



Human-Autonomy Teaming Research and Development Overview for ISAP 2023

Eric T. Chancey

Human-Autonomy Teaming Foundational Research Activity Lead

6/2/2023 Researcher Panel



Transformational Tools and Technologies Project
Innovative solutions through foundational research and cross-cutting tools



autonomous
systems

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- Advanced Air Mobility (AAM)
- Revolutionary Aviation Mobility Sub-Project → m:N
- Human-Autonomy Teaming (HAT) Foundational Research Activity
 - Research Question
 - HAT Framework
- Research Model
 - Type 4 Research and Development: Applied, Field Studies
 - Type 1 Research and Development: Controlled, Lab Studies
- Other NASA HAT Work and Groups
- Selected Publications and Contact Info



Credits: NASA / Graphics

- **Advanced Air Mobility (AAM)**
 - Small UAS (sUAS/UTM) → e.g., Package Delivery
 - Urban Air Mobility (UAM) → e.g., Air Taxis
 - Regional Air Mobility → e.g., Autonomous Cargo

**UAS = Uncrewed Aerial Systems*

**UTM = UAS Traffic Management*



Revolutionary Aviation Mobility (RAM) Sub-Project

Overview

Supports ARMD mission programs by providing a pipeline of solutions and knowledge for **foundational challenges in enabling an AAM market.**

Enables increasingly autonomous transportation in the **UML-4+ timeframe**



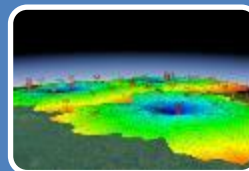
Transformational Tools and Technologies (T³) – RAM
Sub-project Manager: Vanessa Aubuchon
Email: vanessa.v.aubuchon@nasa.gov

GOAL Provide leading edge tools, technologies, and research findings to enable increasingly autonomous AAM transportation in the UML-4+ timeframe

OBJECTIVES



Enable scalable operations for AAM through development of an m:N operational approval roadmap supported by community coordination and critical tool and technique research (TC/FY27)



Explore and develop airspace management and operations architectures and tools in expectation of increased heterogeneous air traffic



Develop modeling, performance, and control tools & techniques for advanced urban capable aircraft

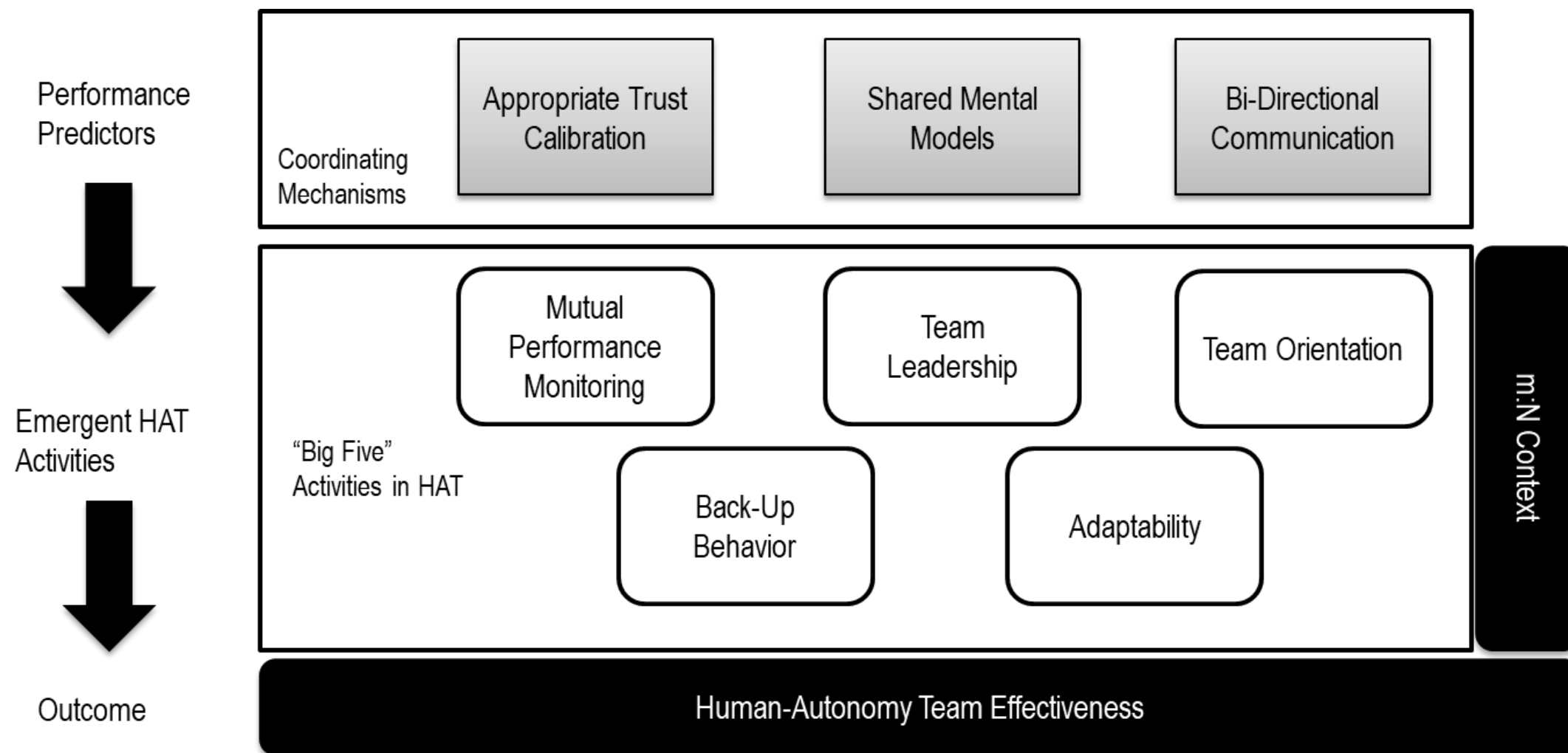
What HAT approaches (design principles, technologies) will facilitate fewer remote operators (m) to manage more increasingly autonomous vehicles (N) in AAM operations?

