PersEIDS:
A Biomedical Decision Support System for Extravehicular Operations Under Significant Communication Latency

52nd International Conference on Environmental Systems (ICES)
16-20 July 2023, Calgary, AB, Canada

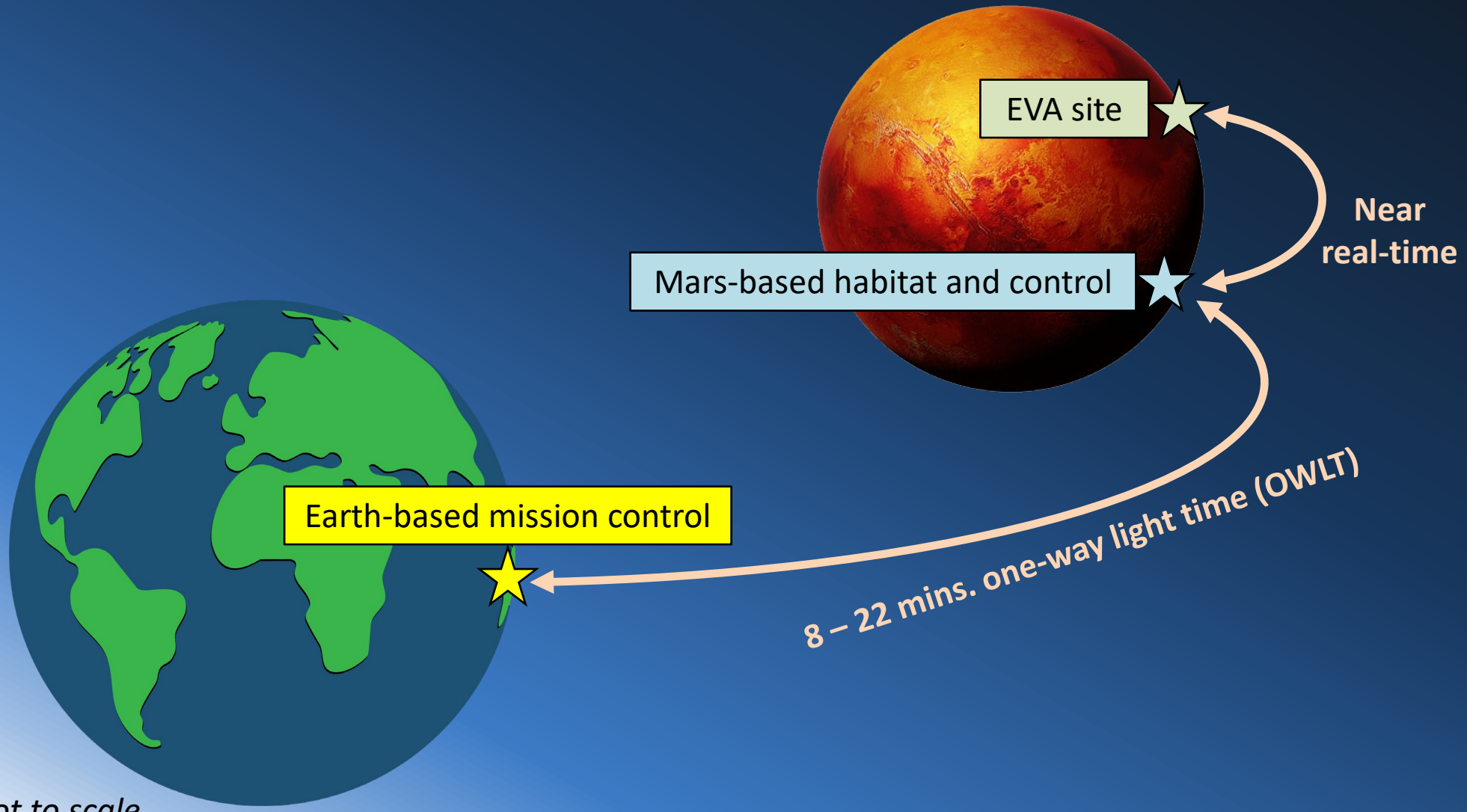
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Outline

