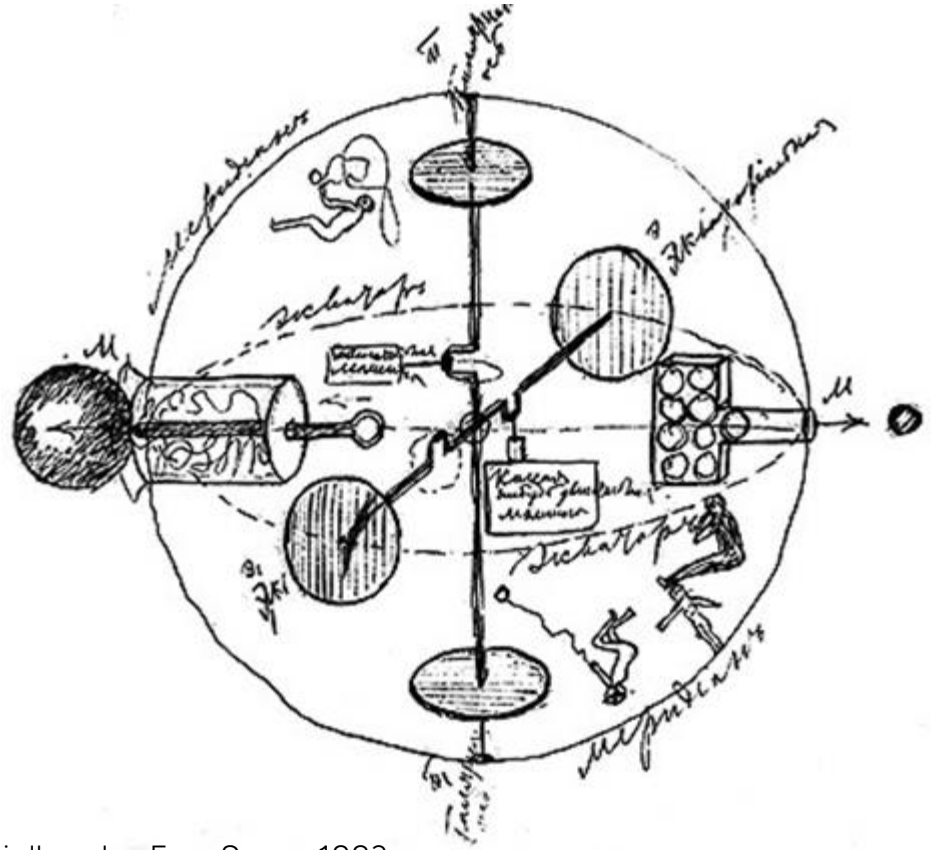
How can we better design spaceships and space stations?

Michail Magkos

Linköping , September 17th 2024

Role of Habitat Design



Tsiolkovsky, Free Space 1883

- Ensuring health, enhancing psychological resilience and cognitive function.
- Proactively supporting crew dynamics, morale, performance.
- Creating affordances for crew tasks

Impact of Environmental Conditions on Well-being

- Importance beyond aesthetics.
- Psychological and physiological stressors.

Stimulation	*Affordances*
intensity	ambiguity
complexity	sudden perceptual changes
mystery	perceptual cue conflict
novelty	feedback
noise	
light	*Control*
odor	crowding
color	boundaries
crowding	climatic & light controls
visual exposure	spatial hierarchy
proximity to circulation	territoriality
adjacencies	symbolism
	flexibility
Coherence	responsiveness
legibility	privacy
organization	depth
thematic structure	interconnectedness
predictability	functional distances
landmark	focal point
signage	sociofugal furniture
pathway configuration	arrangement
distinctiveness	
floorplan complexity	*Restorative*
circulation alignment	minimal distraction
exterior vistas	stimulus shelter
	fascination
	solitude