- HAT Definition: A distinguishable set of two or more *agents (human operator, increasingly autonomous system)* who interact dynamically, interdependently, and adaptively toward a common goal/objective/mission (adapted from Salas et al., 1992)
- HAT Research Goal: Humans and increasingly autonomous systems working and thinking better together (Holbrook et al., 2020)

E. Salas, T. L. Dickinson, S. A. Converse and S. I. Tannenbaum, "Toward an understanding of team performance and training," in Teams: Their training and performance, Norwood, NJ, Ablex, 1992, pp. 3-29.

J. B. Holbrook, L. J. Prinzel III, E. T. Chancey, R. J. Shively, M. S. Feary, Q. V. Dao, M. G. Ballin and C. Teubert, "Enabling Urban Air Mobility: Human-autonomy teaming research challenges and recommendations," in 2020 AIAA AVIATION, Virtual Meeting, 2020.

HAT Framework



Framework Adapted from E. Salas, D. E. Sims and C. S. Burke, "Is there a "Big Five" in teamwork?," Small Group Research, vol. 36, no. 5, pp. 555-599, 2005.

See also: NATO Task Group (HFM-247 (2014-2019), "Human-Autonomy Teaming: Supporting Dynamically Adjustable Collaboration," North Atlantic Treaty Organization: Science and Technology Organization, 2020.



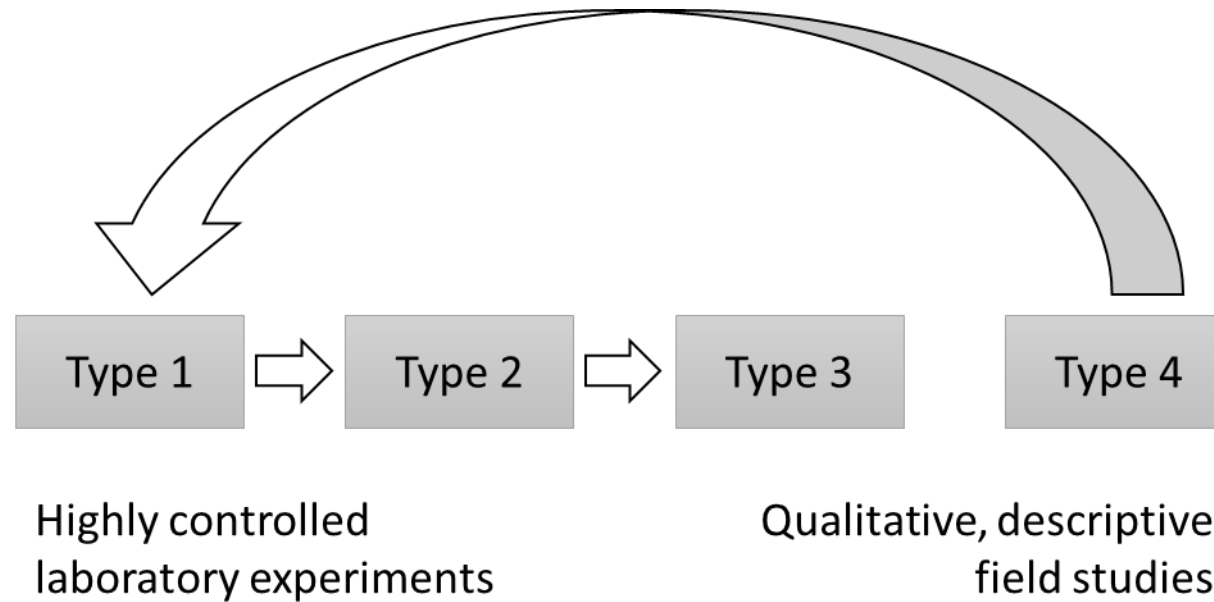
Grounding Basic Research in Practical Application



Research Type	Description
Type 1: Highly controlled laboratory experiments	Studies use simplified tasks in which variables are independently manipulated or held constant to investigate factors related to the phenomenon under study. Useful for competing theories to determine which provides a more correct explanation of the topic being studied.
Type 2: Less controlled but more complex laboratory experiments	Studies use tasks that are more complex than Type 1, losing experimental control to represent an operational setting and produce results that will better generalize to that operational setting more accurately.
Type 3: Evaluations conducted in high-fidelity simulators or in the field	Studies use tasks that are highly representative to the real-world environment and have less experimental control than Type 1 or 2 research. Useful to determine if the results obtained in Types 1 and 2 research overcome the myriad of additional factors that are not held constant.
Type 4: Qualitative, descriptive field studies	Field studies provide the ability to observe and document the pressing, significant issues that require research to understand. Also, field studies provide the basis to determine which factors should be manipulated in laboratory experiments (Type 1) and identifies which measures should be adopted to evaluate performance.

