



Enabling Urban Air Mobility: Human-Autonomy Teaming Research Challenges and Recommendations

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Introduction



- As technologies evolve, humans and machines will be required to work together in new and different ways
- Human-Autonomy Teaming (HAT) has emerged as a critical area of research
 - Focused not on how machines can think like people, but on how machines can help people think better
- Goal: Enable success of future aviation markets through application of HAT principles
 - Identify HAT challenges and opportunities
 - Provide a comprehensive and prioritized approach to HAT research



Human-Autonomy Teaming



- Autonomous machine systems
 - Capable of independently assuming functions typically assigned to human operators
 - Less human intervention overall and for longer periods of time
 - May still require human supervision, direction, and cooperation
- Human-Autonomy Teaming (HAT)
 - Explores mechanisms by which humans and increasingly autonomous systems (IAS) can work and think better together



Urban Air Mobility



- Defined as
 - A safe and efficient system for air passenger and cargo transportation within an urban area
 - Includes small package delivery and other urban unmanned aerial system services
 - Supports a mix of onboard/ground-piloted and increasingly autonomous operations
- Characterized by
 - Increasingly dense airspace
 - Frequent flights that travel among an expanding network of takeoff and landing areas
 - Fundamentally different aircraft
 - Increased use of IAS to address scalability challenges



Image Credit: NASA



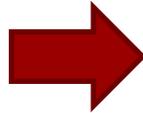
Method



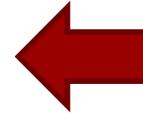
Community
Objectives



HAT
Literature
Review



**Comprehensive
Research Plan**



UAM-HAT
Concepts of
Operation



Methods of
Scientific Discovery



HAT Literature Review



- Identified 6 key topic areas
 - Teaming models
 - Contingency management
 - Shared situational models
 - Trust calibration
 - Methods, metrics, and measurement
 - Paths to operational approval



Stakeholder Community Objectives



Community Operational Objectives

- Enable aircraft without an onboard pilot to routinely operate in the NAS

- Remove the need for the current regulatory paradigm that requires a pilot for every passenger aircraft

- Achieve an order of magnitude more vehicles than operators

HAT Research Need

Coordination between off-board pilot and onboard machine agent

No realistic timeline for technology development; will require human interaction for the foreseeable future

Requires appropriate interaction between vehicles & operators, as function migrates from pilots to supervisors/managers



Stakeholder Community Objectives



Community Operational Objectives

- Enable order-of-magnitude increases to airspace system capacity, unconstrained by workload limitations
- Enable air transports to be piloted safely by a single operator
- Enable new emerging market pilots to receive certification with order-of-magnitude reductions in training
- Enable aircraft to auto-land anywhere and under nearly any conditions

HAT Research Need

Capacity limitations are partially a function of design, but could be mitigated by new teaming strategies

Requires appropriate operator-machine interactions and methods of safety assurance that account for the interactions

Training reductions will require increasingly capable machines, with which the pilots must interact

Auto-land currently has limited capability; impact on human-autonomy interaction remains unexplored and untested





UAM HAT Concepts of Operation

- Simplified vehicle operations (SVO)
 - Reduce training footprint while meeting required level of operational safety
 - Addresses costs and projected pilot shortage to meet envisioned future UAM needs
- UAM airspace
 - Managing complexities of introducing multiple diverse autonomous airspace system applications
- Remote Supervisory Operations (RSO)
 - m:N (m - operator, N – vehicle)
 - Control of multiple vehicles by one or more ground-based operators