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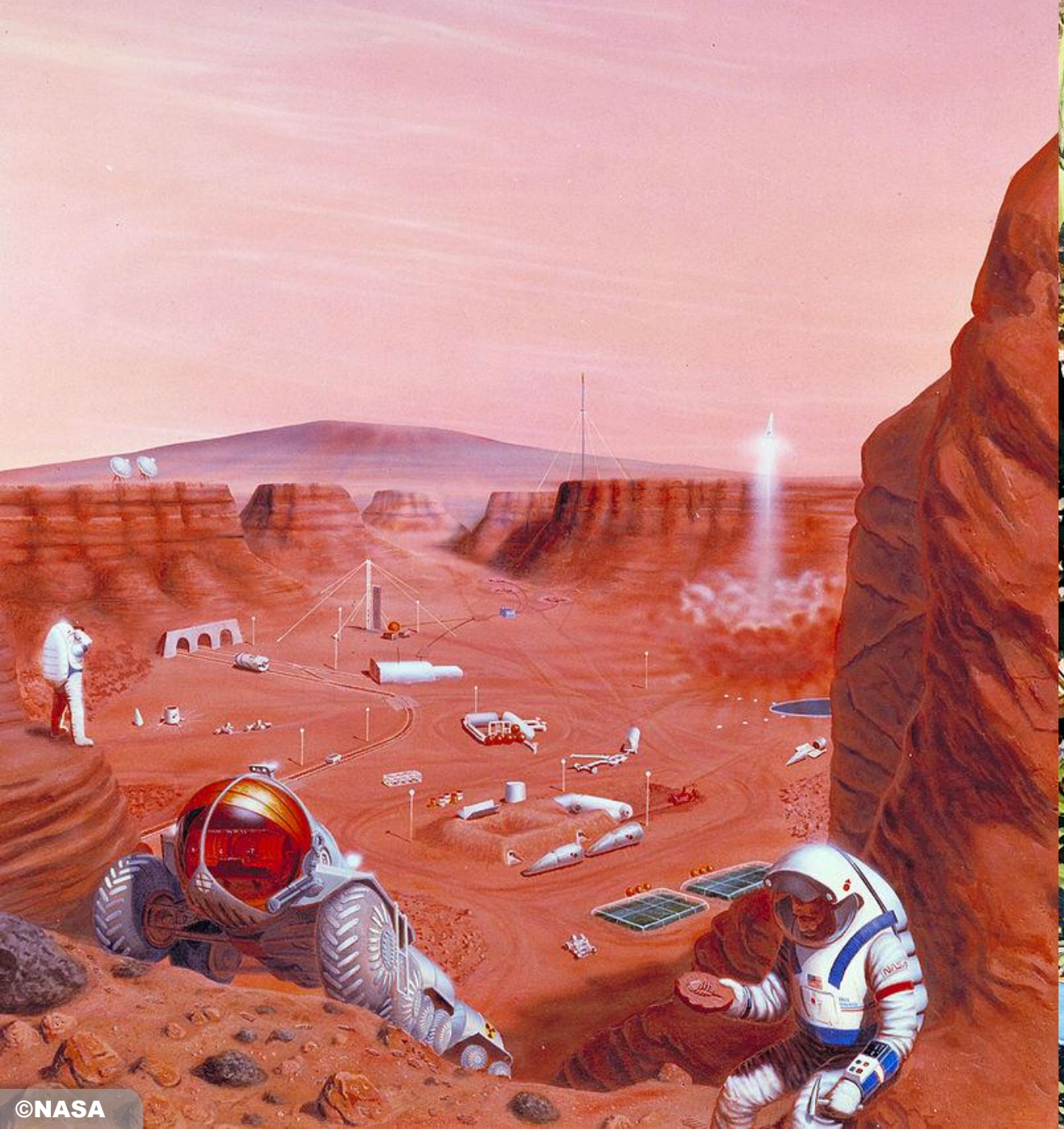
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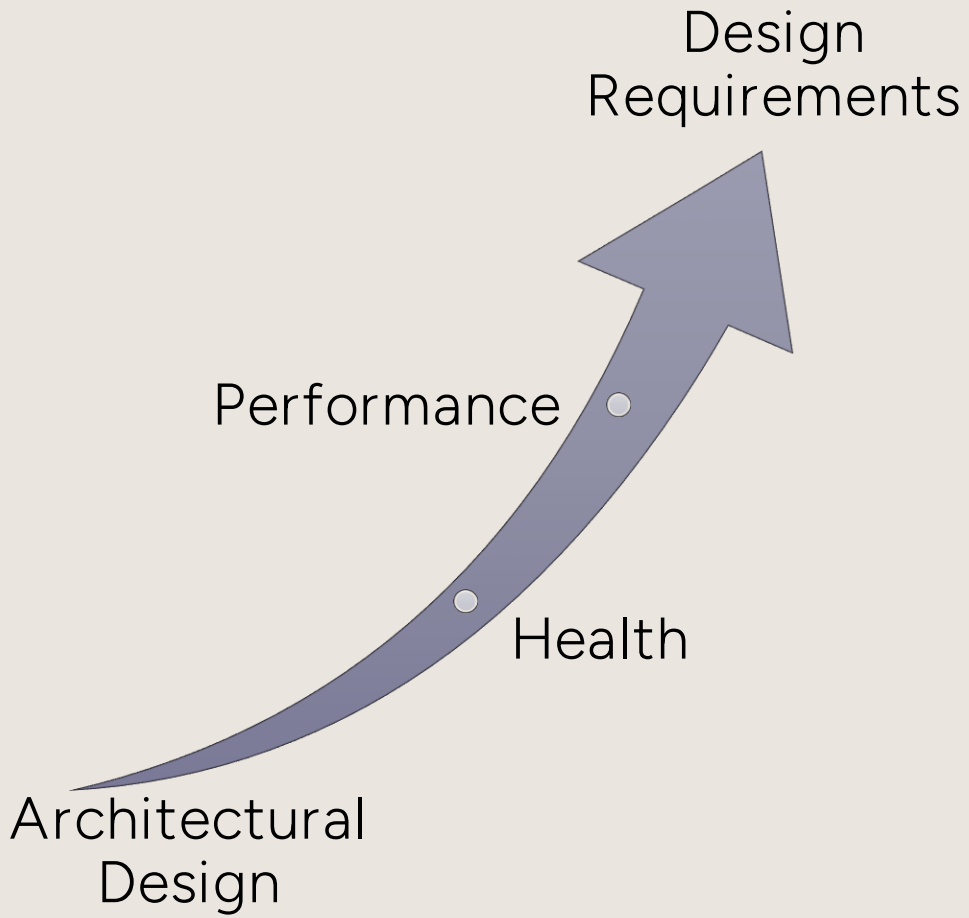
The Study

