Testing, Evaluation, and Control of Heterogeneous Large-scale Systems of Autonomous Vehicles (TECHLAV)

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http://techlav.ncat.edu/
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- Acknowledgments
- Q&A
# Department of Defense Roadmap

## Unmanned Systems Integrated Roadmap FY2013-2038

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<td>UMS Far Term</td>
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About TECHLAV

Testing, Evaluation, and Control of Heterogeneous Large-scale Systems of Autonomous Vehicles (TECHLAV) is a multidisciplinary research center on the leading edge of Control, Communication, Computation, and Human Cognition to address two main problems:

1. Teaming and Cooperative Control of Large-scale Autonomous Systems of Vehicles (LSASVs) integrated with human operators.
2. Testing, Evaluation, Validation, and Verification of LSASVs.
Challenges …

TECHLAV creates a comprehensive umbrella covering different aspects of systems of vehicles ranging from Modeling and Analysis to Control, Communication, Testing and Evaluation.

- How to mathematically describe the collective behaviors of systems of vehicles?
- How to reliably design decentralized control and communication for systems of vehicles to achieve desired collective performance?
- How to test and evaluate the control and communication between systems of vehicles?
TECHLAV Vision and Objectives

Vision:
To become a recognized national leader in autonomy and to foster future leaders in STEM, especially in the field of autonomy.

As a Center of Excellence in Autonomy, the TECHLAV will:

1. Address fundamental problems in modeling, analysis, control, coordination, testing and evaluation of autonomous systems
2. Serve as a national resource in research and education in autonomy
3. Provide outreach services in autonomy-related areas
4. Foster linkages among national institutions of higher education, government agencies, and industries
5. Commercialize TECHLAV technologies for the benefit of the national economy
Collaborators

- TECHLAV is led by North Carolina Agricultural and Technical State University (N.C. A&T) in collaboration with the University of Texas at San Antonio to conduct strong integrated multi-disciplinary research and education activities on Large-scale Autonomous Systems of Vehicles (LSASV). [N.C. A&T lead: A. Homaifar, UTSA Lead: M. Jamshidi]

- The Center partners with Southwestern Indian Polytechnic Institute (SIPI) to provide and promote education and outreach activities and curriculum development to the larger Native American community. [SIPI Lead: N. Vadiee]
TECHLAV Core Research

**Thrust-1**
Modeling, Analysis and Control of Large-scale Autonomous Vehicles (MACLV)

Lead: M. Jamshidi (UTSA)
Investigators: J. Prevost & P. Benavidez (UTSA), and A. Karimoddini (N.C. A&T)

**Thrust-2**
Resilient Control and Communication for Large-scale Autonomous Vehicles (RC²LAV)

Lead: A. Karimoddini (N.C. A&T)
Investigators: S. Yi (N.C. A&T) and M. Jamshidi & B. Kelley (UTSA)

**Thrust-3**
Testing, Evaluation, and Verification of Large-scale Autonomous Vehicles (TEVLAV)

Lead: Y. Seong (N.C. A&T)
Investigators: A. Homaifar, A. Karimoddini & J. Stephens (N.C. A&T)
Research Thrust 1

Lead: Dr. M. Jamshidi, UTSA
Members: Dr. J. J. Prevost and Mr. P. Benavidez, UTSA; Dr. A. Karimoddini, N.C. A&T

Thrust 1 (Modeling, Analysis and Control of Large-scale Autonomous Vehicles [MACLA V])

• Develops scalable methodologies to improve modeling, analysis, localization, navigation, and control of LSASV

• Managing modern large-scale systems that require novel approaches to integrate communication, control, and computation (C3), which can simultaneously interact with humans
Challenges & Deliverables for Thrust 1

Challenges:

- System models are highly complex, nonlinear, interconnected and time-varying. They contain random signals, various delays (process, network, non-Gaussian noises), high levels of dimensions, etc.

- New tools for all aspects of systems engineering are being developed, including modeling, simulation, emergence, image processing and control.

Deliverables:

- Sub-thrust 1-1 will develop scalable mathematical and data-based models to capture the complex dynamics of LSASVs where control, communication, and computing components (C3) will simultaneously and interactively play key roles in determining the behavior of the system.

- Sub-thrust 1-2 will develop capable and scalable models for autonomous collaboration, robust and distributed decision-making, group coordination, planning, and tasking through effective interaction with human operators.
Research Thrust 2

Lead: Dr. A. Karimoddini, N.C. A&T
Members: Dr. S. Yi, N.C. A&T; Drs. M. Jamshidi and B. Kelley, UTSA

Thrust 2 (Resilient Control and Communication of Large-scale Autonomous Vehicles [RC²LAV])

- Develops systematic methods to enhance the reliability and efficacy of the control structure
- Communication backbone for LSASV integrated with human operators in dynamic and uncertain environments such as a battlefield
Thrust 2 Challenges & Deliverables

**Challenges:**

- Modeling and analysis of system failures, communication delays, network jamming, attacks, etc.
- Handling failures, robustness to communication delays, adaptation to operational and situational conditions, reconfiguration of the control and communication networks

