North Carolina A&T State University
NASA ULI Overview
Secure and Safe Assured Autonomy (S^{2}A^2)

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Introduction to the PI

Abdollah (Ebbie) Homaifar

NASA Langley Distinguished Chair Professor
Duke Energy Eminent Professor and Director of
Autonomous **C**ontrol and **I**nformation **T**echnology (**ACIT**) Institute, and
Testing, **E**valuation, and **C**ontrol of **H**eterogeneous **L**arge-scale Systems
of **A**utonomous **V**ehicles (**TECHLAV**) Center

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S²A² Vision and Key Technical Challenges

To provide a Secured and Safe Assured Autonomy that integrates a wide variety of Unmanned Aerial Systems (UAS) with the following technical challenges:

Image credit: https://cleantechnica.com/2019/02/11/airbus-altiscope-blueprint-tackles-urban-air-mobility

- **TC1:** Safe Perception, Coordination, Planning, and Navigation

- **TC2:** Secured Autonomy

- **TC3:** Verification & Validation (V&V) and Test & Evaluation (T&E)

- **TC4:** System Integration

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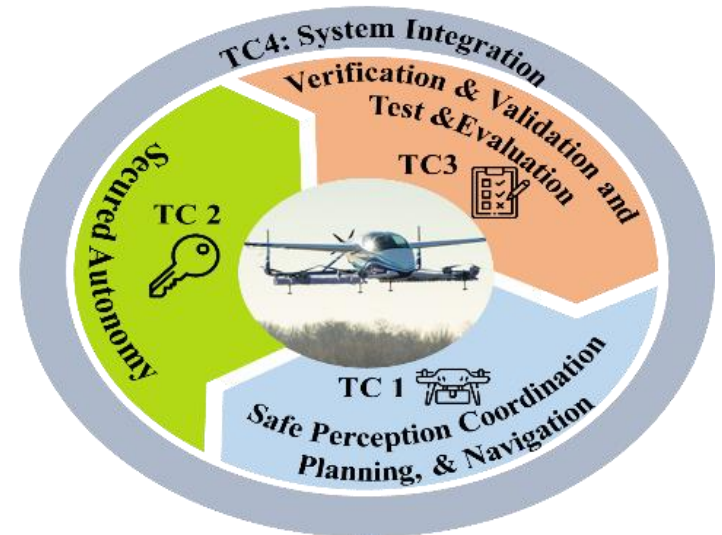
National experts and Key Research Tasks

TC1: Safe Perception, Coordination, Planning, and Navigation

Lead: Ali Karimoddini (NC A&T),

Co-Lead: Kyriakos Vamvoudakis (Georgia Tech),

Supporting Faculty: James Goppert (Purdue University) , Shaoshuai Mou (Purdue University), Ioannis A. Raptis (NC A&T) , Judy Huffman (Georgia Tech)

Research Objectives

- Sensing, Perception, and Semantic Scene Understanding
- On-the-Fly Conflict-Free Tasking and Coordination
- Compositional Learning for Safe Motion Planning, Control and Navigation

Image from gettyimages
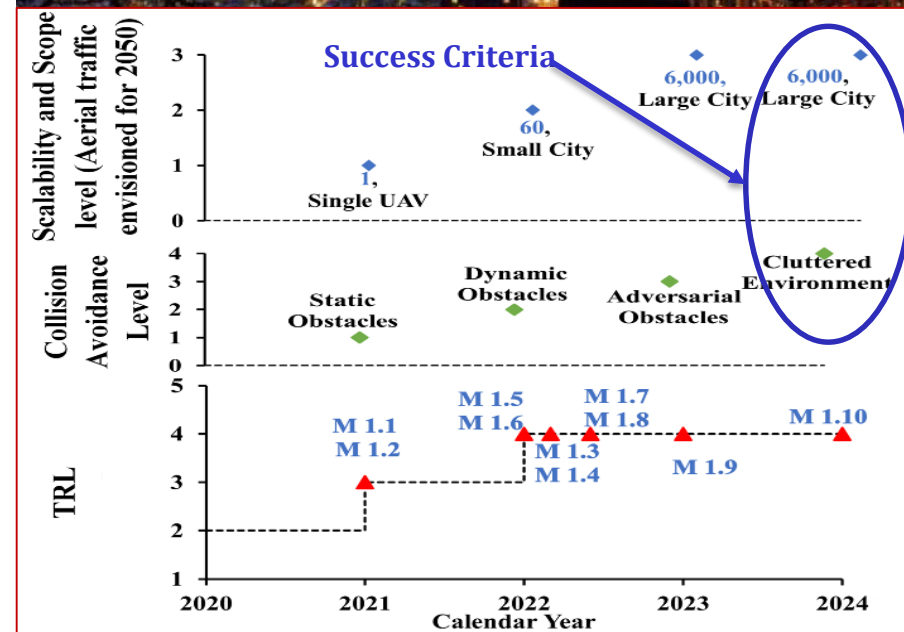
National experts and Key Research Tasks