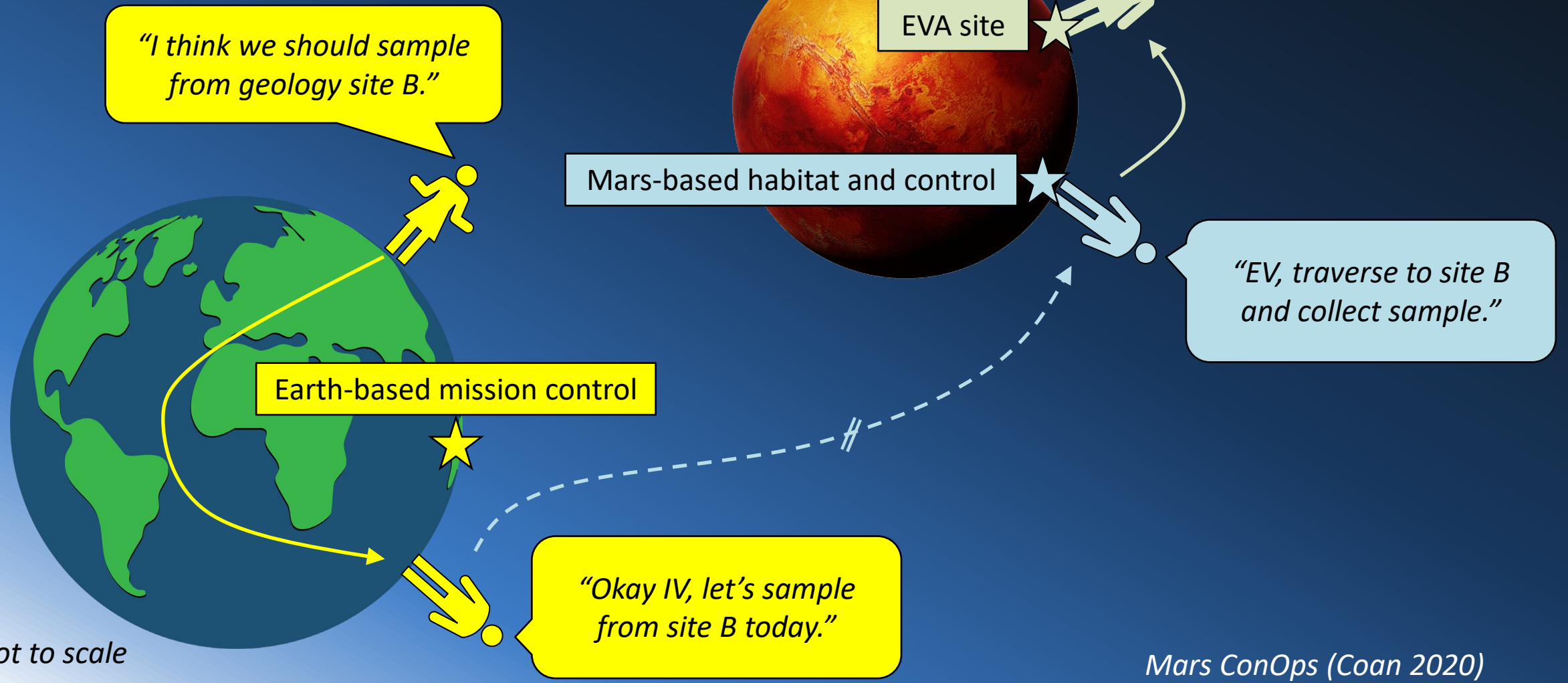
- Relevant Mars EVA Concept of Operations
- Current biomedical decision making
- Future biomedical decision making
- PersEIDS, the application
- May 2023 demos
- Demonstration feedback
- Limitations & future directions

Mars Communication Latencies



Not to scale

Mars ConOps (Coan 2020)



