Strategies for Quantifying Human Space Flight Performance in the Crew Health and Performance System

Crew Health and Performance
Probabilistic Risk Assessment Project
(**CHP-PRA**)

Mona Matar, Ph.D.[1]
Hunter Rehm , Ph.D.[2]
Caroline Austin[3]
Suleyman Gokoglu , Ph.D.[1]
Lauren McIntyre[1]
Jerry Myers , Ph.D.[1]

1 NASA Glenn Research Center
2 HX5
3 University of Colorado Boulder

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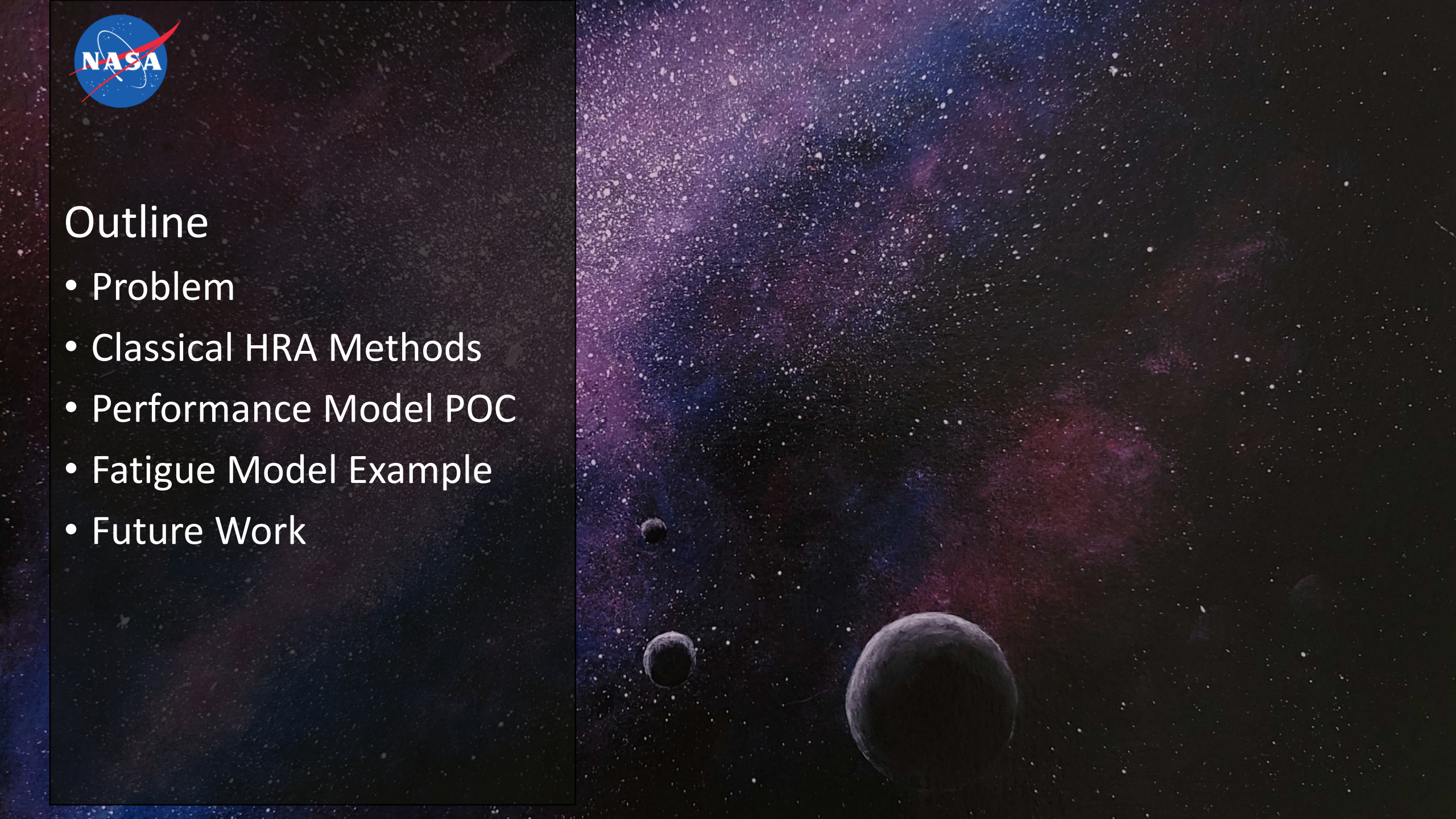
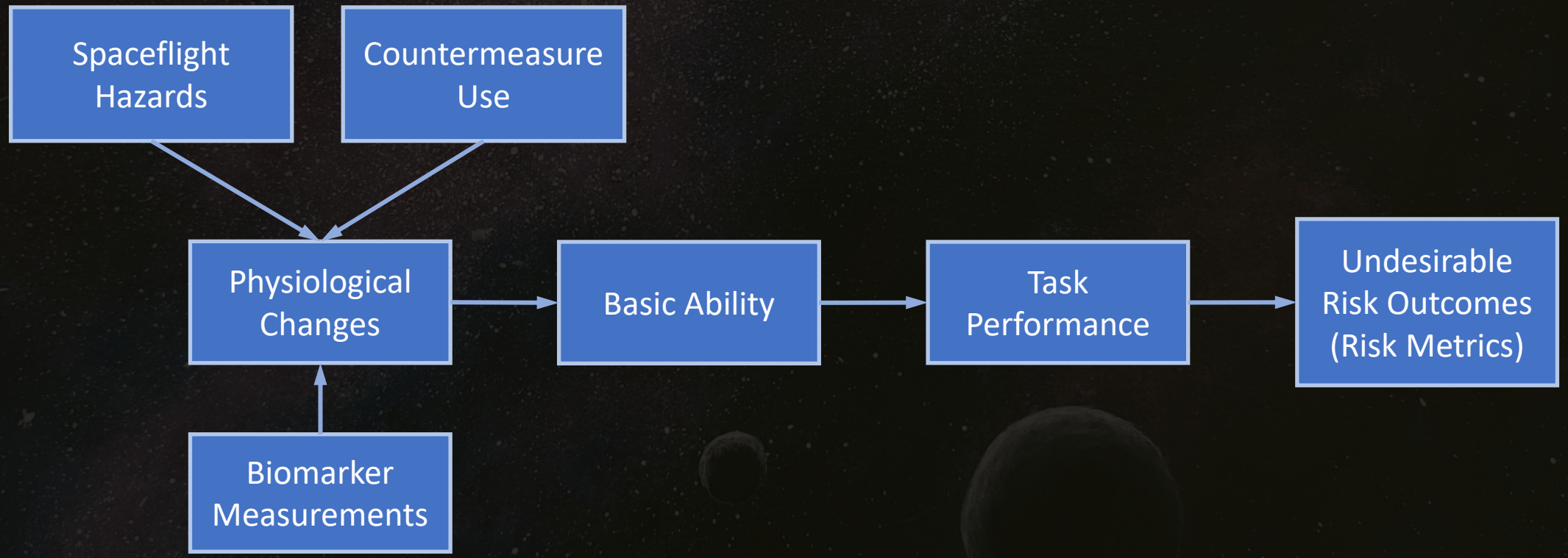