Architectural Properties' Impact on Stress and Cognition in Isolated and Confined Environments (APISC – ICE) OR Orbital Architecture

- Participants (currently):
  - Analogue Astronauts (20 completed 7 enrolled)
  - Astronaut(s) (1)
- Research Idea:
  - Longitudinally measure the effects of architecture on stress and cognition, during isolation missions.
- Goal:
  - To identify design characteristics that improve crew performance and health, to better inform the design of future bases and stations.



Sub-studies

MDRS 275
(Q1 '23)

MDRS 293
(Q1 '24)

MDRS 311
(Q1' 25)

+ Astronauts

+ Analog Missions

+ Extreme Environments

+ High fidelity analogs

✓ ✓ ✓ ✓ ⧗ ? ?

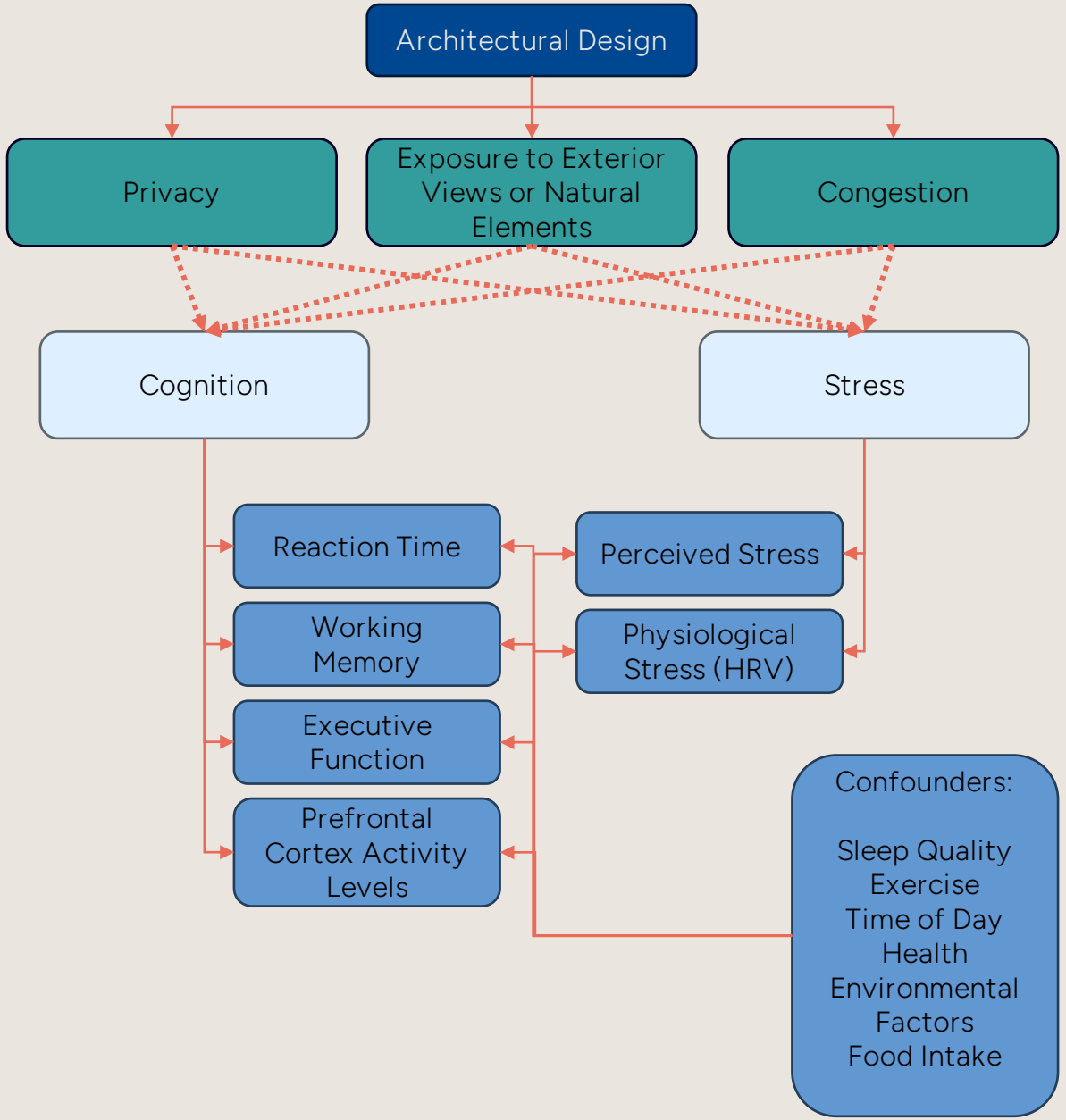
Muninn
(Q1 '24)