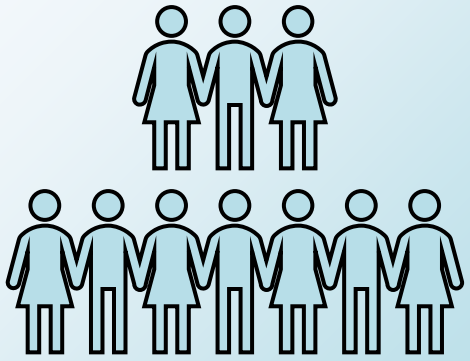
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Mars ConOps (Coan 2020)

Current biomedical decision making

There are *many* decisions informed by in-flight biomedical data to ensure health and safety of the crewmember

For ISS EVAs, mission control may employ *up to ten people* to perform these essential biomedical decision making duties



Earth-based doctors and engineers



One IV astronaut on Mars

The IV crewmember on Mars must execute several tasks formerly reserved for a large staff of people

Computational decision support systems for EVA

Software-based decision support systems must fill these capability gaps! (Abercromby 2022)

Relevant prior literature

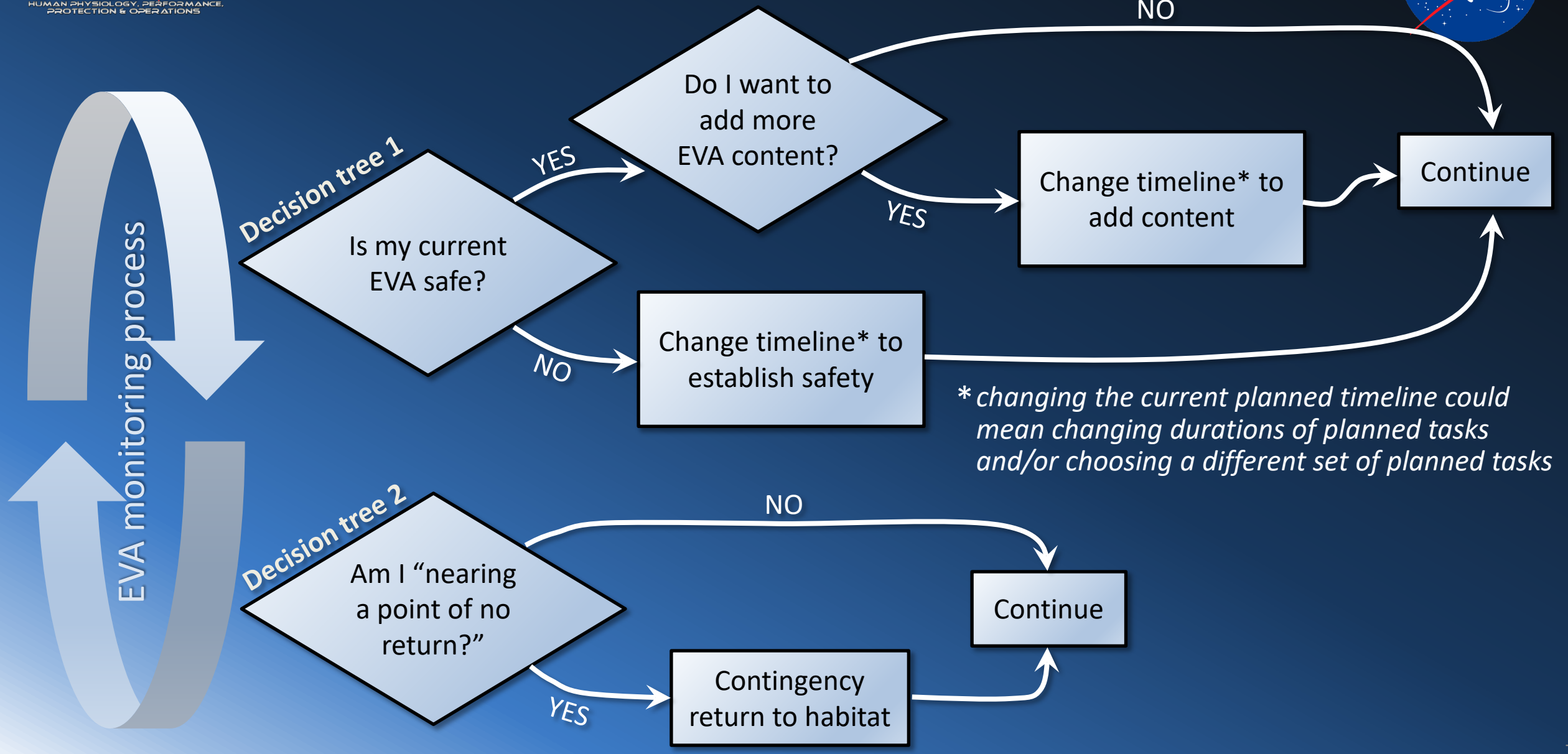
Timeline management systems *e.g.* NASA's Maestro *(Miller et al. 2021)*
and Playbook *(Hillenius 2015; Marquez et al. 2013 and 2019)*

