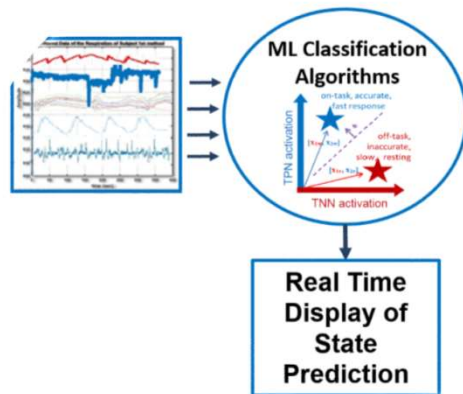
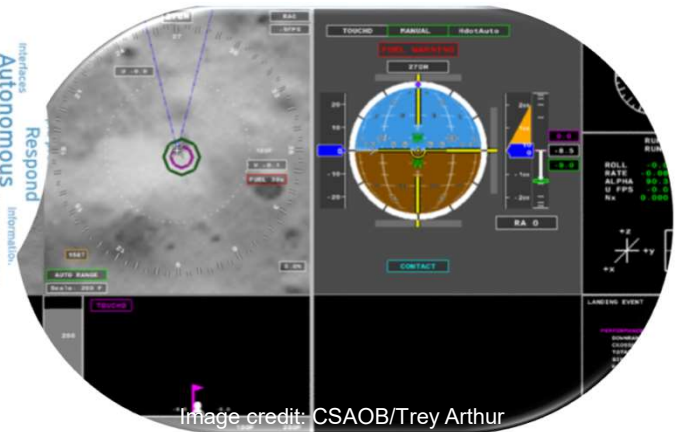




LAR-18996,
US Patent 1
[https://tcr.
a.gov/p](https://tcr.a.gov/p)
TOP



Human Operator and Autonomous System Integration

Human Performance and Lunar Lander Simulations

Physiological Features and ML to Predict Crew State



<https://csaob.larc.nasa.gov/nasahrpiws/>

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CSAOB Capabilities: Human Operator and Autonomous System Integration

Work performed at Langley under the Aeronautics Research Mission Directorate's Advanced Air Mobility concept has enabled capabilities we've developed through decades of experience in human factors and increasingly autonomous systems research, development, and thought leadership. Our researchers in CSAOB, together with fellow members of our Intelligent Flight Systems product line at Langley, have performed much of their work in an aviation context, which includes *highly trained expert operators* performing safety-critical tasks - *safe-keeping hundreds of lives at a time* - in a high-stakes, and at times high-stress, environment.

Research in human-autonomy teaming drives toward the development of multi-agent collaborations, including operator adaptive capacity, bi-directional trust across agents, and formal modeling of human-machine interactions using cognitive architectures. We are experts in the development of the test, evaluation, and performance measurement infrastructure necessary to assure the safety and efficacy of design solutions.

Expert human operators in safety-critical domains - whether situated on the ground or in flight - take actions during operations every day on every mission which *cause safety*. We are experts in studying and identifying these actions through observations, surveys, interviews, and human-in-the-loop simulations. This is relevant, for example, to ensuring a rigorous and thorough understanding of what will be missing when ground support is no longer available, and what will be needed for integrating with "replacement" Autonomous Systems. *We need to flush out such potentially latent requirements for establishing safe Earth independent operations.*

Assessment of expert operators as they cause safety, and as they interact with autonomous systems

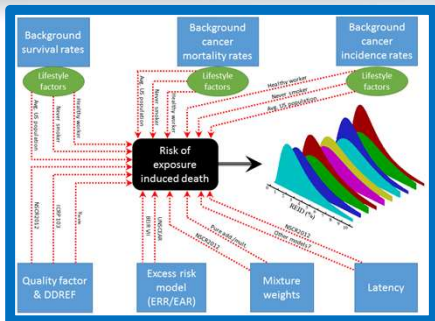


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CSAOB Capabilities: Cognitive Task Analysis for Data-Driven Requirements



We have expertise in the use of Cognitive Task Analysis (CTA) to generate data-driven system requirements for a variety of projects. Through the statistical analysis of data provided by Subject Matter Experts (SMEs) via interviews, surveys, questionnaires, and task observation, CSAOB researchers have developed a replicable CTA protocol which can be tailored to identify the strengths and weaknesses for both existing and proposed systems.