K. J. Vicente, "Heeding the legacy of Meister, Brunswik, & Gibson: Toward a broader view of human factors research," Human Factors, vol. 39, no. 2, pp. 323-328, 1997.

“An alternative model for defensible, generalizable human factors research”

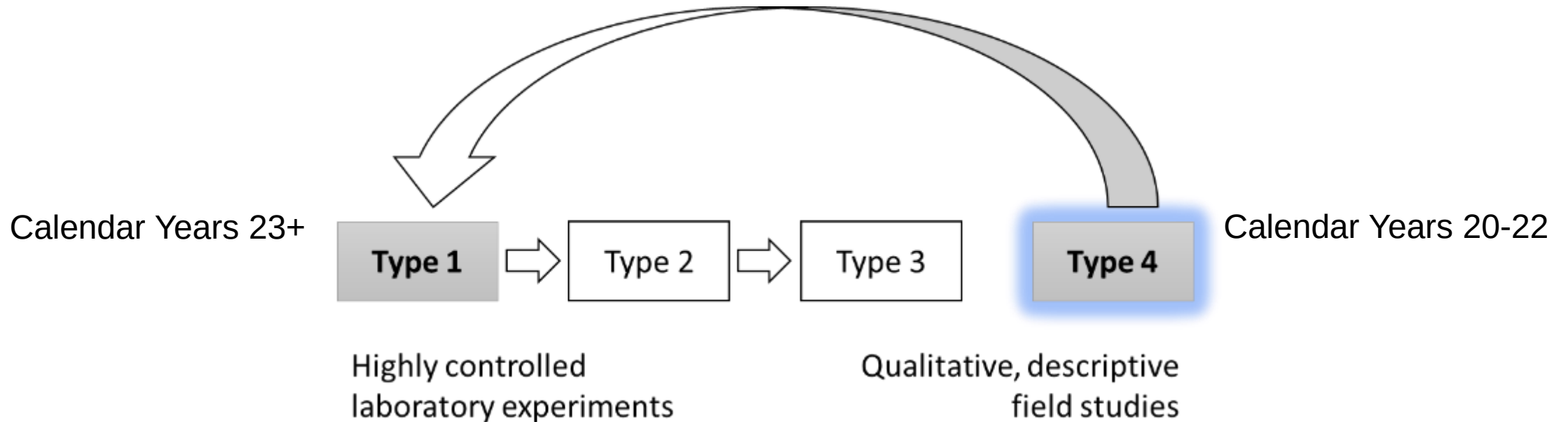


Chancey, E. T., Politowicz, M. S., Buck, B. K., Ballard, K. M., Unverricht, J., Houston, V., Chandarana, M., Le Vie, L. R. (2023). Foundational human-autonomy teaming research and development in scalable remotely operated Advanced Air Mobility operations: Research model and initial work. AIAA SciTech Forum. National Harbor, MD & Online: AIAA.

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Grounding Basic Research in Practical Application

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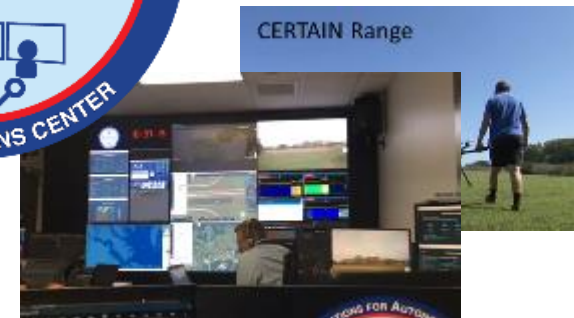
Completed:

- FY19 NASA UTM-Pathfinder Study – First instantiation of ROAM (Politowicz et al., 2020)
- ROAM Buildup: interviews, role-based ontology framework (Buck et al., *under review*)
- NASA AAM/High Density Vertiplex Subproject Collaboration
 - 2021-2023 Live & Simulated studies (Chancey et al., *under review*; Unverricht et al., 2022, 2023)
 - Usability Assessments (MPATH Ground Control Station, ROAM)
 - Human factors assessment: Subject matter expert interviews, after-action review, eye tracking, & questionnaires (situation awareness, workload, perceived risk, trust)
- NASA MaRERA Collaboration (Sept. 2022) – m:N Live/Virtual Demo