Outline

- Problem
- Classical HRA Methods
- Performance Model POC
- Fatigue Model Example
- Future Work

Problem

The Crew Health and Performance (CHP) system relies on astronauts' individual readiness and crew performance in decisions and tasks.



Classical HRA Methods

Human Reliability Analysis (HRA)

Analysis of the contribution of human errors to systems' safety and failure

HRA steps

- Task analysis and Performance Shaping Factor (PSF) definition
- Human error identification, representation, and quantification

Classical methods have generic predefined tasks and PSFs with associated scaling factors.

Classical HRA Methods

HRA Methods used in NASA programs

For Shuttle and International Space Station (ISS) :

- Technique for Human Error Rate Prediction (THERP)
- Cognitive Reliability and Error Analysis Method (CREAM)

Classical HRA Methods

Concerns

- Count errors, do not consider performance spectrum
- Not designed for long-duration mission
- Traditionally involve hardware and software failure
- Tasks very general, do not reflect space life

Previous efforts

- Many recommendations to add space risks as PSFs
- SCREAM: Replace PSF “time of day” with “Fatigue: sleep deprivation”

Performance Model POC

Goal

Quantify the change in performance based on change in human physiological resources

Performance Model POC

Method

1. Identify *physiological resources* that change over time
   - Muscle (strength, endurance)
   - Cognitive (attention, memory, task switch)
   - Sensorimotor (perception, balance)
   - Behavioral (mood state)

Performance Model POC

Method

1. Identify *physiological resources* that change over time
2. Define *categories* of physiological resource

Physiological Resource	HRA Category
A	Observation
B	Observation
C	Interpretation
D	Interpretation
E	Planning
F	Execution
G	Execution

Performance Model POC

Method

1. Identify *physiological resources* that change over time
2. Define *categories* of physiological resource
3. For each *task* identify which/how much physiological resources are needed

Physiological Resource	HRA Category
A	Observation
B	Observation
C	Interpretation
D	Interpretation
E	Planning
F	Execution
G	Execution

Task	Associated Physiological Resources
Red	A, E, F, G
Orange	A, B, D
Yellow	10%B, 50% D, 40% G
Green	15%A, 65% D, 20% E
Blue	95% G
Purple	3xA, 2xC, 5xF

Performance Model POC

Method

1. Identify *physiological resources* that change over time
2. Define *categories* of physiological resource
3. For each *task* identify which/how much physiological resources are needed
4. Determine the level of *granularity* (mission, segment, day, task)

Static Approach

Day 1 / Segment 1/ Mission	Day 2 / Segment 2/ Mission
10xA	11xA
4xB	4xB
3xC	5xC
6xD	7xD
5xE	3xE
5xG	3xG

Day 1 or Segment 1 or Mission	Day 2 or Segment 2 or Mission
14x Observation	15x Observation
9x Interpretation	12x Interpretation
5x Planning	3x Planning
11x Execution	8x Execution

Performance Model POC

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Dynamic Approach

	Day 1	Day 2
Task 1	A, E, F, G	A, D, E
Task 2	G	A, B, D
Task 3	A, D, E	A, C, F
Task 4	A, B, D	B, D, G
Task 5	A, B, D	A, B, D
Task 6	B, D, G	A, C, F
Task 7	A, D, E	A, D, E
Task 8	G	G

Task	Associated Physiological Resources
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Mona Matar | mona.matar@nasa.gov

Performance Model POC

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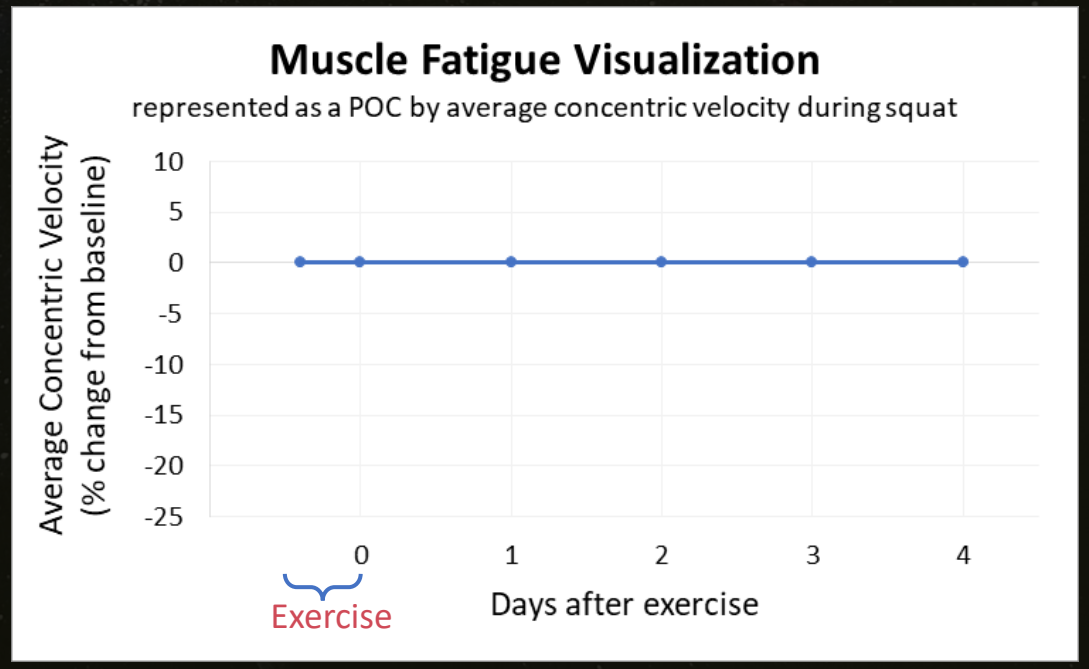
4. Determine the level of *granularity* (mission, segment, day, task)
5. Define *PSFs*