CSAOB researchers provided expertise in CTA for a NASA Engineering Safety Center (NESC) project to develop data-driven requirements for the Wallops Flight Facility (WFF) Launch Termination System (LTS). Observations of WFF Range Safety Officers interacting with the safety-critical Range Data Display System (RDDS) for launches (both real-time and simulated) were used to perform heuristic analyses of the current LTS and its limitations. A series of SME interviews and detailed questionnaires identified current and future system needs. Through statistical analysis of the collected data, CSAOB researchers generated a series of robust system requirements which will provide the blueprint for a new LTS capable of meeting current and future launch needs.

This expertise in CTA is currently being utilized to support the Multi-model Ensemble Risk Assessment (MERA) Project for HRP's Space Radiation Element. The purpose of this research effort is to improve communication, and thus understanding, of space radiation risks and probabilistic risk model projections, including the underlying statistical methods and assessments.

CSAOB Researchers are currently conducting interviews with JSC Flight Surgeons and have distributed questionnaires to retired NASA astronauts to better understand radiation risk communication needs (past, present, and future). Once data collection is complete, statistical analyses will be applied to generate data-driven system requirements for future space radiation risk modeling software which will aid in both risk communication and future mission planning.

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Daiker, R., Harrivel A., Ghatas, R., Lake, R., & Maddock, S., "Cognitive Task Analysis and Knowledge Elicitation to inform Medical Workstation Design for Long Duration Space Missions", Applied Human Factors and Ergonomics Conference 2020, July 2020.



Daiker, R., Ghatas, R., & Vincent, M., "A Cognitive Task Analysis of Safety-Critical Launch Termination Systems", Applied Human Factors and Ergonomics Conference 2018, July 2018.





CSAOB Capabilities: Human Performance and Lunar Lander Simulations

We have broad experience and expertise in human-in-the-loop simulation (both low and high fidelity) and study tasking, relevant to studying the Acute CNS impacts of Space Radiation and multiple stressors, e.g., with precision landing site identification and execution, under time pressure.

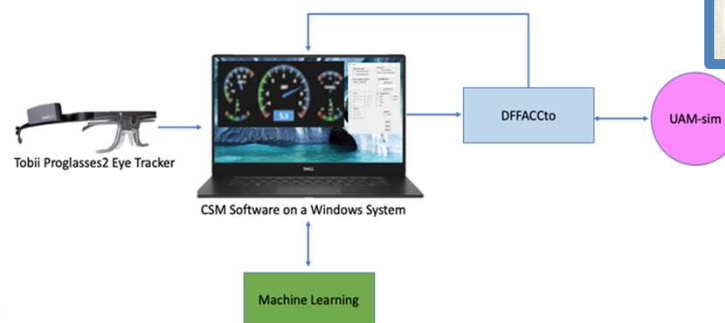


Fig. 1. Diagram of the CSM-UAM simulator connections

Harrivel, A., Blattnig, S., Norman, R., Simonsen, L. (2021, July 25-29). Planned Investigations to Address Acute Central Nervous System Effects of Space Radiation Exposure with Human Performance Data, AHFE 2021, virtual event. *Track Best Paper*.

Samani S., Jessop, R., Harrivel, A. Collaborative Communications between a Human and A Resilient Safety Support System, IEEE ICAS 2021, International Conference on Autonomous Systems, August 11-13, 2021, Montreal, Canada

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Simulation Methods for Human Operator and Machine Integration LAR-19978-1, US Patent Pending <https://technology.nasa.gov/patent/LAR-TOPS-301>

NASA Langley Research Center, Crew Systems and Aviation Operations Branch (D318)