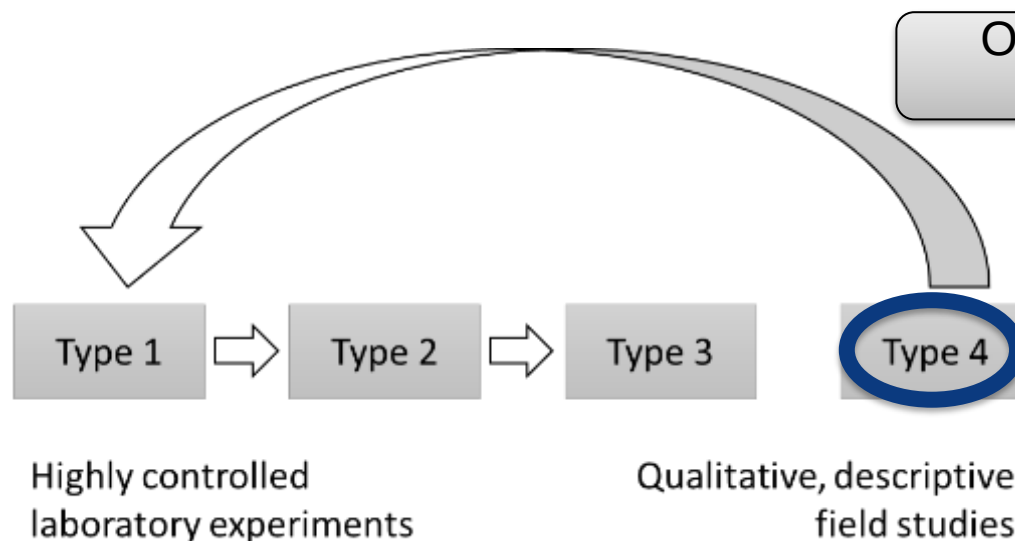


(Remote Operations for Autonomous Missions)

Buck et al. (2023). A remote vehicle operations center's role in collecting human factors data. AIAA SciTech Forum. National Harbor, MD & Online: AIAA.



MPATH
GROUND CONTROL STATION



Observational Studies

Characteristics:

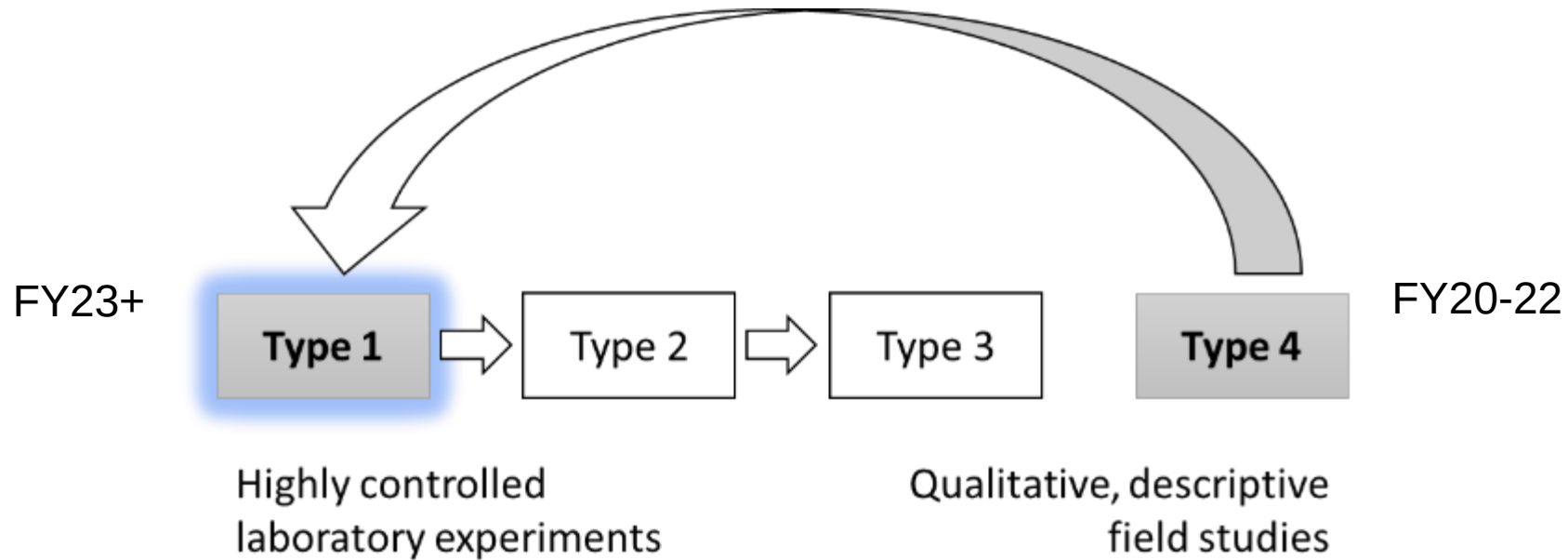
- Minimal-to-no control
- Real-world task
- Inductive, not deductive approach

Goals:

- Generate hypotheses
- Find as many issues as possible

Grounding Basic Research in Practical Application

“An alternative model for defensible, generalizable human factors research”