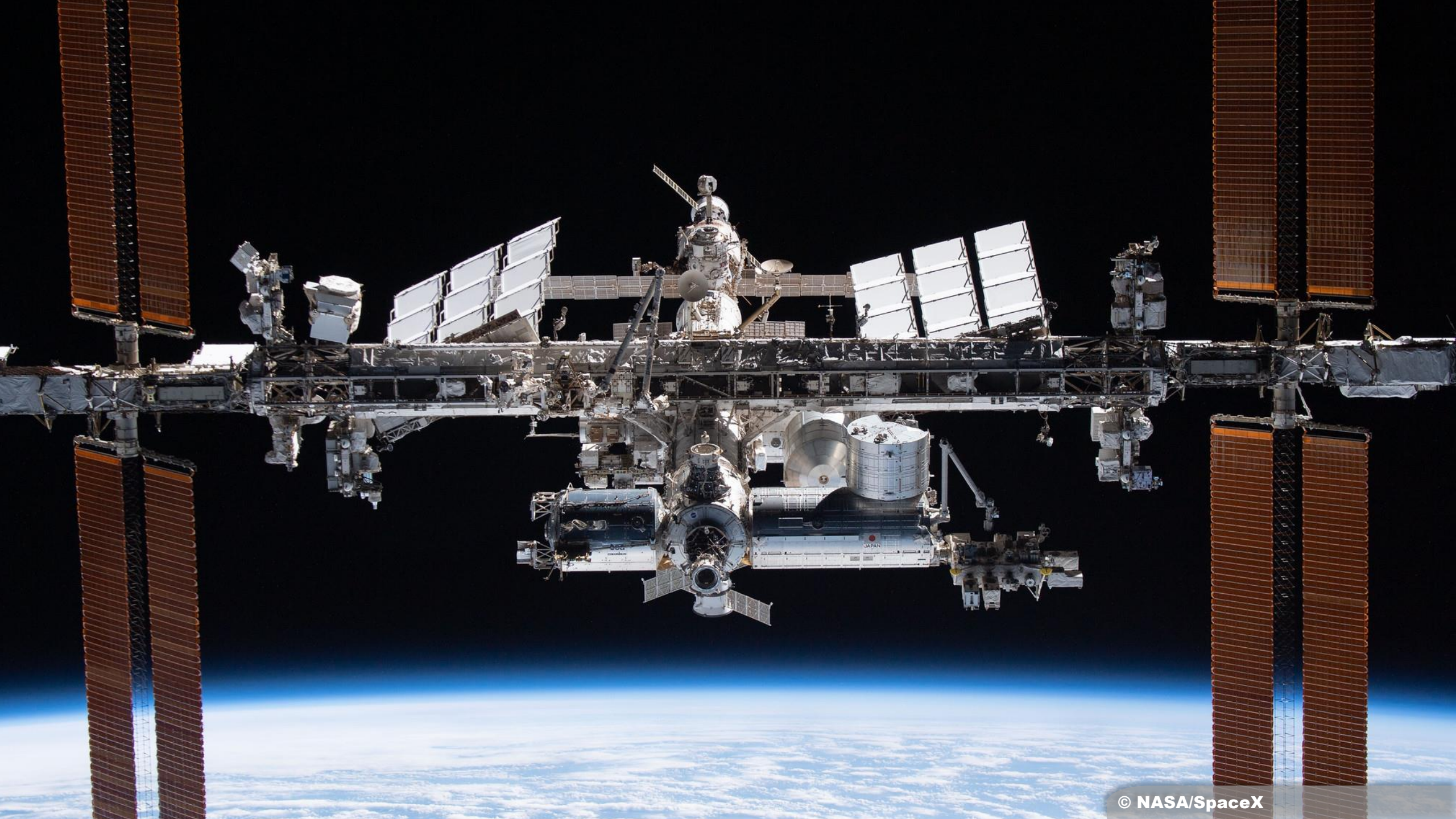
Asclepios IV
(Q3' 24)

