



COLLABORATIVE COMMUNICATIONS BETWEEN A HUMAN AND A RESILIENT SAFETY SUPPORT SYSTEM

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Aug. 2021





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NASA's Vision for Urban Air Mobility

- Urban Air Mobility envisions a safe and efficient aviation transportation system
 - Will use highly automated aircraft which will operate and transport passengers or cargo at low altitudes within urban and suburban areas [10] (Thipphavong et al., 2018)
- Ensuring safety is an ongoing concern for aviation safety organizations such as NASA and the FAA
 - This involves research on safe airspace operations
 - The Unmanned Aircraft System Traffic Management ConOps is focused on safely enabling large-scale small Unmanned Aircraft System operations in low altitude airspace [30] (Kopardekar et al., 2016)
- NASA is working on developing a framework to integrate the UAM research
 - This involves an automated electrical Vertical Take-Off and Landing aircraft (e-VTOL) with a capacity of four to six passengers



It's Autonomy! Why study Humans?

- Optimizing human-machine interaction remains critical for improving safety as emerging aircraft vehicle become increasingly autonomous to fulfill Urban Air Mobility demands.
- Robust metrics for assessing and optimizing such human-autonomy teaming in real time are underdefined.
- The development and application of quantitative operator state measures could enable in-time dynamic function allocation between the operator and the system for moment-to-moment optimization of teaming to maximize safety and efficiency during operations.
 - Emerging operators will be non-pilots and individuals with little training.
 - Yet they will be relied upon to manage off-nominal events until fully autonomous systems are matured, validated and certified for safe use.

Psychophysiological Monitoring

- **Muse**
 - **Electroencephalography (EEG)**
 - Electrical neurological brain activity detection
 - **Electrocardiogram (ECG)**
 - Electrical heartbeat sensing
 - EEG: 500 Hz, ACC: 50 Hz
- **Empatica**
 - **Galvanic Skin Response (GSR) & Electrodermal activity (EDA)**
 - **Blood Volume Pulse (BVP)**
 - **IBI (Inter beat intervals)**
 - **Temp (c)**
 - Optical detection of peripheral pulse
 - ACC: 32 Hz, BVP: 64 Hz, EDA 4 Hz, IBI: 1/64 sec, Temp: 4HZ
- **Spire**
 - **Respiration**
 - Small belt-worn force-measurement device
- **Tobii Pro glasses 2**
 - **Oculometry / Eye-tracking**
 - Pupil size, gaze position, gaze direction
 - head tracking measurements
 - 30-50 Hz



Muse

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NASA/Samani

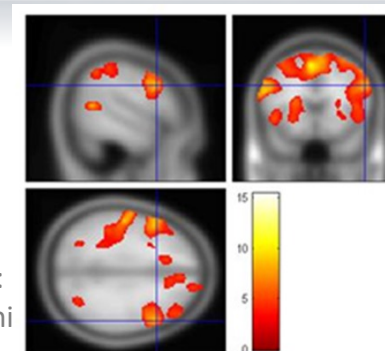


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NASA/Harrivel



Empatica

image credit:
NASA/Samani



Spire

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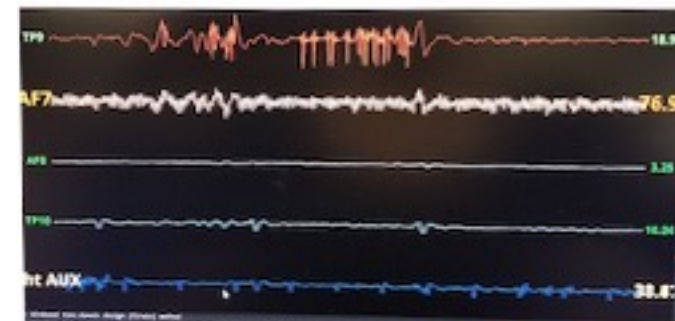


Tobii

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NASA/Samani

Psychophysiological Monitoring

- Physiological Monitoring System
 - Machine learning algorithms for cognitive state prediction
 - Real time data acquisition from physiological sensors
- Real-time identification of suboptimal states
 - High Workload
 - Channelized attention
 - Diverted attention
 - Startle/surprise



Harrivel, A., Stephens, C., Milletich, R., Heinrich, C., Last, M. C., Napoli, N., Abraham, N., Prinzel, L., Motter, M., Pope, A. (2017). **Prediction of Cognitive States during Flight Simulation using Multimodal Psychophysiological Sensing.** *AIAA Science and Technology Forum and Exposition, Applications of Sensor and Information Fusion*. Grapevine, TX.