CSAOB Capabilities: Human Operator and Autonomous System Integration

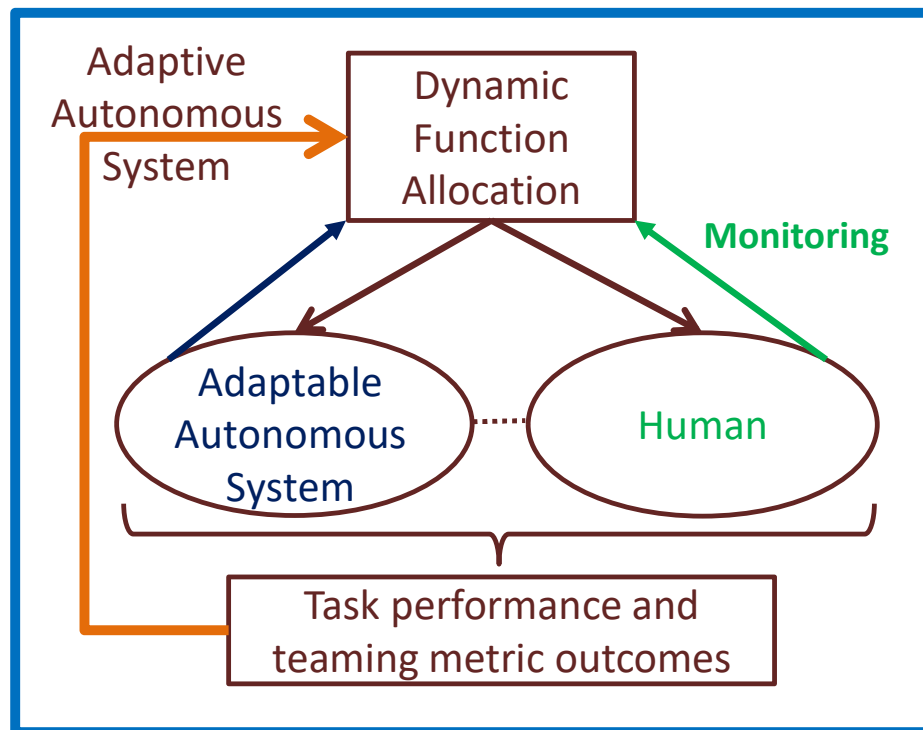
Cyber-Physical-Human teaming enables crew autonomy via interfaces with trusted and trustworthy autonomous agents and decision support systems. Both automated and autonomous systems will be needed to achieve Earth-independent operations.

Systems need to adapt across levels of automation to account for inevitable crew performance variance due to mission stressors, cognitive resilience, workload, and environmental dynamics. Systems can make use of their own state, contextual information from the environment, and the state of the crew members themselves to establish bi-directional trust, thus assessing Trust in the Human Operator.

Do we have the RDT&E systems in place to reduce Human System Integration risk, and optimize safety, efficiency, and mission success?

Can we perform simulation studies to determine whether a task should be done - in this moment - by the human or by the system? When should decision support agents "kick in"? When should they stay out of the crew's way?

Simulations that enable System Trust in the Human Operator:



System and Method for Human Operator and Machine Integration
LAR-19051, US Patent 10,997,526

<https://technology.nasa.gov/patent/LAR-TOPS-301>

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CSAOB Capabilities: Human Operator and Autonomous System Integration

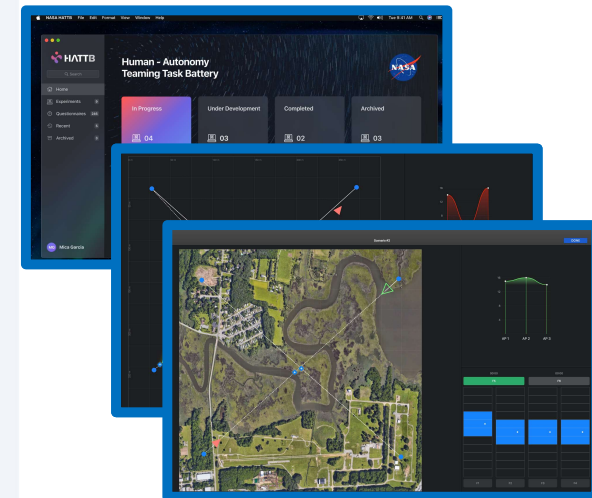
The concept of a human “teaming” with a technology fundamentally alters the assumptions of traditional human-automation interaction paradigms, as the technology is required to assume many of the responsibilities (and authorities) traditionally held by humans within the overall system. The HAT Foundational Research Activity has been tasked with producing human-in-the-loop (HITL) experiments that test, identify, and apply HAT principles.