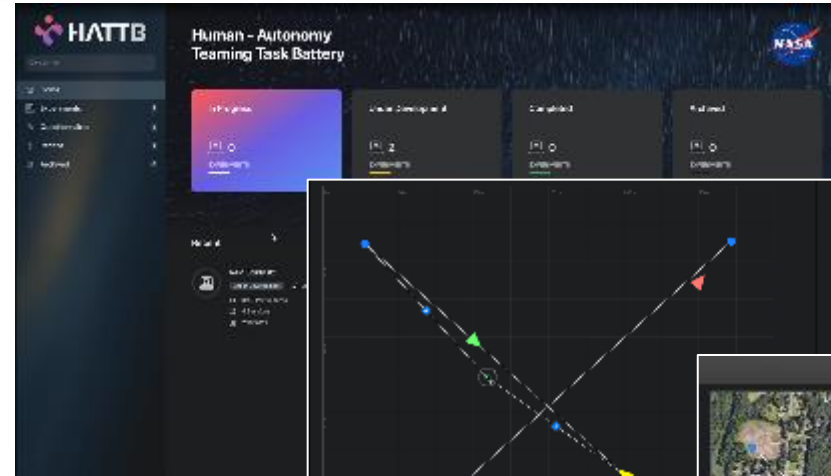
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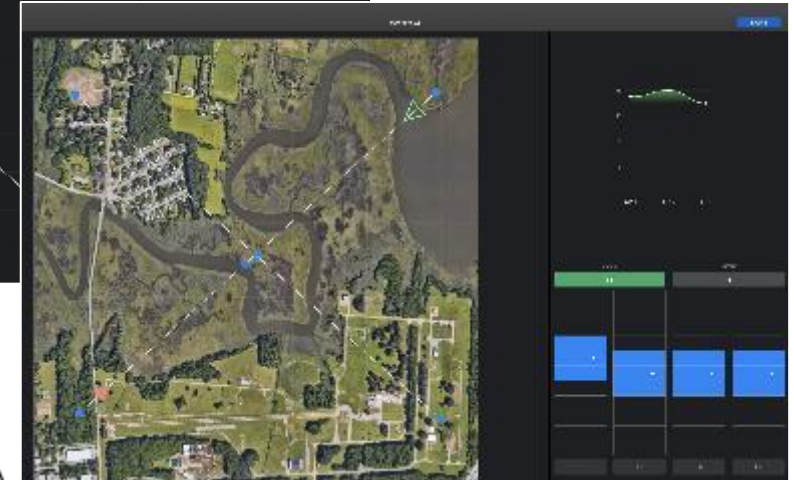
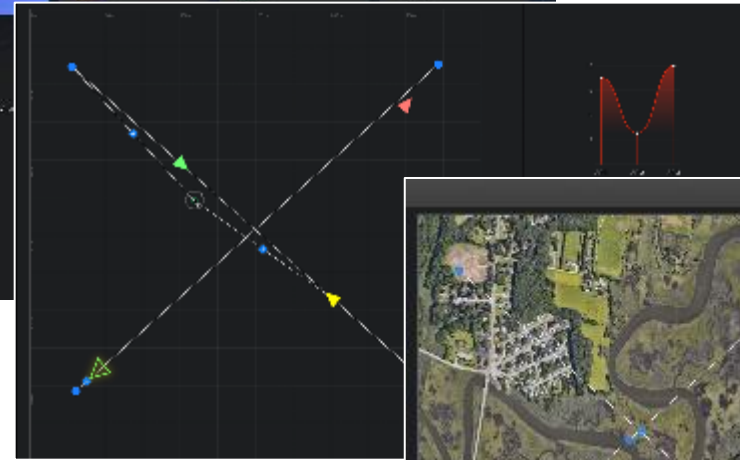
Type 1 Research: Controlled, Lab Studies

Planned HAT studies:

- Using mental models to predict trust and automation dependence
- The role of mental models in predicting multi-vehicle management performance
- Attentional limitations in multi-vehicle management



*Human-Autonomy
Teaming Task Battery*



Experiments
(Basic)

Characteristics:

- Abstracted versions of real-world tasks
- High control over experimental manipulations and testing environment
- Do NOT require expert participants
- Low fidelity



Highly controlled
laboratory experiments

Qualitative, descriptive
field studies

Measuring Human Contributions to Safe and Successful Performance

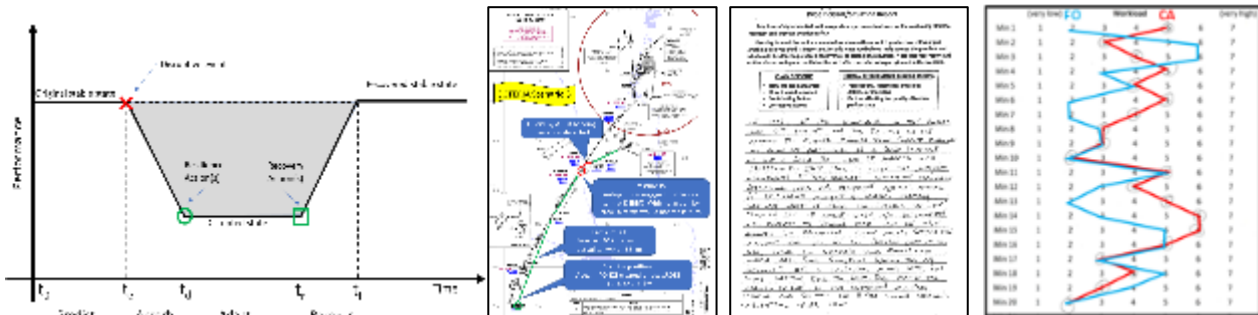
Motivation and Objectives

- Address often-unrecognized gap in data collected about operator performance
 - The majority of currently collected data focuses on rare safety failures, rather than frequent safety successes
 - Can lead to “data driven” policy & design risks due to sampling bias; rare failures are not representative of human performance
- Explored using commercial aviation flight deck due to maturity of simulation capabilities and proliferation of safety data collected in this operational domain

• **Principles & metrics for assessment could be generalized to any safety-critical domain, including emerging operations**

Progress and Highlights

- Created a data testbed for identifying approaches for measuring the actions and strategies that operators use to successfully anticipate, monitor for, respond to, and learn from events in their environment