Background

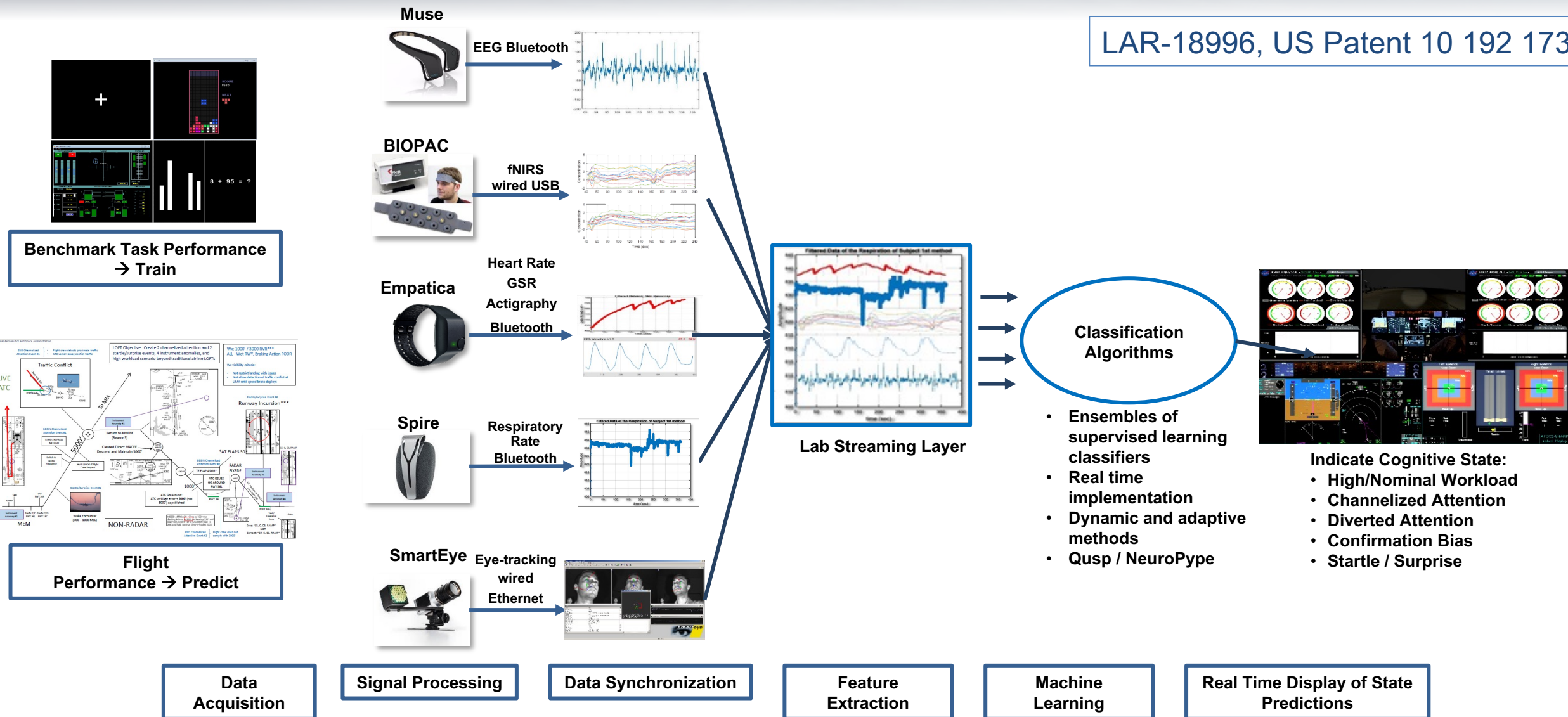
- Multi-modal Immersive Intelligent Interface for Remote Operation (MIIRO) is developed to discover some human factors issues with automation level. [19] (Ruff et al., 2002)
- Autonomous Constrained Flight Planner (ACFP) is a recommender system that supports rapid diversion decision-making for commercial pilots in non-normal situation. [20] (Brandt et al., 2017)
- All the research for human-autonomy teaming is laboratory-based and the studies are based on execution simulations. Most of the studies address partially-not highly-autonomous systems. [22-25] (Shannon et al., 2017, Cook et al., 2016, Malin et al., 1991, O'Neil et al., 2020)