PSF	Affected Physiological Resources	Possible PSF Weight
Exercise	A, B, C, D, E, F, G	One scaling factor for each physiological resource or a function of exercise time or exercise type …
Sleep	F, G	One scaling factor for each physiological resource or a function of sleep time
Hydration	A, D	One scaling factor for each physiological resource or a function of hydration variables
Countermeasure X	E	Step function (using vs. not using)
Countermeasure Y	D, E	Unique additive scaling factors function of time
Space Factor V	B, C, D	Unique additive scaling factors function of exposure

Fatigue Model Example

Method

1. Identify *physiological resources* that change over time
2. Define *categories* of physiological resource
3. For each *task* identify which/how much physiological resources are needed
4. Determine the level of *granularity* (mission, segment, day, task)
5. Define PSFs
6. Quantify the *fluctuation* of physiological resources over time and with activities



Mona Matar | mona.matar@nasa.gov

Fatigue Model Example

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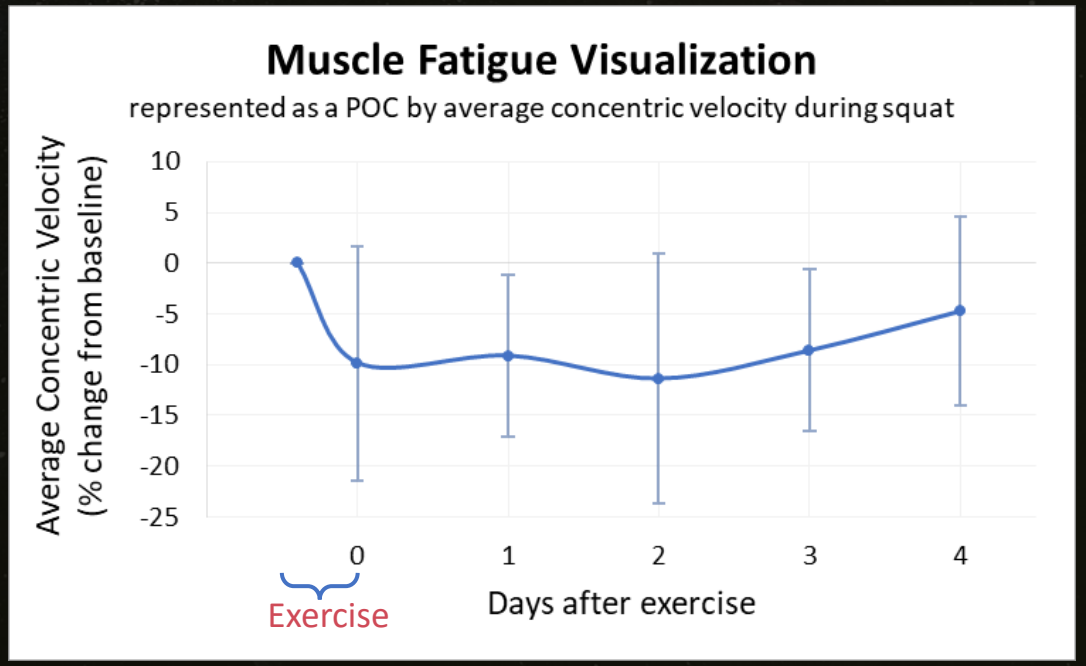


Belcher, Daniel J., et al. "Time course of recovery is similar for the back squat, bench press, and deadlift in well-trained males." *Applied Physiology, Nutrition, and Metabolism* 44.10 (2019): 1033-1042.