ESA 100-day analog
(Q2 – Q4 25)

Methods

- Experimental setup in different locations and timepoints
- Measure cognitive performance through different self-administered computer tasks
- Daily questionnaires on perceived stress
- Measure oxygenation levels in the general prefrontal-cortex area of the brain
- Collect and analyze physiological stress responses, along with location of crew.
- Gather and analyze already collected data as potential confounders to cognitive performance





Experimental Locations - Space

Columbus Module

- Public area

Cupola Module

-Exposure to exterior views

CASA – Crew Alternate Sleep Accomodation

- Private area


© ISAE-SUPAERO, MDRS 293 Crew

Experimental Locations - MDRS

Core Habitat / Common Room

- Public area

Laboratory Module

-Exposure to exterior views

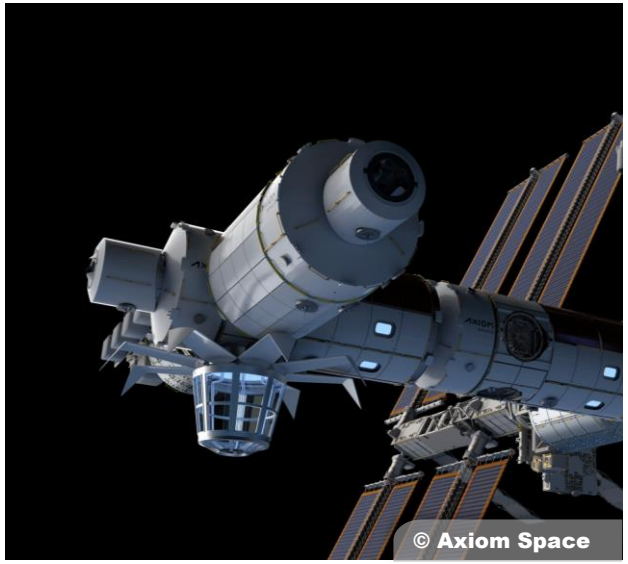
-Private Area

Greenhouse Module

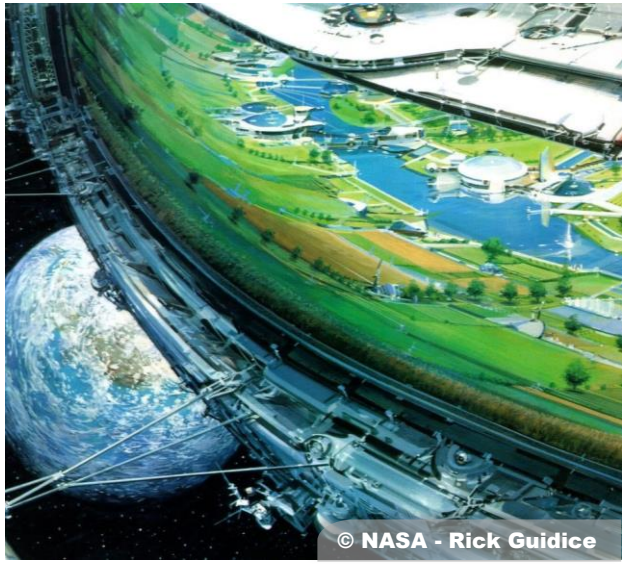
- Private area
-Exposure to Natural Elements

Why?