Translational CSM System Development

prototyping CSM technologies in a mobile framework

LAR-18996, US Patent 10 192 173

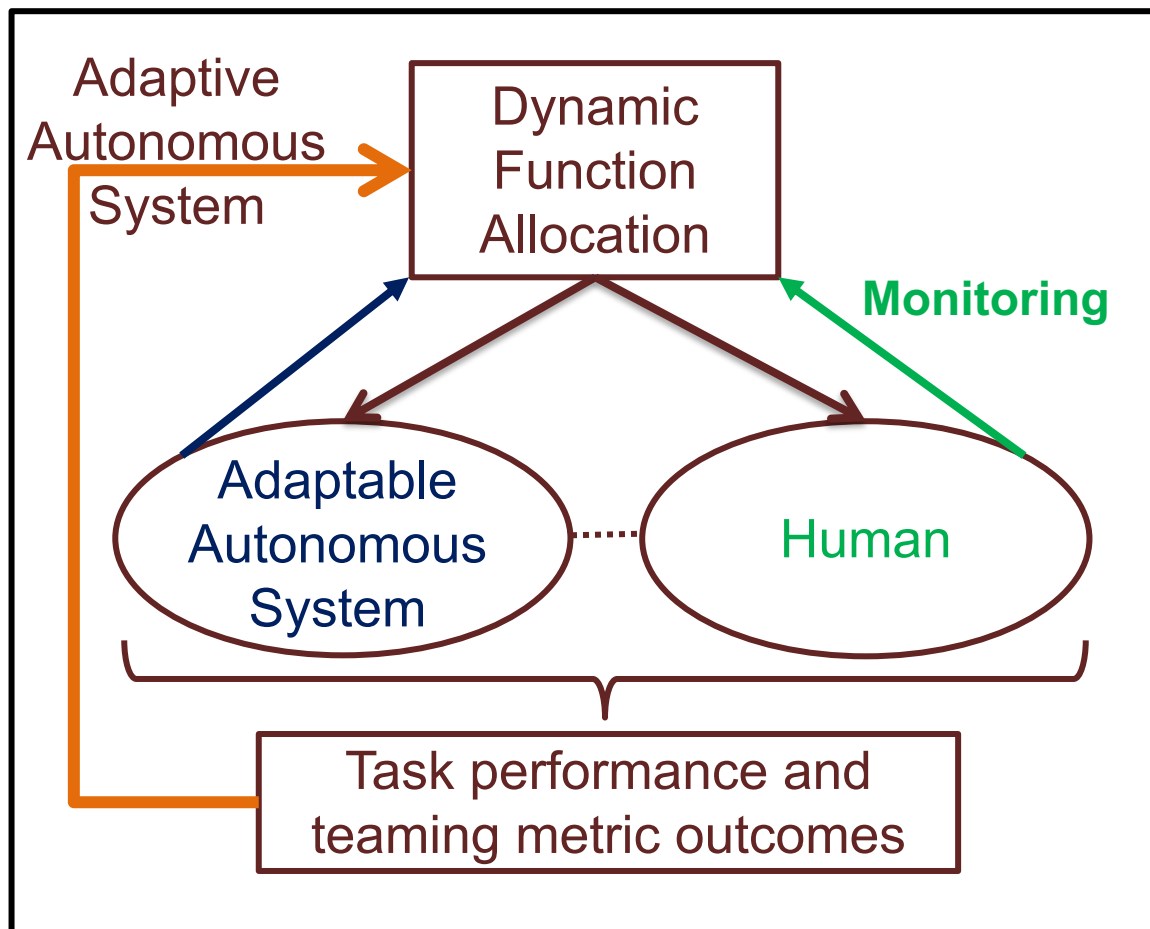




Human Monitoring for Human-Autonomy Teaming (HuMHAT), or “Trust in the Human Operator”

CSAOB* is developing and combining tools to study Human-Autonomy Teaming:

- flight and autonomous system simulation development
- human monitoring tools
- human performance metrics



Monitoring allows the system to support the operator at the right time to avoid the pitfalls of sub-optimal states.