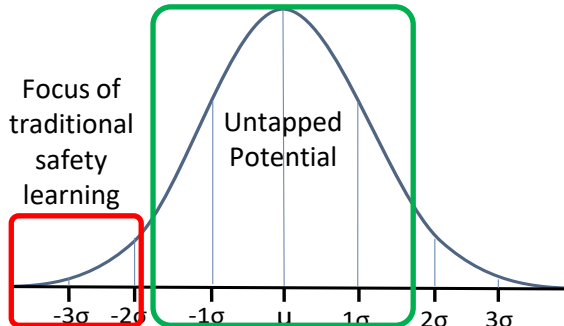
Approach

- 13 B737 flight crews took part in a 1.5-day study at Langley’s Integration Flight Deck (IFD), using a high-fidelity B737 motion-base simulator
- Participating flight crews flew a series of eight 20-minute scenarios based on arrivals into Charlotte Airport. Each scenario was designed to contain at least 2 manageable “threats” for crews to experience



Impact

- Enable assessment of methods for learning from what *happens*, not just from what *fails*
- **Potential to massively expand the pool of safety-relevant data, which will enhance the ability to be “in time” and reduce risk of sampling bias**



For more information, contact:

Jon Holbrook, PhD

NASA Langley Res Ctr

jon.holbrook@nasa.gov

757-864-9275



Measuring Human Contributions to Safe and Successful Performance



Motivation and Objectives

- Address often-unrecognized gap in data collected about operator performance
 - The majority of currently collected data is from infrequent safety events rather than frequent safe operations
 - Can lead to “data driven” decisions where safety failures are not representative of overall performance
- Explored using commercial flight simulator capabilities and data to understand this operational domain

- **Principles & metrics for a data driven approach to a critical domain, including**

Approach

- 13 B737 flight crews took part in a study at Langley’s Integrated Flight Deck (IFD), using a high-fidelity flight simulator
- Participating flight crews performed 20-minute scenarios based on real-world events at Charlotte Airport. Each scenario was designed to contain at least one “threat” for crews to experience

Progress and Highlights

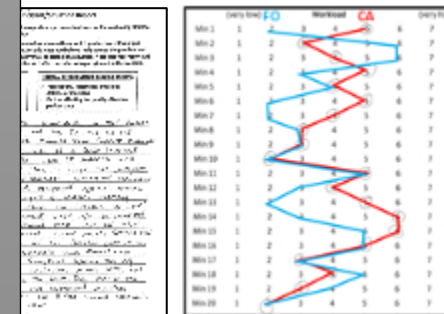
- Created a data testbed for identifying approaches for measuring human contributions to successfully completing tasks from events in their operational domain

Saturday (Tomorrow)
10:30am - 12pm

Piloting Techniques
Chair: Nicoletta Fala
Location: RIT Room B

“Learning about routine successful pilot techniques using a cued retrospective think-aloud task”

Jon B. Holbrook, Chad Stephens, Lawrence J. Prinzel III,
Sepehr Bastami, & Daniel J. Kiggins



from what *happens*,

safety-relevant data, “e” and reduce risk of

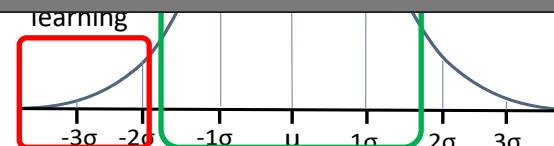
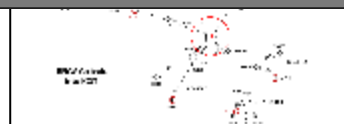
For more information, contact:

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NASA Langley Res Ctr

jon.holbrook@nasa.gov

757-864-9275



- Located in the Human Systems Integration Division at NASA Ames Research Center
- Conducts *human-in-the-loop (HITL) simulation and flight test research*
- Focus on how *human performance can be augmented* by increasingly autonomous systems
- Create a relationship between human operator and autonomous systems that *replicate a teammate relationship*
- **Goal:** test and enhance the safety and efficiency for novel, proposed operations in the National Airspace System

POC: Garrett Sadler
garrett.g.sadler@nasa.gov
 NASA Ames Research



Ground Control Station



Urban Air Mobility (Crewed) Simulator



- Approach
 - Apply/develop HAT techniques to enable multiple operators to control multiple aircraft (m:N)
 - Collaborate with industry and academia
 - Develop and test techniques for multiple domains of m:N operations: Small UAS, Large UAS, Urban Air Mobility, High Altitude Platform Systems, Swarms
- Previous/Current TTT Research
 - Interface and GCS Design (2020 - ongoing)
 - ConOps/Roles & Responsibilities (Summer 2020, Feb-Mar 2021)
 - m:N Handoff Procedures (Spring 2022)
 - m:N Communications Procedures (Summer/Fall 2022)
 - Small UAS GCS Capabilities (Spring 2023)

POC: Garrett Sadler
garrett.g.sadler@nasa.gov
 NASA Ames Research



Contact and Selected HAT Publications

Eric Chancey, Ph.D.

eric.t.chancey@nasa.gov



Selected Write-Ups:

