**Transformative Aeronautics Concepts Program**

# Secure and Safe Assured Autonomy (S2A2)

Active Technology Project (2020 - 2024)

## Project Introduction

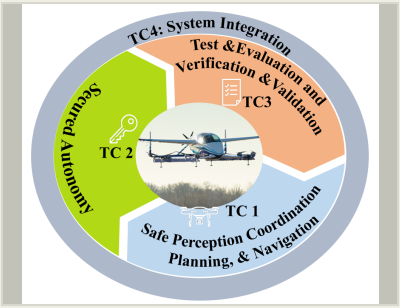
Aviation's future will likely see the integration of a wide variety of Advanced Air Mobility (AAM) systems including Unmanned Aerial Systems (UAS) for cargo/delivery, personal air vehicles, and commercial Urban Air Mobility (UAM) vehicles. However, substantial challenges exist that could delay (and possibly prevent) these developments and thus research is needed in a variety of areas to leverage technologies in autonomy, Air Traffic Management (ATM), multi-redundant flight systems architectures, and advanced wireless connectivity like 5G to meet these challenges.

The goal of this ULI project is to develop new technologies and innovative operational concepts which will ensure safe, secure and robust integration of autonomous vehicles into Advanced Air Mobility-tailored transportation infrastructure. All this must be done while maintaining inter-operability with current civil air transportation systems and associated safety standards.

The project is organized into *four Technical Challenges (TCs) areas* designed to provide unique UAM solutions and a transition roadmap for industry and government to utilize research product output.

**1 Safe Perception, Coordination, Planning, and Navigation is the basis of our first technical challenge TC1:** The full-scale incorporation of low-altitude Unmanned Aerial Vehicles (UAVs) and UAM systems introduces unexplored safety risks, and necessitates high-reliability sensing, coordination, planning, and navigation approaches to cope with dynamic and unpredictable environments. TC1 addresses the amalgamation of various algorithms (and software components) that correspond to addressing disparate technological challenges. These challenges include operating at different time-scales and integrating dissimilar types of data into a unified, holistic format compatible with both existing and near-future embedded flight control system for UAV and UAM systems.

**2 Secured autonomy our second technical challenge TC2**: For future secured autonomy in UAM systems resolving issues surrounding operations in potentially hostile environments with highly dynamic situations, the system's inherent heterogeneity among cyber and physical components, the large-scale overall system, and limited computation/processing capability of individual components poses complex challenges. TC2 investigates the system's capability to handle malicious cyber-physical activities based on the strength and potential for damage and categorized into five levels: (1) Low (2) Guarded (3) Elevated (4) High and (5) Severe. Accordingly, cyber-attack detection and accommodation techniques will be developed while considering the overhead added to the system by the cyberattack detection algorithms as a percentage value of memory, time, and power.



The four TCs for Secure and Safe Assured Autonomy

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**3 Verification & Validation (V&V) and Test & Evaluation (T&E) is the third challenge, TC3:** The hybrid dynamics of complex cyber-physical systems within UAM networks are difficult to model and analyze to enable reasoning concerning human interference, intervention, guidance, and assistance. Therefore, novel V&V and T&E tools that are scalable and modular, and that can flexibly accommodate evolving specifications and requirements, are needed Effective V&V and T&E frameworks in TC3 provide provable guarantees of correctness in the UAM network, improve safety, and provide certification methodologies for autonomous operation in the airspace.

**4 System integration is the final component we will address in TC4:** Proper integration of the emerging secure and safe autonomy algorithms into practical flight software is challenging and complex. Moreover, experimenting developed algorithms in different environments (dynamic simulation system, small-scale Indoor Flight Facility (IFF), and large-scale Outdoor Flight Facility (OFF)) and performing different missions (with dependency analytics, integrated simulation (SIM) and experimental flight tests through fast learning cycles) is the required outcome to ensure robust integration and operations, i.e., a system that the public can trust and accept. The projects' industry partners play a central and crucial role in TC4.

## Anticipated Benefits

This project is poised in advancing the industrial deployment of secure and safe assured autonomy to meet the needs and benefit commercial aviation, and general public transportation by advancing state-of-the art practices to:

- Manage large and heterogeneous numbers of aircraft in dynamic and uncertain operations.
- Operate securely and safely under varying levels of autonomy and system complexity.

The specific benefits of this project will include developing a *novel research ecosystem* with –

1. Sensing, perception, intelligent safe coordination, planning, and navigation algorithms for autonomy-enabled air transportation
2. Secure and resilient cyber-physical systems for air vehicles
3. V&V and T&E procedures supporting certification of the developed technologies and tools via user scenarios and finally
4. Scientific methods for optimal system integration and scaling analysis

The developed tools will be tested and assessed to improve their maturity into Technology Readiness Level (TRL) 6 over multiple generations, supporting a seamless transition to operations with industry partners, to realize mobility,

## Organizational Responsibility

**Responsible Mission Directorate:**

Aeronautics Research Mission Directorate (ARMD)