Clinical Decision Support Systems (CDSSs) compare the characteristics of an individual patient to a digital knowledge base, assessments or recommendations then presented to clinician for decision *(Sutton et al. 2020)*

> *"computational methods"* incorporate additional info about a patient's life e.g. sleep quality, marriage status, etc. *(Shanmathi 2018)*

Literature lacks mission-specific biomedical context: expected timelines, success criteria, etc.

A simplified decision process model for EVA



*changing the current planned timeline could mean changing durations of planned tasks and/or choosing a different set of planned tasks

Informal system definition

In order to enable effective biomedical decision making on Mars, a system shall:

1. Provide the current physiological state(s) of the EV crewmember
2. Using information about the expected future of the EVA being performed, provide some safety-acceptability metric of the current EVA
3. When current EVA is deemed unsafe, provide recommended interventions (e.g., alternative EVA timelines) to the user
4. When current EVA is sufficiently safe, provide recommended extensions of current EVA content
5. Simulate in real-time a dedicated “emergency return” EVA timeline

PersEIDS the application

Displays real-time current physiological state of the crew and projection of that state over the selected EVA timeline

Biomedical states implemented

- BTU consumption (i.e., Oxygen)
- Time exposure to critical partial pressures of carbon dioxide in the suit ($PiCO_2$)