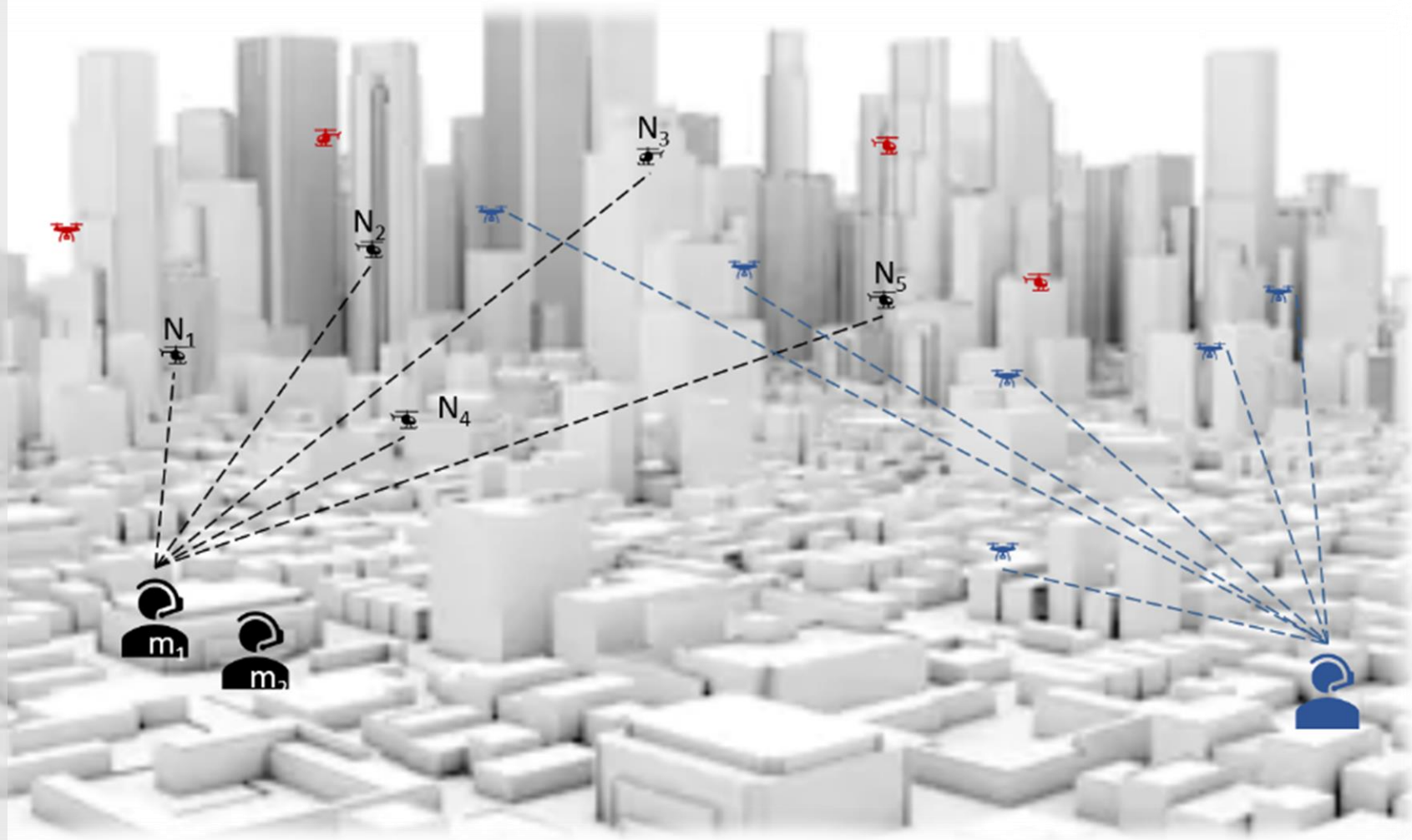
- Sato, T., Inman, J., Politowicz, M. S., Chancey, E. T., & Yamani, Y. (accepted). Human-autonomy trust in the context of Advanced Air Mobility operations: A pilot survey study. Proceedings of the Human Factors and Ergonomics Society 2023 Annual Meeting. Washington, DC: HFES.
- Sato, T., Inman, J., Politowicz, M. S., Chancey, E. T., & Yamani, Y. (accepted). A meta-analytic approach to investigating the relationship between trust and attention allocation. Proceedings of the Human Factors and Ergonomics Society 2023 Annual Meeting. Washington, DC: HFES.
- Chancey, E. T., Politowicz, M. S., Buck, B. K., Ballard, K. M., Unverricht, J., Houston, V., Chandarana, M., Le Vie, L. R. (2023). Foundational human-autonomy teaming research and development in scalable remotely operated Advanced Air Mobility operations: Research model and initial work. AIAA SciTech Forum. National Harbor, MD & Online: AIAA.
- Politowicz, M. S., Chancey, E. T., Buck, B. K., Unverricht, J. R., & Petty, B. J. (2023). MPATH (Measuring Performance for Autonomy Teaming with Humans) Ground Control Station: Design approach and initial usability results. AIAA SciTech Forum. National Harbor, MD: AIAA.
- Buck, B. K., Chancey, E. T., Politowicz, M. S., & Unverricht, J. (2023). A remote vehicle operations center's role in collecting human factors data. AIAA SciTech Forum. National Harbor, MD & Online: AIAA.
- Houston, V., Chancey, E. T., Politowicz, M. S., & Jennings, N. (2023). Intelligent Change Detection System (ICDS): A machine learning approach to combat change blindness in remote operation environments. AIAA SciTech Forum. National Harbor, MD & Online: AIAA.
- Unverricht, J., Chancey, E. T., Politowicz, M. S., Buck, B. K., Geuther, S. C., & Ballard, K. M. (2023). Where is the human in the loop? Analysis of extended visual line of sight uncrewed aerial system operations within a remote operations environment. AIAA SciTech Forum. National Harbor, MD & Online: AIAA.
- Politowicz, M. S., Sato, T., Chancey, E. T., & Yamani, Y. (2022). Pathfinder Networks for measuring operator mental model structure with a simple autopilot system. Proceedings of the Human Factors and Ergonomics Society 2022 Annual Meeting. Atlanta, GA.
- Chandarana, M., Chancey, E. T., Le Vie, L. R., & Politowicz, M. S. (2022). Evaluation of a remote data collection method to study human-automation interaction and workload. Proceedings of the Human Factors and Ergonomics Society 2022 Annual Meeting. Atlanta, GA.
- Sato, T., Politowicz, M. S., Chancey, E. T., & Yamani, Y. (2022). Attentional considerations in Advanced Air Mobility operations: control, manage, or assist? Proceedings of the Human Factors and Ergonomics Society 2022 Annual Meeting. Atlanta, GA.
- Unverricht, J., Chancey, E. T., Politowicz, M. S., Buck, B. K., & Geuther, S. (2022). Eye glance behaviors of ground control station operators in a simulated Urban Air Mobility environment. 41st Digital Avionics Systems Conference. Portsmouth, VA.
- Chancey, E. T., Politowicz, M. S., & Le Vie, L. R. (2021). Enabling Advanced Air Mobility operations through appropriate trust in human-autonomy teaming: Foundational research approaches and applications. 2021 AIAA SciTech. Virtual Meeting.
- Politowicz, M. S., Chancey, E. T., & Glaab, L. J. (2021). Effects of autonomous sUAS separation methods on subjective workload, situation awareness, and trust. 2021 AIAA SciTech. Virtual Meeting.
- Chancey, E. T., & Politowicz, M. S. (2020). Public trust and acceptance for concepts of remotely operated Urban Air Mobility transportation. Proceedings of the Human Factors and Ergonomics Society 2020 Annual Meeting. Chicago, IL.
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- Wing, D. J., Chancey, E. T., Politowicz, M. S., & Ballin, M. G. (2020). Achieving resilient in-flight performance for Advanced Air Mobility through simplified vehicle operations. 2020 AIAA Aviation. Virtual Meeting.