We have developed real-time tools to identify suboptimal mental states

- Incapacitation / impaired crew performance
- High and Low workload
- Channelized Attention
- Diverted attention
- Startle or surprise

Multivariate Monitoring for Human Operator and Machine Teaming
LAR-19051, US Patent 10,997,526

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



Example Dynamic Function Allocation Simulation Scenarios for UAM contexts

Human state	Adaptable Autonomous System (AAS) state	Potential teaming metric dependencies	Dynamic Function Allocation (DFA) change
Passed out / Incapacitated	(does not matter)	• Lack of control input • Lack of communication • Envelope excursion	AAS assigned full control, heads toward medical facility
Attentive and situationally aware	Working, Nominal	• Divergent / incongruent actions based on human hazard detection • Lack of shared situational awareness	Human takes / is assigned full control, remains engaged and avoids over-reliance
Overloaded / Attentional Lapse	Working, Nominal	• Lack of control input • Lack of communication	AAS shares the burden where it can, avoids under-reliance
Bad actor	Adapting to accommodate flight parameter exceedances or unexpected control inputs	• Incongruent actions • Flight plan divergence • Lack of shared intent • Lack of communication • Envelope excursion	AAS assigned full control, restricted controls



DFACCto Protocol

- Dynamic Function Allocation is a systems engineering/Human Autonomy Teaming (HAT) process
 - Our approach examined a set of operations that are available to the operator
 - climbing, accelerating, turning, turning on lights, changing radio frequencies, or checking systems or passenger status
 - A user interface which includes avionics modifications and speech synthesis has been developed
 - DFACCto is the developmental and operational Application Programming Interface (API) and protocol for message-oriented middle-ware
 - DFACCto permits human factors experts to develop User Interface and control algorithms without the need for software engineering expertise



Use Cases

- Incapacitated Operator
 - A vehicle operator who has lost consciousness.
 - May occur when the operator experiences a serious medical event.
 - Detected by a Tobii Pro eye-tracker which measures various ocular attributes when receives 0.0 inch for pupil diameter for at least 5 seconds.
 - All emergency DFACCto operations will lock out controls to prevent spurious inputs from an operator who may slump over the controls.
- Overloaded Operator
 - A vehicle operator who appears to be under stress and possibly visually distracted.
 - Detected by a Tobii eye-tracker by gaze position and direction within the display regions of interests
 - May occur when the operator is handling an off-nominal vehicle event, inclement weather, and sick or injured passenger(s).
 - DFACCto performs the command and holds it until superseded by the operator.



CSM-UAM Overview

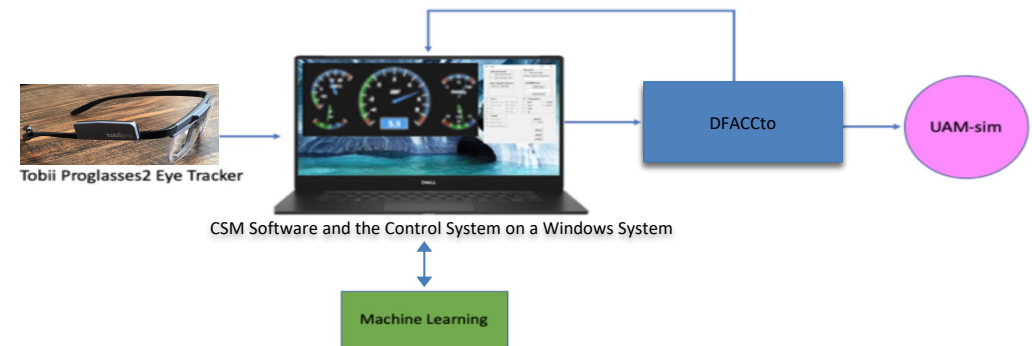


Fig. 1. Diagram of the CSM-UAM simulator connections

Samani, S., Harrivel, A., Jessop, R., (2021). Collaborative Communications Between A Human and A Resilient Safety Support System. *IEEE International Conference on Autonomous Systems, 2021*. Montreal, CANADA.



Demo

DFA OPS

AVIATE

ALTITUDE

HEADING

SPEED

NAVIGATE

COMMUNICATE

EMERGENCY

ROUTINE

SYSTEMS

FLIGHT MODE

NAV/CAM

LIGHTING

Del Altitude

Del Lock Altitude

Del Lock Navigate

Altitude Status

Reset

MASTER

UV0001X

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20

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MANUAL

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10

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Show Camera



Conclusion and Future Work

- A real-time system is used with the help of a human-in-the-loop air traffic control simulation
 - To explore methods to operate the aircraft safely
- The system in real-time uses physiological state monitoring
 - To assess when the operator is experiencing anomalous states
- Dynamic, context-based collaborative function allocation of operational tasks is used to achieve our goal
- Initial results motivate the development of further use cases relevant to the UAM and AAM
- Data should be collected
 - To validate detection, execution, and user response time



Questions





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