Upcoming missions in even more extreme environments



NewSpace initiatives into private missions to LEO

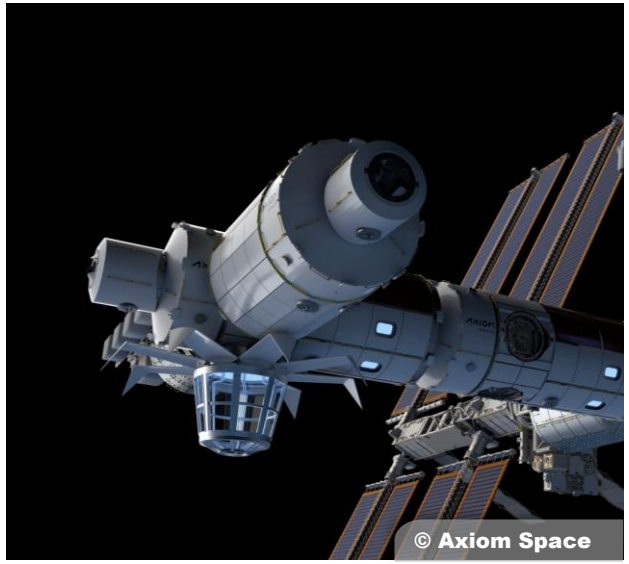


Future broadening of space exploration and exploitation

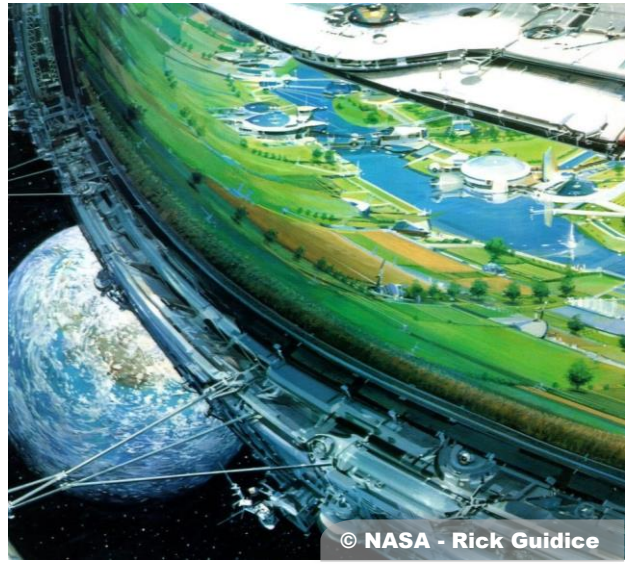
Outcomes

Provide key insights and recommendations for future habitat design requirements and standards.

Assess the relevance and applicability of analog studies in habitat development.



Offer guidance for private habitat designers to proactively create habitats that comply with potential future space agency standards and requirements.



Develop methodologies for evaluating and comparing various habitat designs and their components.

Validate comparisons between terrestrial and orbital habitat environments.

Support

- Funded by Rymdstyrelsen
- Organizational Support from ESA and KTH
- Space Analogue Missions in Collaboration with ISAE-SUPAERO (Toulouse, France)

Rymdstyrelsen
Swedish National Space Agency

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- At ESA:
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- At KTH
  - Catherine Trask, Farhad Abtahi, Jonas Willén, Martin Jakobsson and more





KTH
VETENSKAP
OCH KONST

Backup Slides

MDRS 275 & 293

- Medium duration mission (4 weeks)
- Measure cognitive performance on different station locations and timepoints
- Continuous Stress and Location Monitoring
- Collect data on confounding factors
- 2 missions this far, seven participants each time (14 subjects)

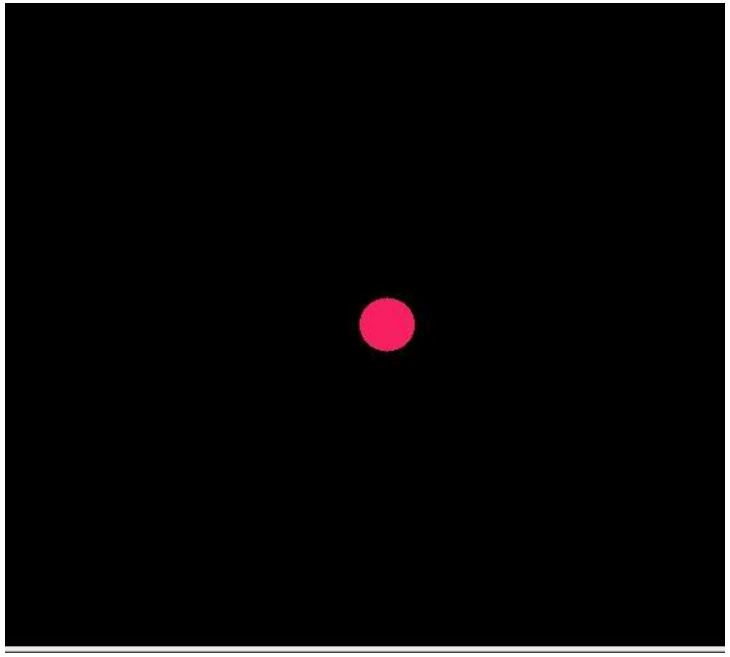
- Continous measurments for 30 days on location and stress
- 9 measurments/participant for cognitive performance

Muninn

- Short duration mission (~~2~~ 3 Weeks)
- Measure cognitive performance on different station locations and timepoints
- Compare results to what was seen on earth
- Study differences in brain oxygenation levels during cognitive tasks
- Collect data on confounding factors