The Human-Autonomy Teaming Task Battery (HATTB) is a research software application that provides a simplified version of real-world tasks that are performed by remote operators (or “pilots”) monitoring and controlling multiple vehicles (e.g., drones) with varying levels of automation. Specifically, the HATTB is used to conduct human-in-the-loop (HITL) experiments that evaluate the performance of research participants as they manage or monitor increasingly autonomous vehicles and simultaneously perform various other predefined tasks. The primary use case for the HATTB is a human factors or cognitive psychology researcher studying the performance of participants as they complete specific scenarios that have been defined by the researcher. The scenarios are created by the researcher within the HATTB software and vary depending on the researcher’s specific goals. The scenarios can use a combination of the available tasks and may be very complex.

The HATTB was created to provide a test-bed that will support not only internal NASA experimentation but will also be made freely available as an open-source software solution for the general research community. This approach will significantly accelerate NASA’s research interests related to humans interacting and teaming with increasingly autonomous remotely operated systems, as the quantity of HATTB studies addressing these topics will not be limited to NASA researchers and resources supporting individual efforts. The HATTB software was developed for the Apple iPad tablet and Apple Mac computer environments.

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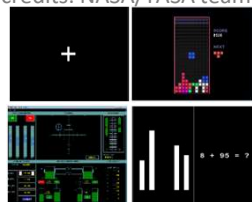
Performance assessment:





CSAOB Capabilities: Physiological Features + ML to Predict Crew State

image credits: NASA/TASA team



**Benchmark Task Performance
→ Train**

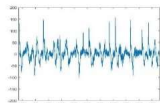
Photo credit: Angela Harrivel



**Simulated Flight Performance
→ Predict**

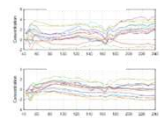
EEG and ECG
with
Muse

Bluetooth



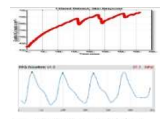
fNIRS
with
ISS Inc. Imagent

wired

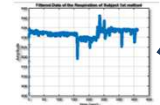


GSR and BVP
with
Empatica E4

Bluetooth



Respiration
with
Spire



Eye-tracking
with
Tobii Pro

wired

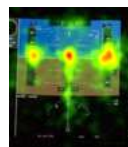
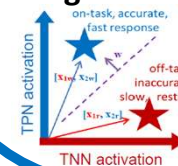


image credit:
NASA/CSM team

We have machine learning and crew state experience and expertise. We pioneered the study and use of real-time-compatible methods ten years ago. The best thus far used autoencoding to deal with biological noise, and two 6-layer dense neural networks. Non-nominal attentional states are identified at a rates > 0.8 .

NeuroPype by
Intheon and
Lab Streaming
Layer for real
time data
acquisition

**ML Classification
Algorithms**



**Real Time
Display of
State
Prediction**

Data
Acquisition

Signal
Processing

Feature
Extraction

Data
Synchronization

Machine
Learning

Terwilliger, P., Sarle, J., Walker, S., Harrivel, A. A ResNet Autoencoder Approach for Time Series Classification of Cognitive State, MODSIM World 2020, Paper No. 0053, (virtual event).

Napoli, N., Stephens, C., Kennedy, K., Barnes, L., Juarez Garcia, E., Harrivel, A. NAPS Fusion: A framework to overcome experimental data limitations to predict human performance and cognitive task outcomes. Information Fusion. 2023; 91:15-30.

Harrivel, A., Weissman, D., Noll, D., Huppert, T., and Peltier, S. (2016). Dynamic filtering improves attentional state prediction with fNIRS. Biomedical Optics Express. 7(3), 979-1002.

LAR-18996, US Patent 10,192,173

<https://technology.nasa.gov/patent/LAR-TOPS-88>

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