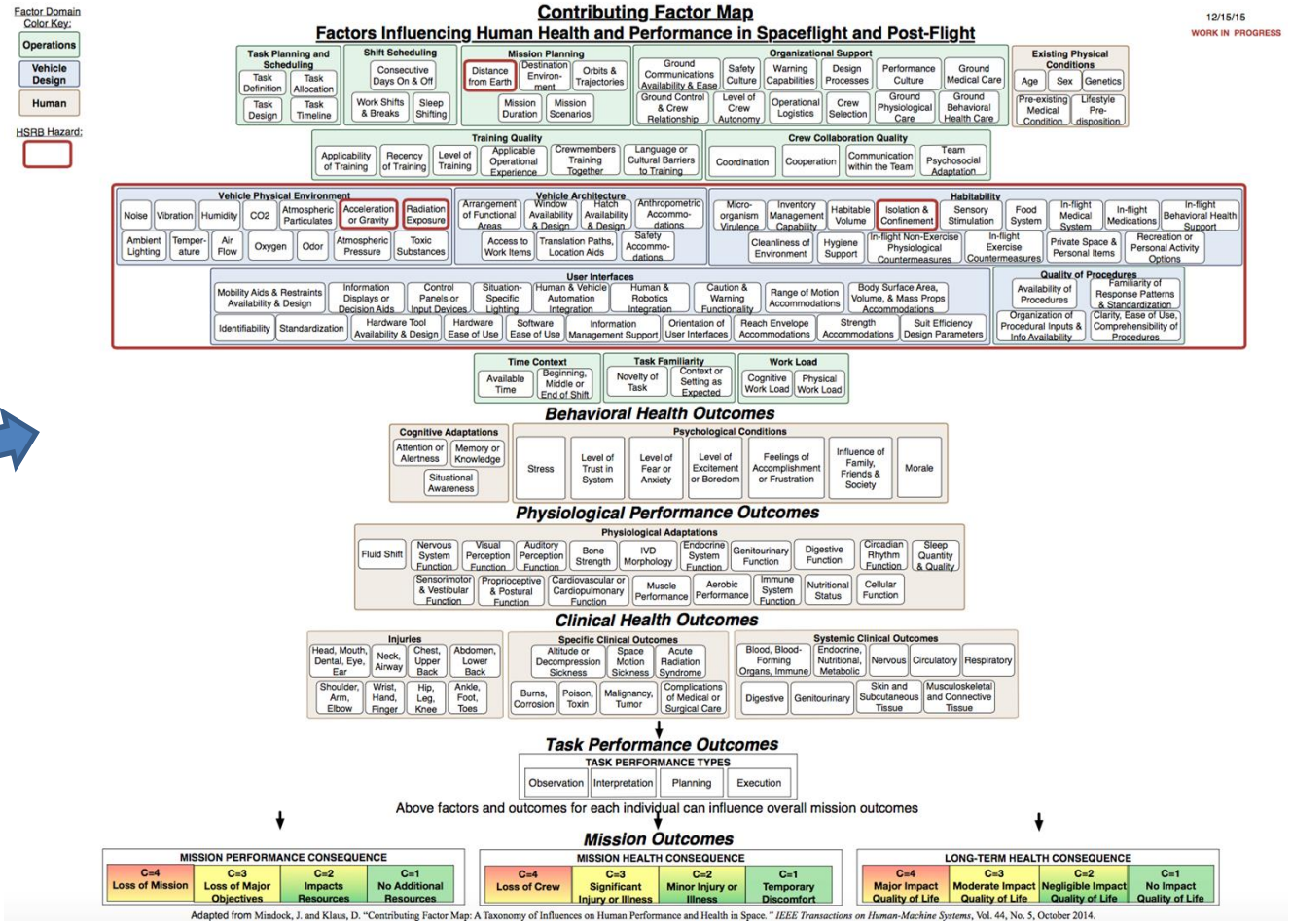
HRP Human Research Roadmap

http://humanresearchroadmap.nasa.gov/

How are the unique issues addressed?

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

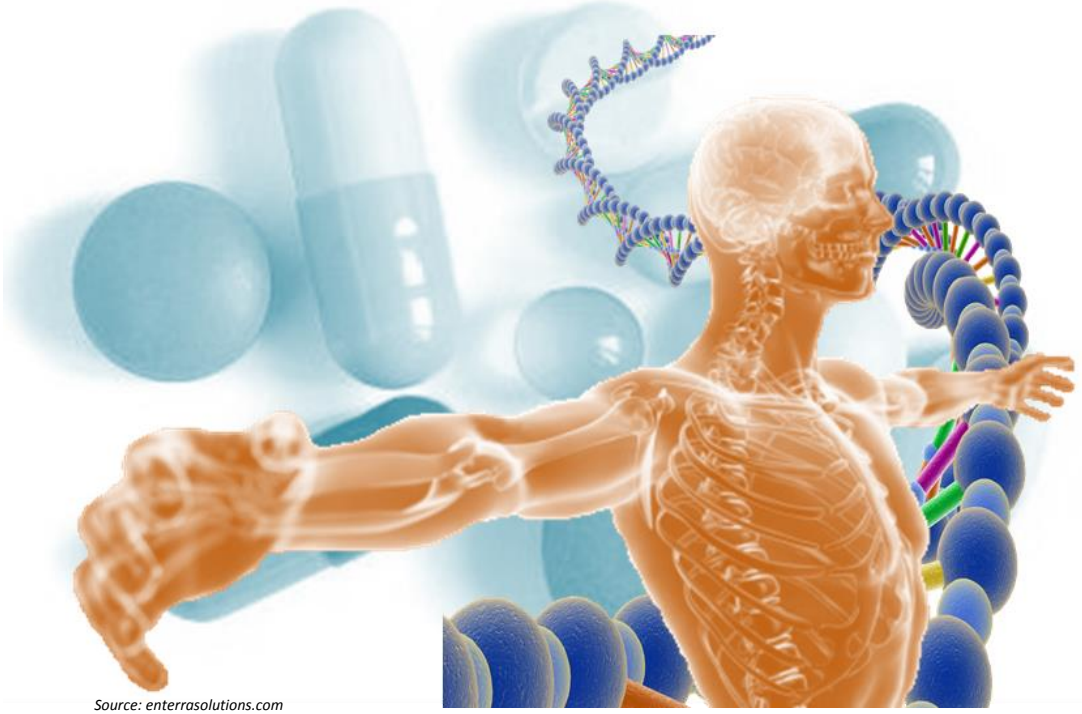
Taxonomy for human system variables



Adapted from Mindock, J. and Klaus, D. "Contributing Factor Map: A Taxonomy of Influences on Human Performance and Health in Space." *IEEE Transactions on Human-Machine Systems*, Vol. 44, No. 5, October 2014.

How are the unique issues addressed?

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



Source: enterrasolutions.com

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)

Maria Havenhill
Risk Manager
Human Research Program
mariatheresa.a.havenhill@nasa.gov
216-433-3694

Eric Overton
Risk Manager
Human Research Program
eric.overton-1@nasa.gov
216-433-2280

Wilma Anton
Senior Risk Analyst
Human Research Program
wilma.anton@nasa.gov
281-461-2613