RAM Focus: m:N Operations Move Us to UML-5

Looking beyond UML-4 to ubiquitous, large-scale AAM ops

- UAM Maturity Level 5 (UML-5)¹
- Shift human role from providing decisions to providing intent
- No pilot in the loop
- **m** represents a small number of off-board humans operating a larger number **N** of highly autonomous aircraft
- Enabled by autonomous vehicle technology and regulatory change
- Enables **scalable operations** and business case for applications like UAM



¹Goodrich, K. H. and Theodore, C. H. (2021). Description of the NASA Urban Air Mobility Maturity Level (UML) Scale. AIAA SciTech Forum. AIAA-2021-1627



RAM Portfolio Overview

Multidisciplinary approach to tackling the fundamental challenges for ubiquitous AAM



Human-Autonomy Teaming

As autonomy increases, need to carefully consider human behavior. It'll require humans and machines to work and think together in new and different ways.

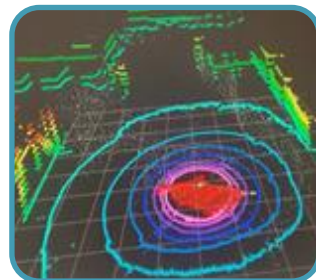
Activities: Research tools & sims with partners; community working group



Crowdsourced Perception Datasets

Datasets enable advancements in computer vision & perception for autonomous vehicles. Visual-inertial datasets in the AAM context are not widely available.

Activities: Develop ride-along pods for fleet helicopters; accumulate and curate perception datasets in online repositories



Distributed Sensing

Replacing the "pilot's eyeballs" is no easy feat. Distributed sensing provides a more comprehensive knowledge of the environment, increasing safety and capability of the system.

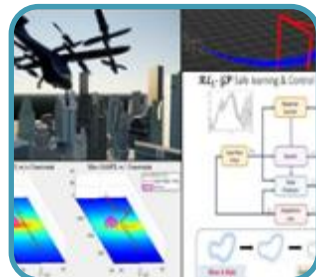
Activities: Common perception framework with distributed info sources; flight demos



Communication, Navigation, & Surveillance

As air traffic density increases, new strains on the system will occur, such as increased comm interference and spectrum demand.

Activities: Autonomous spectrum allocation; self-optimizing phased array antennas



Intelligent Contingency Management

Need advances in state-of-the-art autonomous vehicle systems. Vehicles will need to deal with predictable and unpredictable scenarios without human intervention.

Activities: Learning-based approaches to handle off-nominal conditions; autonomous decision tools



Efficient Design & Testing of AAM Vehicles

AAM eVTOL vehicles are very complex, resulting in increased time and expense to design and test.

Activities: Novel methods for efficient flight and ground testing; perception-influenced design of propeller blades