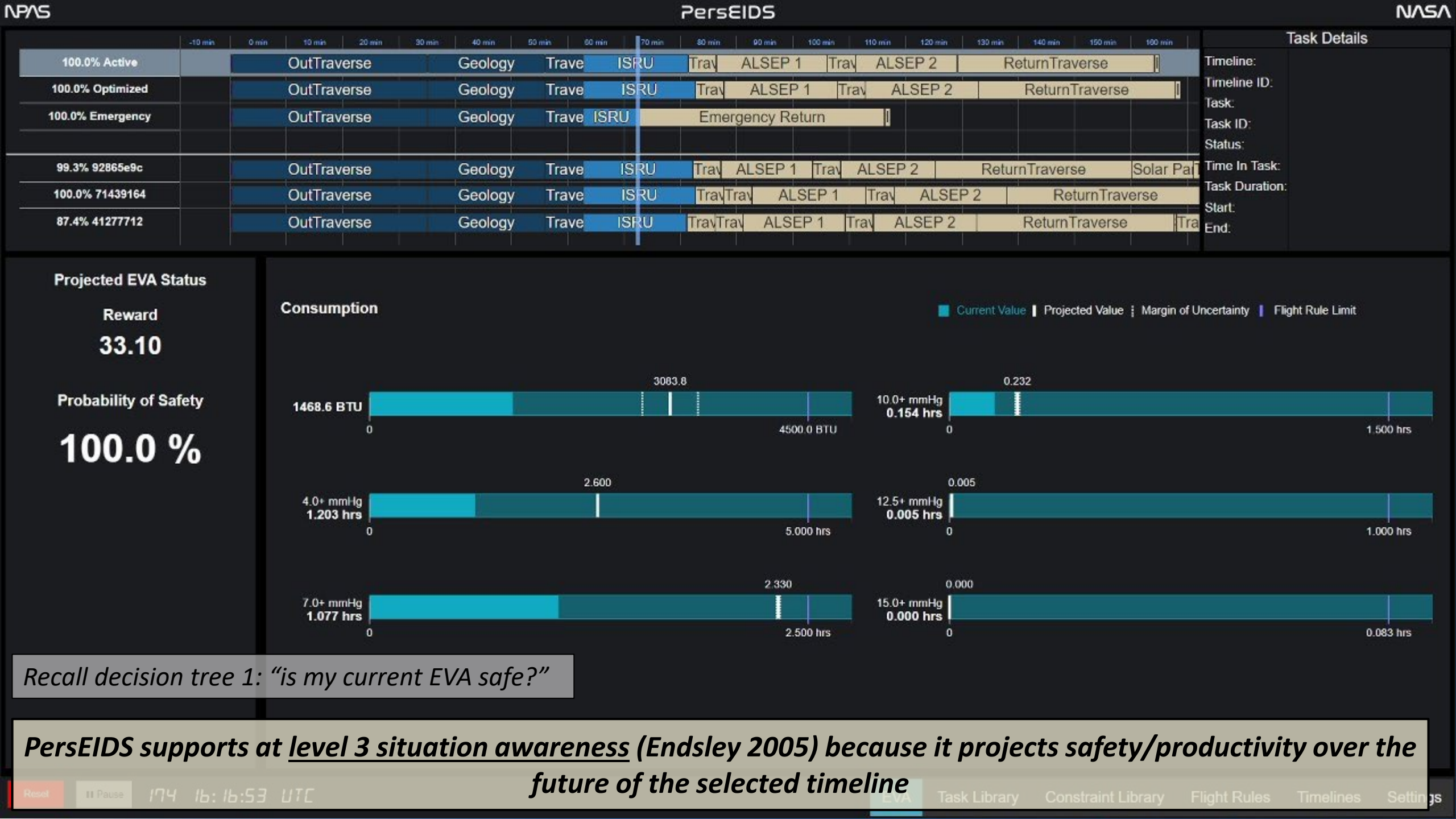
} *Correspond to EVA flight rules*

Timelines monitored

- The current "active" EVA
- An "optimized" version of the active EVA
- A dedicated "emergency return" EVA timeline
- Any number of additional timelines the user enters to manually monitor