**Lead Organization:**

North Carolina Agricultural and Technical State University

**Responsible Program:**

Transformative Aeronautics Concepts Program

## Project Management

**Program Director:**

John A Cavolowsky

**Project Manager:**

Koushik Datta

**Principal Investigator:**

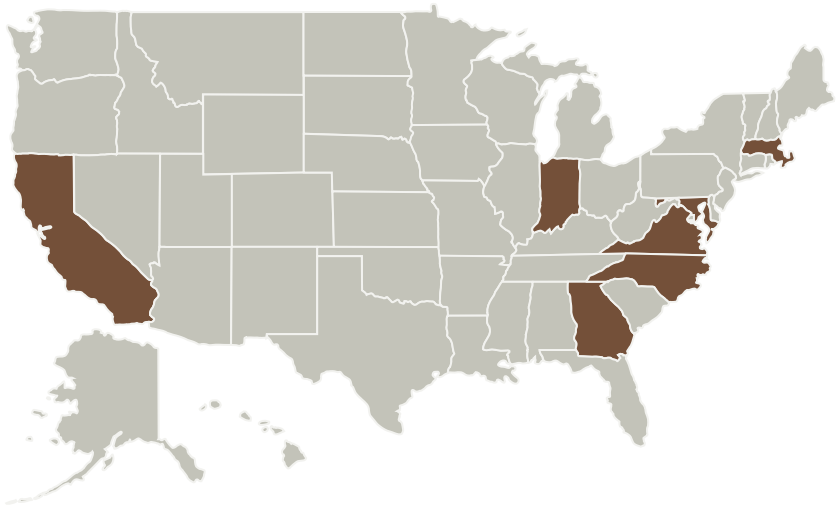
Abdollah Homaifar

*Continued on following page.*

scalability and economic goals envisioned for 2050.

Our team's roster of dedicated faculty will promote the education of the next generation of engineers. As the nations' largest Historically Black College and University (HBCU), North Carolina Agricultural and Technical State University (NC A&T) leads the nation in engineering degrees awarded to African Americans at the undergraduate and graduate levels and is the leading educator of undergraduate African-American female engineers. All partnering universities are committed to increasing student preparation for, and engagement in, future Science, Technology, Engineering, and Mathematics (STEM) workforce, especially underrepresented minorities in engineering. The ranks of our student and Post-Doctoral researchers include mentoring programs and training to advance the next generation of certification experts and industry leaders who can support this rapidly growing economically empowering field of study. The ULI's leadership will promote the education and engagement of the next generation of engineers. We will contribute to the future workforce preparation through implementation of student mobility, communication and ethics, social media, specialized course offerings, entrepreneurship, and other outreach programs.

### Primary U.S. Work Locations and Key Partners



## Project Management *(cont.)*

**Co-Investigators:**

Daniel Delaurentis
Mark Costello
Ali Karimoddini
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Sam Coogan
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Shaoshuai Mou
M. Nabil Mahmoud
Judy Hoffman
Ioannis A Raptis
James Paduano
Bruce J Holmes
Damon Jenkins
Larry Datko

## Technology Areas

**Primary:**

- TX16 Air Traffic Management and Range Tracking Systems
  - TX16.1 Safe All Vehicle Access

## Target Destination

Foundational Knowledge

## Supported Mission Type

Push

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| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| North Carolina Agricultural and Technical State University | Lead Organization | Academic | Greensboro, NC |
| Alaka'i Technologies Corporation | Supporting Organization | Industry | Hopkinton, MA |
| Aurora Flight Sciences Corporation | Supporting Organization | Industry | Manassas, VA |
| General Atomics | Supporting Organization | Industry | |
| Georgia Institute of Technology | Supporting Organization | Academic | Atlanta, GA |
| Northrop Grumman | Supporting Organization | Industry | Redondo Beach, CA |
| Purdue University | Supporting Organization | Academic | West Lafayette, IN |

| Primary U.S. Work Locations | |
|---|---|
| California | Georgia |
| Indiana | Massachusetts |
| Maryland | North Carolina |
| Virginia | |

# Secure and Safe Assured Autonomy (S2A2)

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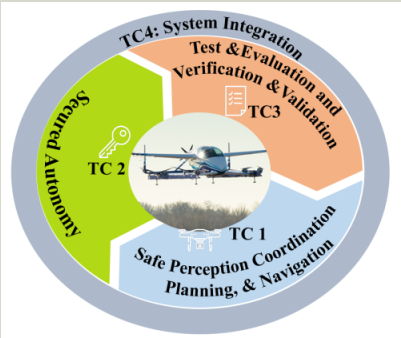
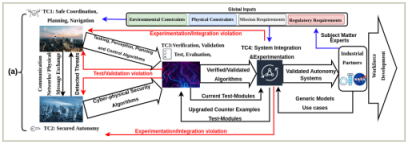
## Images




**Overview of four Technical Challenges for Secure and Safe Assured Autonomy**
The four TCs for Secure and Safe Assured Autonomy
*(https://techport.nasa.gov/image/40833)*



**System architecture, illustrating the interconnections and data flow between Technical Challenges**
System architecture, illustrating the interconnections and data flow between Technical Challenges
*(https://techport.nasa.gov/image/40834)*

## Project Website:

http://s2a2.engineering.ncat.edu