**Deliverables:**

- Sub-thrust 2-1 develops a formal framework for fault-tolerant cooperative control of a team of autonomous systems comprised of heterogeneous autonomous vehicles
- Sub-thrust 2-2 designs an enhanced, efficient and flexible communication network that guarantees reliable connections among the agents which is robust against the failures in communication links
Research Thrust 3

Lead: Dr. Y. Seong, N.C. A&T
Members: Drs. A. Homaifar, A. Karimoddini, and J. Stephens, N.C. A&T

Thrust 3 (Testing, Evaluation and Verification of Large-scale Autonomous Vehicles [TEVLAV])

• Develops models and theories for TEVLAV integrated with human operators

• Ensures that the developed control & communication structure in thrusts 1 and 2 can accomplish the assigned mission in dynamic and uncertain environments
Thrust 3 Challenges & Deliverables

**Challenges:**
- Inherently dynamic, complex and “wicked” domain problem
- How to standardize heterogeneous environmental data
- Testing teaming of autonomous vehicles
- How to handle uncertainty in machine and human-machine interactions

**Deliverables:**
- Sub-thrust 3-1 develops formal verification methods for LSASVs by reducing the stated dimensions of the system model and developing divide-and-conquer methods to break the verification task into smaller tasks
- Sub-thrust 3-2 develops the Perception Inference Engine (PIE) for evaluating intelligent systems from a cognitive perspective and correlating their internal processes with observed behaviors
- Sub-thrust 3-3 will develop methods for testing human interaction with the simulated LSASV by examining human perception of system states, human trust in the system, and human judgment performance with the system
Demonstration, Implementation and Integration (DII)

- Integrates proposed tasks
- Facilitates coordination among the team members to perform collaborative test scenarios
- Provides two heterogeneous testbeds of ground robots and aerial robots at N.C. A&T and UTSA
- Tests and validates the performance of the developed tools and protocols in real-world scenarios related to the DoD’s mission
Collaborative Curriculum Development

- Developing shared courses and modules to address fundamental problems in autonomy
- Developed and offered two collaborative courses at both N.C. A&T and UTSA
- Increased student mobility in order to capture and disseminate our best practices

Sharing the research outcome with the community at large

- Organizing seminars, technical sessions, seminar series, workshops and invitational talks [http://techlav.ncat.edu/seminars.html](http://techlav.ncat.edu/seminars.html)
- Publishing and presenting research results in top-ranking journals and at conferences [http://techlav.ncat.edu/publications.html](http://techlav.ncat.edu/publications.html)
Co-sponsoring and Co-organizing FIRST Tech Challenge at NC A&T

- TECHLAV has sponsored and organized the FIRST Tech Challenge workshop for Guilford County Schools teachers since 2015.
TECHLAV Goals

Long Term Goal by 04/07/2020
• Develop and implement techniques for reliable control, resilient communication, testing and verification of LSASV
• Demonstration, Implementation and Integration (DII)

Mid Term Goal by 11/15/2018
• Technical Development of Large-scale Autonomous Systems of Vehicles (LSASV) – localization, navigation, reasoning, decision making, and cooperative control as well as testing techniques for training and testing

Short Term Goal by 10/14/2016
• Personnel and student recruitment
• Lab setup and the first advisory board meeting
• Equipment purchase and setup
• Preliminary steps for modeling, analysis, and control of LSASV
Co-organizing and Co-sponsoring SoSE 2017 Conference

- TECHLAV organizes a technical panel on large scale systems of vehicles in the 12th International IEEE Conference on System of Systems Engineering (SoSE 2017)

  June 18-21, 2017
  Waikoloa, Hawaii, USA

- The 12th International Conference on System of Systems Engineering (SoSE)
- Within IEEE System, Man, and Cybernetics Society and IEEE Reliability Society
- Focus: Theories, methodologies, and applications of System of Systems Engineering in science, technology, industry, and education are welcome.
- Topics: Covers numerous engineering fields such as control, computing, communication and information technology and includes applications such manufacturing, defense, national security, aerospace, aeronautics, energy, environment, healthcare, and transportation.
- Conference theme: “Internet of Things as System of Systems”.
• TECHLAV’s second annual meeting will be held from May 31, 2017 to June 1, 2017 in Greensboro, NC.

• The meeting will bring together researchers from academia, the military, and industry.

• The purpose of the visit is to provide updates on various tasks: modeling, control, testing, and evaluation of autonomous vehicles, as well as demonstrations and poster presentations on the most recent TECHLAV research outcomes.

• In addition, there will be a technical panel and two keynote speakers who will be providing an in depth exploration of the current world of autonomy.

For further information, please contact Shar Seyedin, the TECHLAV Program Manager at 336-285-3271 or at sseyedin@ncat.edu.
TECHLAV Team

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N.C. A&T

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Lead for Thrust 3  
N.C. A&T

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N.C. A&T

Dr. N. Vadiee  
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Alton S. Wallace

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Oak Ridge National Laboratory
Acknowledgments

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• TECHLAV’s Academic and Industrial Advisory Boards for their guidance and advice