TC2: Secured Autonomy

Lead: Inseok Hwang (Purdue University),

Co-Lead: Dengfeng Sun (Purdue University),

Supporting Faculty: Shaoshuai Mou (Purdue University), Mahmoud Nabil Mahmoud (NC A&T)
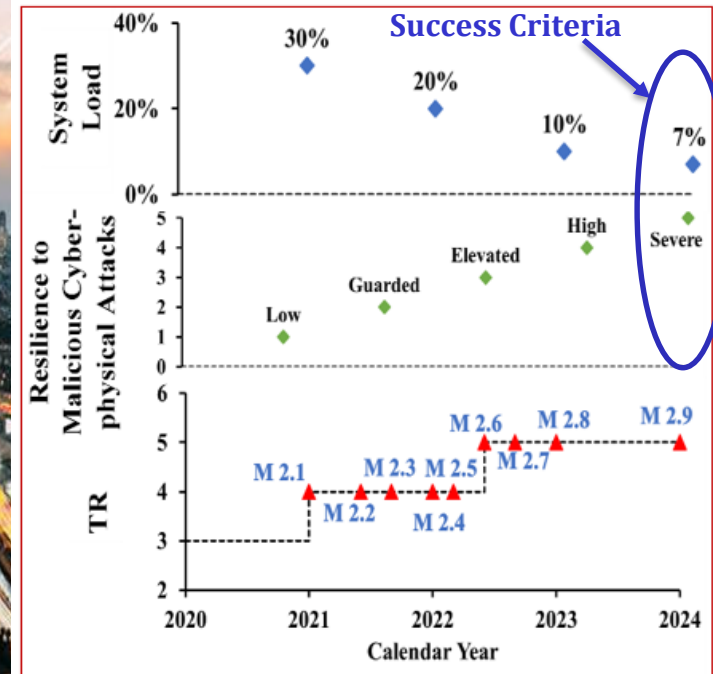
Research Objectives

- Mathematical Modeling of UAM and Cyberattack
- Cyberattack Analysis, Detection, and Risk Management.
- AI-driven Cyberattack Monitoring.
- Benchmark Resilience in Fully Distributed Scenarios.

Closely Integrated

https://www.strettoindia.com
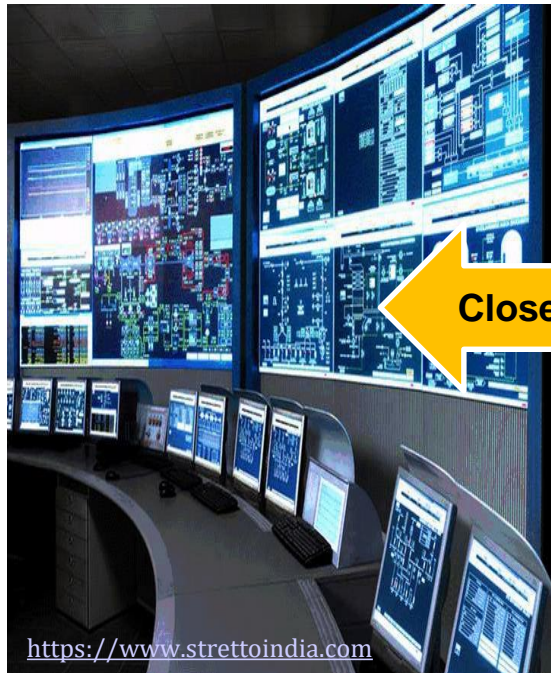
UAM Traffic Management System

Credit: Getty Images/iStockphoto

Multi-UAM Operation

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National experts and Key Research Tasks