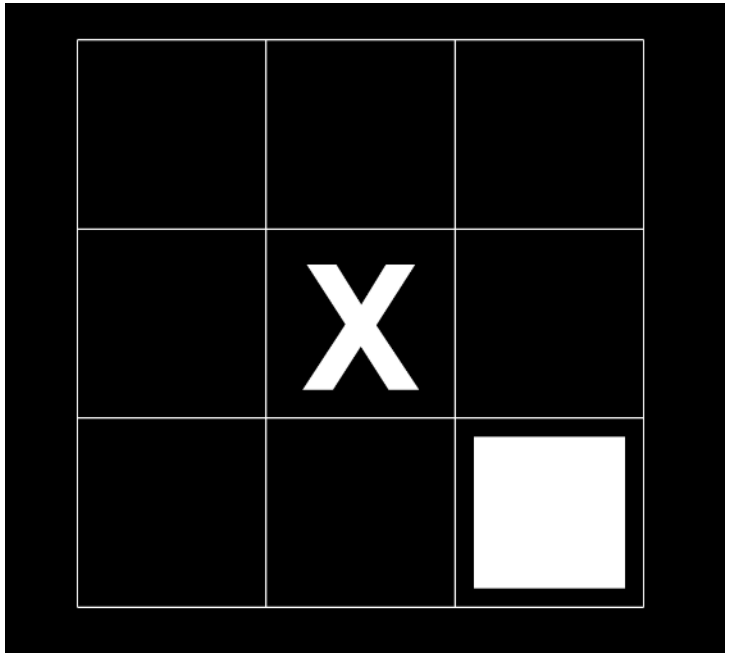
- Overall completed 10 measurement sessions, 8 of which with all the methods.