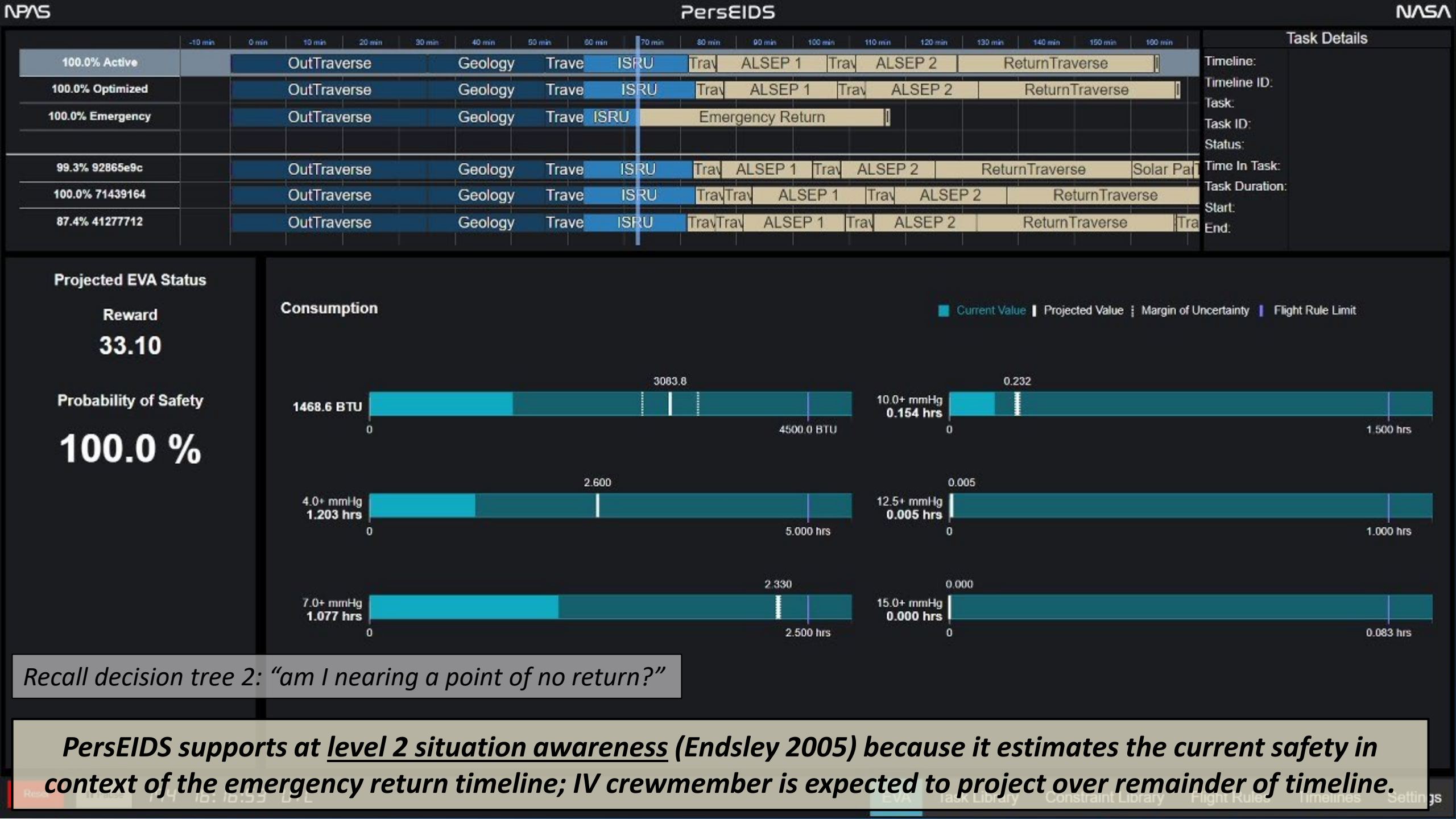
For each timeline monitored, PersEIDS provides a unified safety metric

(colloquially referred to as the timeline's "probability of safety")



Recall decision tree 1: "is my current EVA safe?"

PersEIDS supports at <u>level 3 situation awareness</u> (Endsley 2005) because it projects safety/productivity over the future of the selected timeline



Recall decision tree 2: "am I nearing a point of no return?"

PersEIDS supports at level 2 situation awareness (Endsley 2005) because it estimates the current safety in context of the emergency return timeline; IV crewmember is expected to project over remainder of timeline.

Methods

- Most recently demonstrated 16-23 May, 2023
- 9 trials, each with an EV and IV crewmember





Demonstration feedback

- 7 of 9 EV crewmembers “survived” in-simulation
- Stakeholder feedback largely positive; users felt like software was aligned with mission management needs
- Comments from users that the alternative timeline simulation feature is not consistent with user needs at the moment

Limitations & Future Work

Limitations

- Demo merely an early approximation of Mars EVA operations
- Subjects had varying levels of exposure to EVA operations and VR
- Individual subject heartrate to metabolic rate variability
- Unexplored subject baselines & task-based performance

Future work

- Larger *N*, powered study designs
- Field study opportunities
- Software and model validation(s)
- Customer cognitive inquiry; efforts to align product to flight

Conclusion

- PersEIDS is a project and software from NASA JSC to support future Martian EVA with limited crew under communication latency
- Software has completed Mars Campaign Office initial milestones, expanding scope over GFY24
- Robust demonstration capabilities of the full-stack software in virtual reality environments
- Initial customer feedback positive, need future work to align software features with perceived customer needs

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