TC3: Verification & Validation (V&V) and Test & Evaluation (T&E)
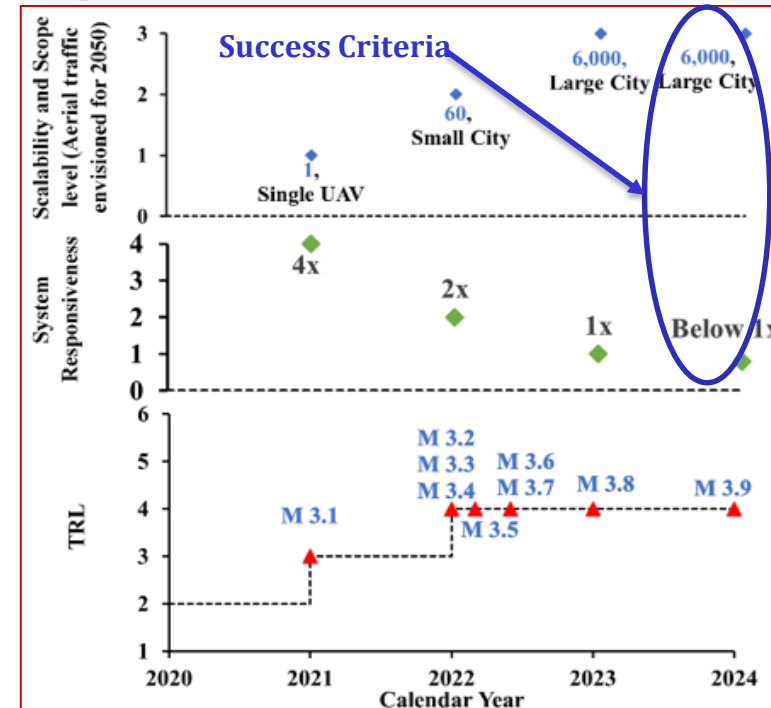
Lead: Abdollah Homaifar (NC A&T),

Co-Lead: Samuel Coogan (Georgia Tech),

Supporting Faculty: James Goppert (Purdue University), Ali Karimoddini (NC A&T)

Research Objectives

- Verified Run-Time Assurance Mechanisms (RTA)

- Hybrid UAM Model Checking

- Incremental Verification Techniques

- Testing autonomous capability of UAVs using data-driven techniques

Image credit: https://www.ainonline.com/aviation-news/aerospace/2016-12-22/nasa-drives-vision-air-traffic-management-drones

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Lead: Daniel Delaurentis (Purdue University),
**Co-Lead:** Mark F. Costello (Georgia Tech),
Supporting: Abdollah Homaifar (NC A&T), James Paduano (Aurora Flight Sciences), Bruce J. Holmes (Alaka'i Technologies Corporation), Neta Ezer (Northrop Grumman Corporation), Demon Jenkins (General Atomics Aeronautical Systems)

Research Objectives

- System Integration Methods

- Secure Autonomy Integration and Experimentation

- Safe Autonomy Integration and Experimentation

Image credit: NASA Illustration/Lillian Gipson

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Industry Partners
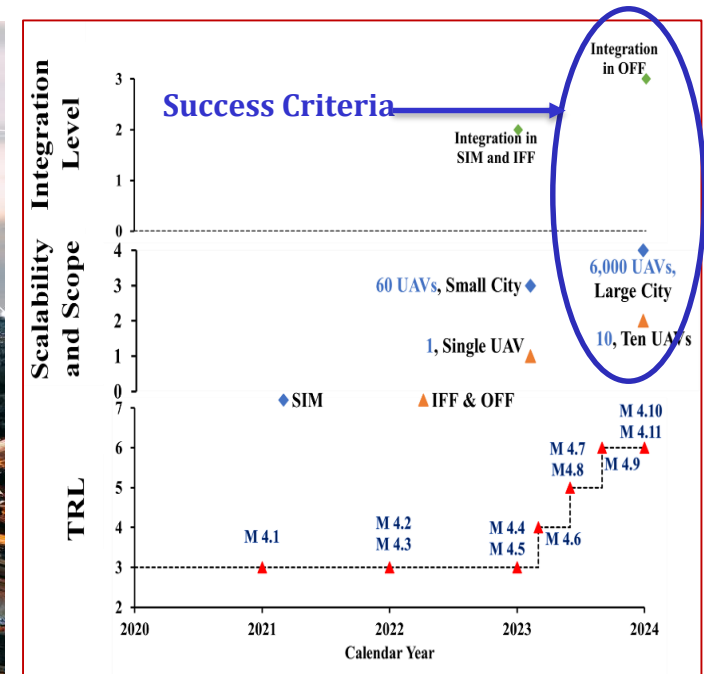
Aurora FLIGHT SCIENCES — A Boeing Company
- Access to Flight Test Data Acquisition
- Simplified Vehicle Operational Capability (SVO)
- Simulation Capability
- **Industry champion to TC1**