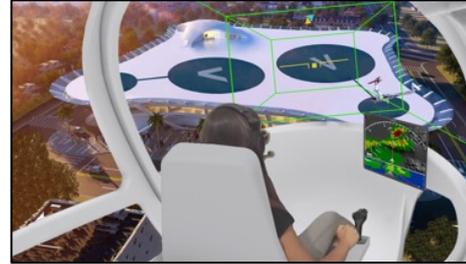


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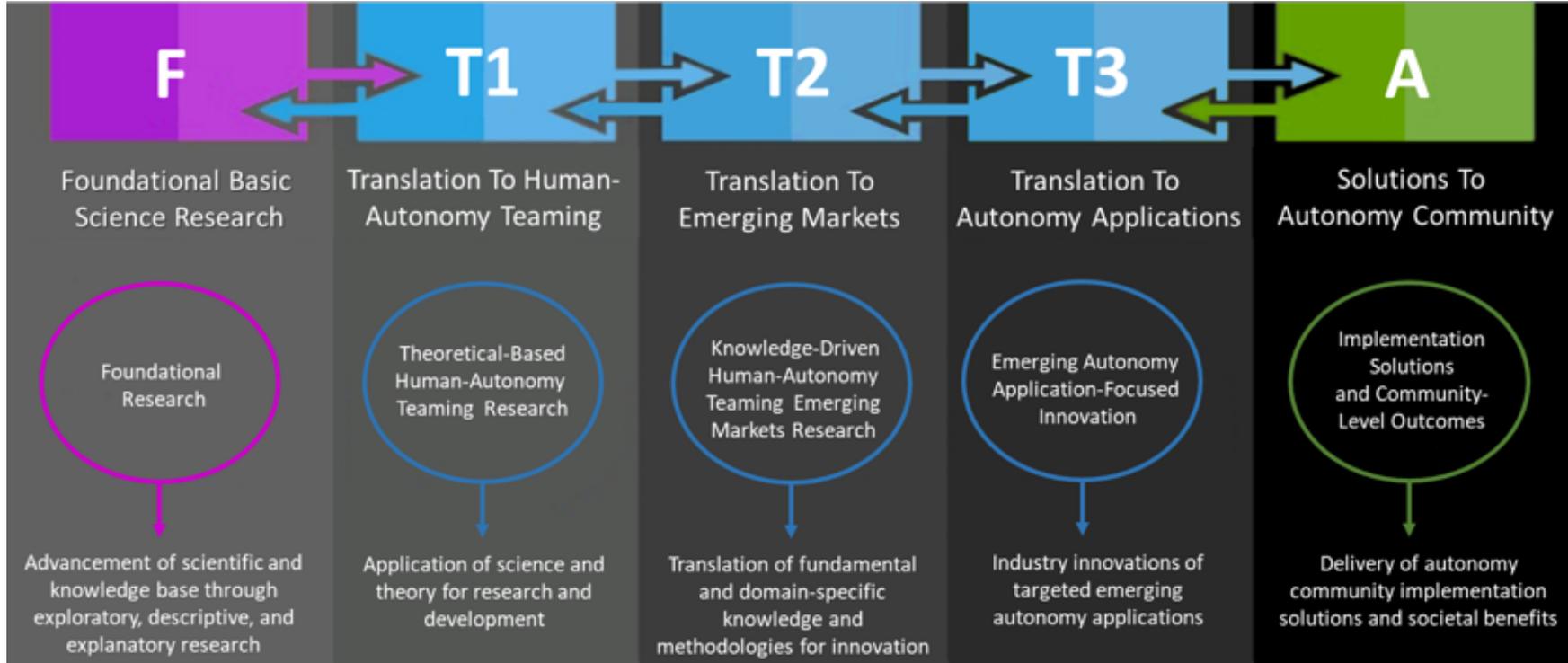


Image Credit: NASA





Methods for Scientific Discovery



Overarching HAT Research Challenges



- What models of multi-agent interaction should be used, and how can we evaluate them?
- How can a common knowledge base and capability for intent inferencing between human and machine agents be established?
- How can inter-agent trust be appropriately built, calibrated, and leveraged to establish roles, authority, and transitions of control?
- How can we ensure that human-machine teams retain or improve upon current capabilities to sustain operations under expected, uncertain, unanticipated, and unpredicted conditions?
- How can human-machine team performance be measured and leveraged to enable ongoing system performance improvements?
- What are the viable paths to certification and operational approval of human-machine teaming concepts?



HAT CONOPS Research Opportunities



CONOPS-related changes

- New opportunities for success and failure
- New team configurations and compositions
- Reduced pilot expertise and training requirements
- New classes of aircraft and operational environments
- New methods of flight control
- New physical arrangements of operator location
- New information availability and architectures
- New operational pace and scope

Emerging research opportunities

- New teaming architectures
- New procedures, displays, controls, interfaces, workspaces, etc.
- New methods of training
- New methods for characterizing risks and opportunities
- New methods for assessing safety-producing and safety-degrading conditions
- New methods for integrated-system performance evaluation
- New methods of assuring compliance



Conclusion



- Evolving technologies create new and different opportunities for humans and machines to interact
- HAT focuses on how human and machine can work and think better together
- The goals of this effort were to
 - Describe the importance of HAT and HAT challenges that will need to be explored to enable autonomous UAM
 - Provide a research-driven approach to enable the success of those future aviation market applications by leveraging HAT principles



Image Credit: NASA