Cognitive Tasks



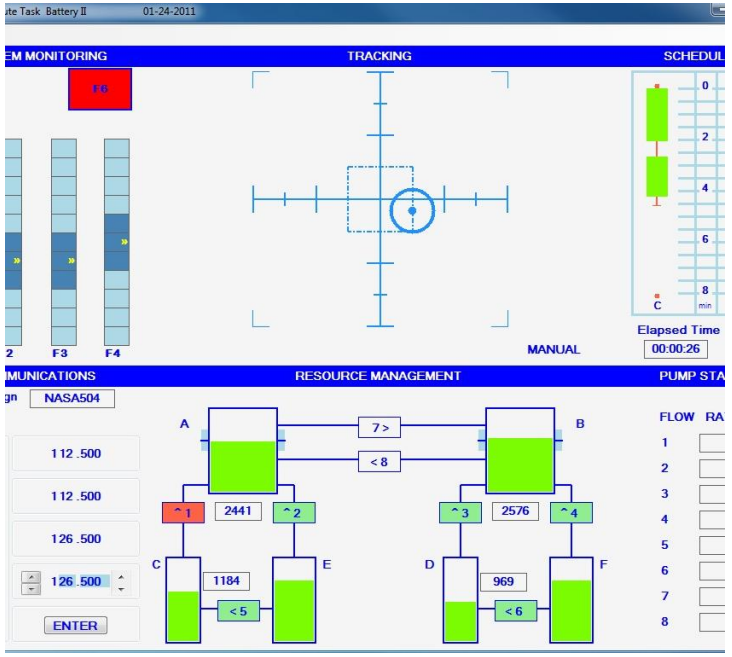
Psychomotor Vigilance Task

- Reaction Time



n-Back Task

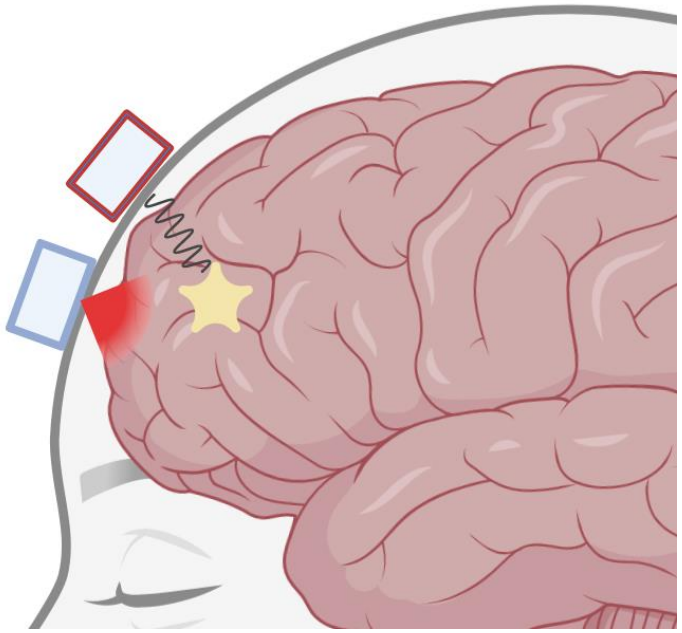
- Working Memory



Multi Attribute Task Battery

- Executive Performance

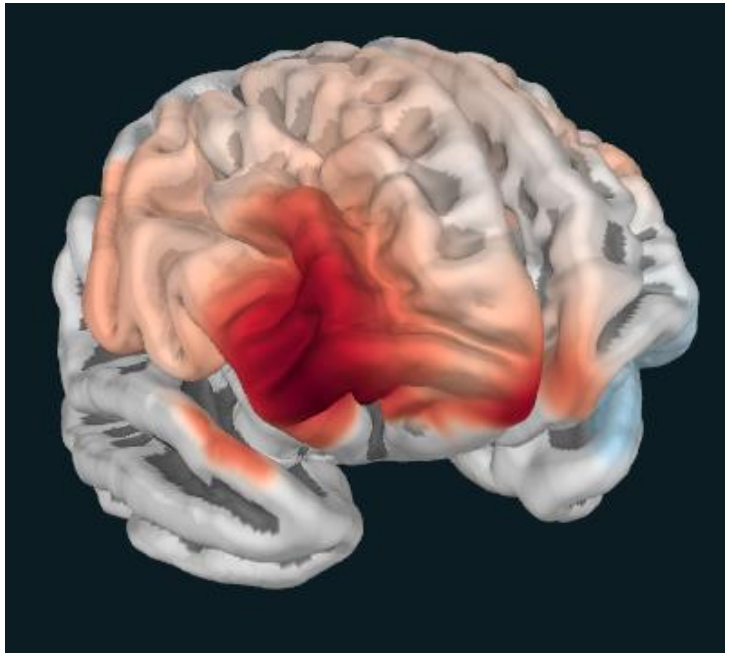
Prefrontal-Cortex Oxygenation levels



Sources emit light at 760 nm and 850 nm wavelengths.

Oxygenated and deoxygenated Hb absorb different wavelengths.

Configuration of emitters and detectors allows for the observation of different AOIs



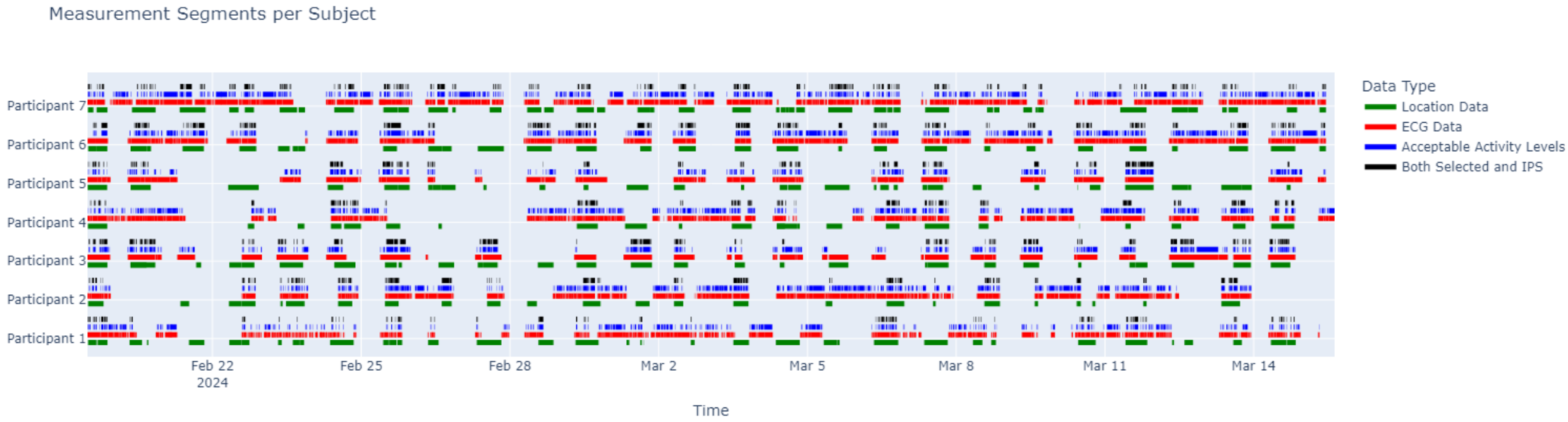
We measure differences in oxygenation levels between different states and responses during the test.

Methods

- Track participants location continually through UWB positioning
- Simultaneously collect ECG Data on a continuous base
- Filter data for activity level, and minimize artifacts.
- Calculate measures of Heart Rate Variability to assess stress state on different locations
- Match HRV measures with locations
- Evaluate correlations between different locations and stress state.

Measurment Methodology

- Wearable Sensors
  - Polar H10
  - Custom ESP32-based UWB tranceivers
- Logged to phones



Average total hours per subject: 783.68 hours
Median total hours per subject: 726.41 hours
Standard deviation of total hours per subject: 145.58 hours
Minimum total hours recorded by a subject: 636.21 hours
Maximum total hours recorded by a subject: 1057.13 hours

Total Duration of Each Measurement Type Across All Subjects:
Total duration of IPS measurements: 1280.48 hours
Total duration of ACC measurements: 2309.54 hours
Total duration of SEL measurements: 1345.65 hours
Total duration of Both selected and IPS measurements: 550.10 hours

Expected Results

Worsened reaction time in public area

Improved working memory in areas with exposure to exterior views

Worsened performance in public areas