ALAKA'I TECHNOLOGIES
- Evaluate all approaches (TC1-TC3) for applicability in UAM.
- Advise team regarding TC4 flight test goals
- Instantiate a linkage mechanism between ULI vehicle simulations and a World Simulation Framework (WSF) that Aurora uses for its vehicles
- **Industry champion to TC3**

NORTHROP GRUMMAN
- Secondary engagement with TC1, TC3 and TC4
- Tech talks, mentoring and internship opportunities to students
- **Industry champion to TC2**

GENERAL ATOMICS AERONAUTICAL
- Provide knowledge base in aUAS development, design, flight and operations.
- Provide insight in adaptive autonomous vehicle sensing, coordination, planning, and navigation.
- Iteratively test autonomous system behaviors.

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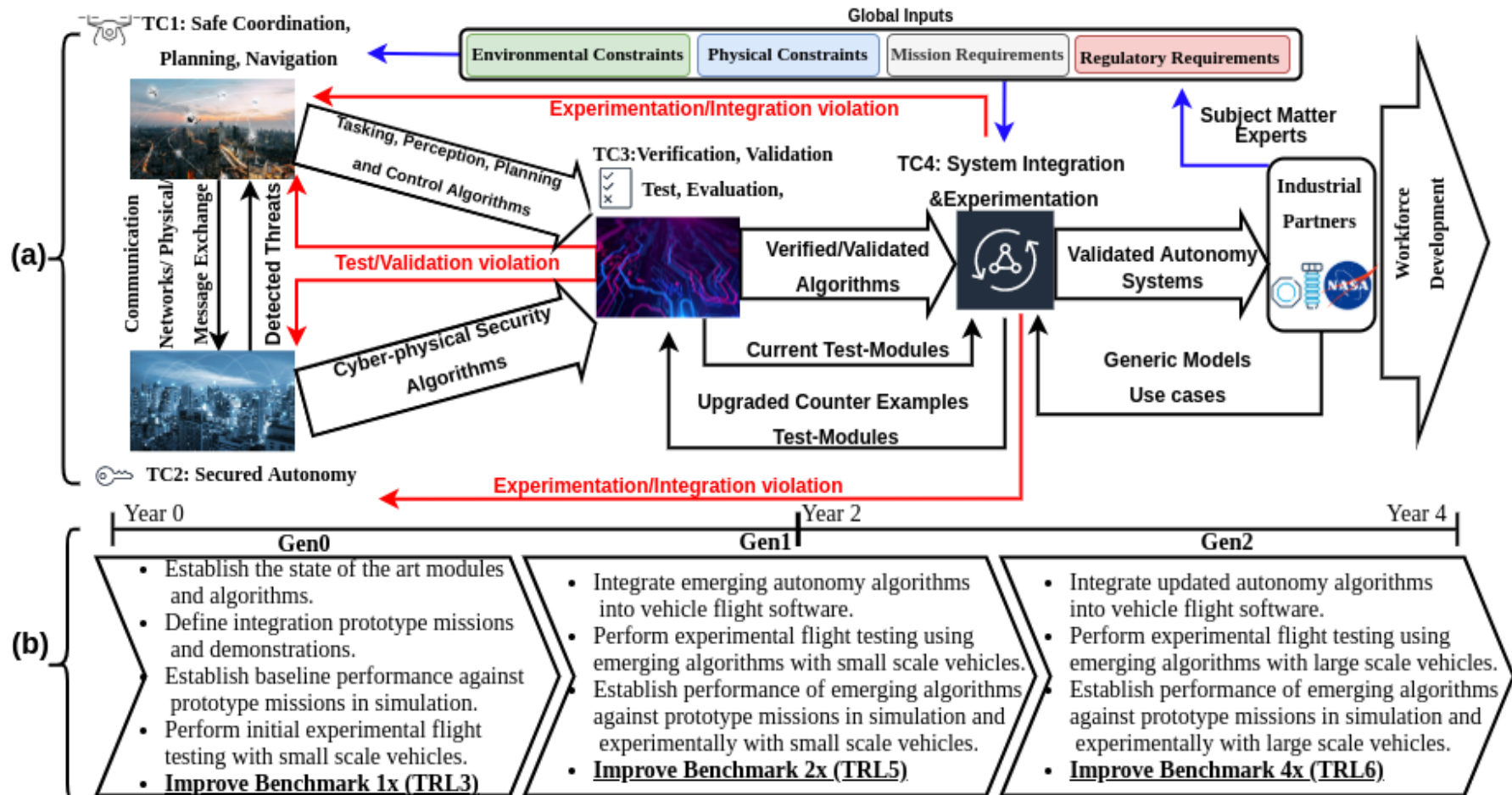
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Synergy and Project Timeline