Performance Model POC

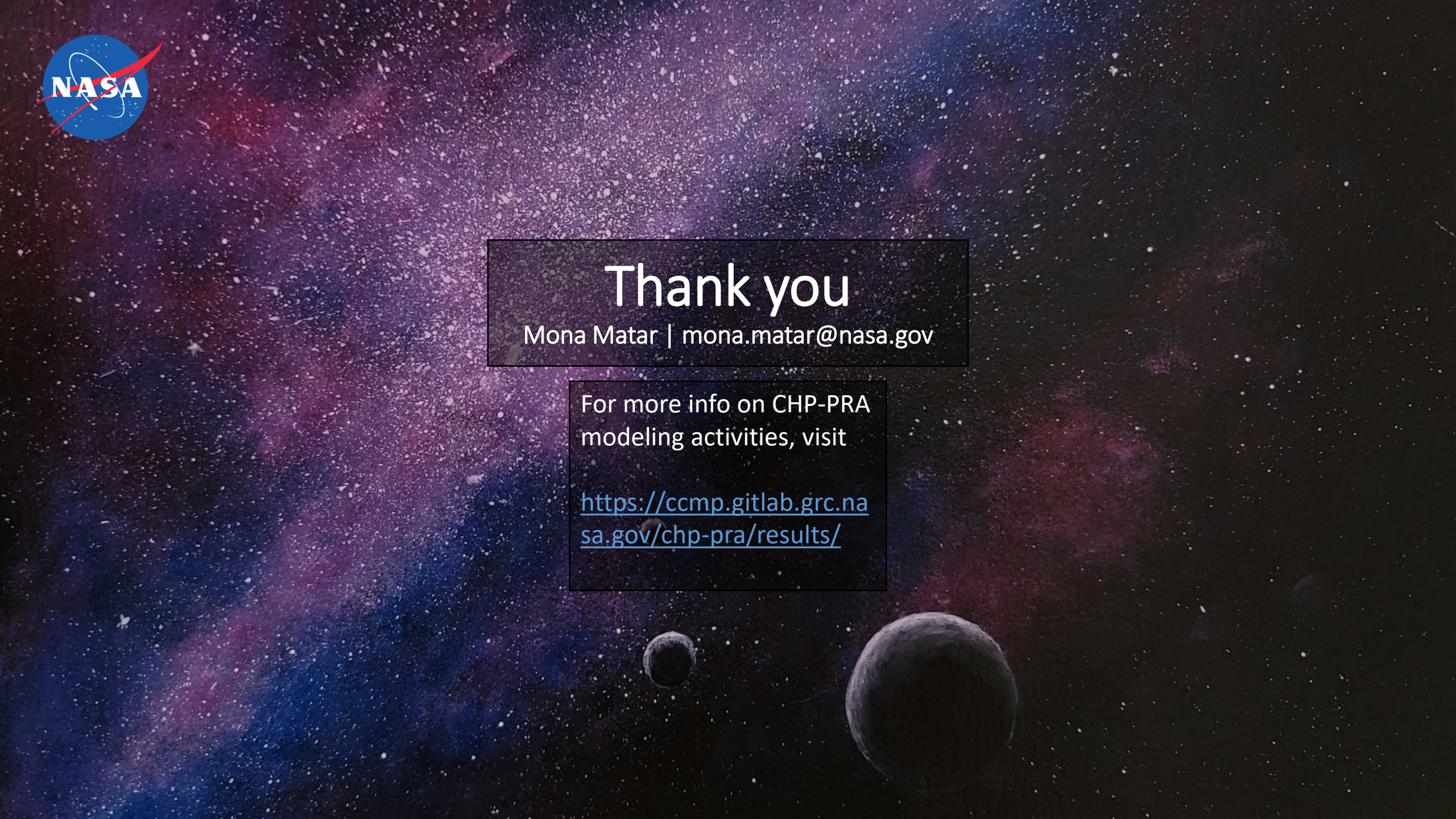
Method

1. Identify *physiological resources* that change over time
2. Define *categories* of physiological resource
3. For each *task* identify which/how much physiological resources are needed
4. Determine the level of *granularity* (mission, segment, day, task)
5. Define PSFs
6. Quantify the fluctuation of physiological resources over time and with activities
7. Analyze the effect on astronaut performance

Future Work

- Prioritize physiological resources specific to spaceflight tasks
- Categorize resources
- Determine the level of task and time granularity
- Analyze inter-dependency between different factors and resultant combined effect
- Integrate HRA into CHP-PRA models for a comprehensive mission risk metrics quantification

*Future work depends on the availability of data from the field and related disciplines.


Thank you
Mona Matar | mona.matar@nasa.gov
For more info on CHP-PRA modeling activities, visit
https://ccmp.gitlab.grc.nasa.gov/chp-pra/results/