Figure 2: System architecture, illustrating the interconnections and data flow between TCs.

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Student Centric-Approach: Integrated research, curriculum, internship/outreach development

Lead: John Kelly (NC A&T),

Co-Lead: James Goppert (Purdue University),

Supporting Faculty: Yahya Kamalipour (NC A&T),

Lori Skillings (Georgia Tech)

Image credit : https://educationvotes.nea.org/

Existing gaps between HBCUs/MSIs and other universities

lack of :
- collaboration between technical/applied sciences and humanities and social sciences
- access to experts from leading universities in the nation
- resources available at the leading institutions
- collaboration ties among participating institutions

Our ULI's leadership team will address these gaps

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Student Centric-Approach: Integrated research, curriculum, internship/outreach development

1) Communications and Ethics Program

A two-day workshop offered during the ULI **annual meetings** will expose students and faculty to a broad set of topics in **communications and ethics.**

2) Student Mobility Program

Short-term visits by NC A&T, Purdue, and Georgia Tech. graduate students to visit the partner institutions, **industry partners and government labs, especially NASA Centers and NIA.**

ULI will also foster the **NC A&T's weekly seminar series**

Image credit: http://techlav.ncat.edu/

3) Entrepreneurship Program

Workshop to be offered **twice a year** for students to expose them to ethical, legal, and communication aspects of working in a business environment. Enrollment will be open to all partner universities.

4) Course Sharing Program

14 graduate/undergraduate-level courses will be available as online special topic courses to students at the partnering universities.

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Student Centric-Approach: Integrated research, curriculum, internship/outreach development

| Program Name	Description
Minority-Serving Institutions (MSI) Outreach	A three-day summer workshop at NC A&T focusing on safe and assured autonomy
NASA Indiana Space Grant Consortium	NASA Internship and Fellowship funds to campus-based summer research internships for students from non-Indiana minority-serving institutions
The Innovative Mars Exploration Education & Technology (IMEET)	Two week collaborative summer day camp offered at three Georgia Space Grant Consortium (GSGC).

- 7 Educations and outreach programs
- Multiple transition opportunities to industry and government labs.
- Postdoctoral researchers: 1.5
- PhD & Master's Students: 24
- Undergraduate students: 20
- Summer camp K-12 teachers and students: 50

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Management Structure
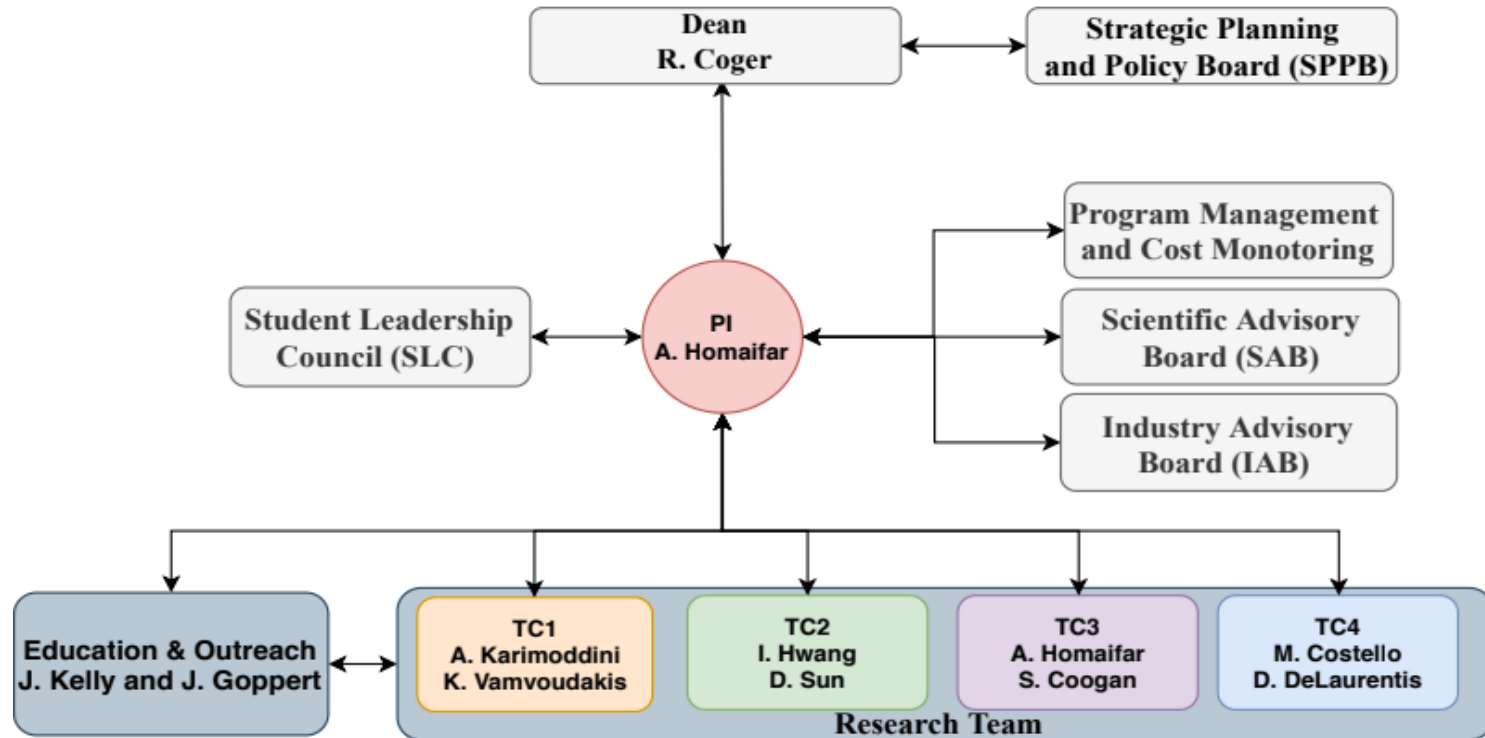
Secure and Safe Assured Autonomy (S^2A^2) Management Structure

Communication

- **Monthly** leadership meetings among via video conferencing to establish planning & coordination.

- **Weekly** seminars including invited speakers, TC member scholars & students -via Zoom and Webex.

- **Weekly** student-supervisor meetings - via Zoom and Webex.

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Expected impacts of NASA ULI

- **Development of:**

    - Novel **real time, scalable, and computationally efficient** sensing, perception, coordination, planning, and control approaches for UAM network to **handle the inherent vulnerability** to failures, cyber-physical attacks, collisions, and conflicts

    - Comprehensive mathematical model of the UAM networks subject to cyber-physical attacks with intrusion detection algorithms to enable autonomous vehicles to **automatically reconfigure control** structures **when faced with different types of attack**

    - Innovative compositional V&V framework to **compute and verify the various subsystems' properties** in a distributed manner

    - Scalable and novel frame work to evaluate the performance of a group of UAVs for concurrent operation in the physical world in the presence of environmental uncertainties, largely independent of the type of UAV

    - A scientific integration environment that **merges simulation and flight test knowledge gains and assesses TRL** to provide a systematic way of generating evidence for technology maturation and compatibility with integration with UAM missions **with realistic policy and economic constraints**

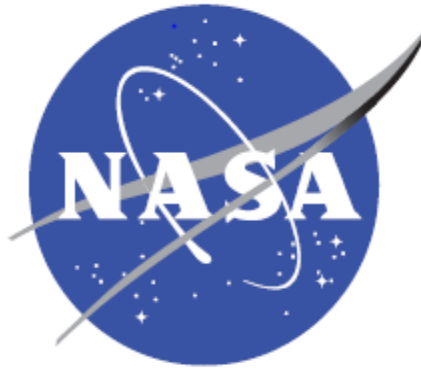- We will have launched **over 100 students** to the aviation community as the next leaders in S^2A^2

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S²A² Team

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Acknowledgement

The ACIT-NCAT would like to acknowledge The NASA ARMD University Leadership Initiative (ULI).

Remark: The views and conclusions being discussed here are those of the presenters and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of NASA ARMD University Leadership Initiative.

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Thank you!

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