# Center Overview

http://ncr.mae.ufl.edu/aacoe.php

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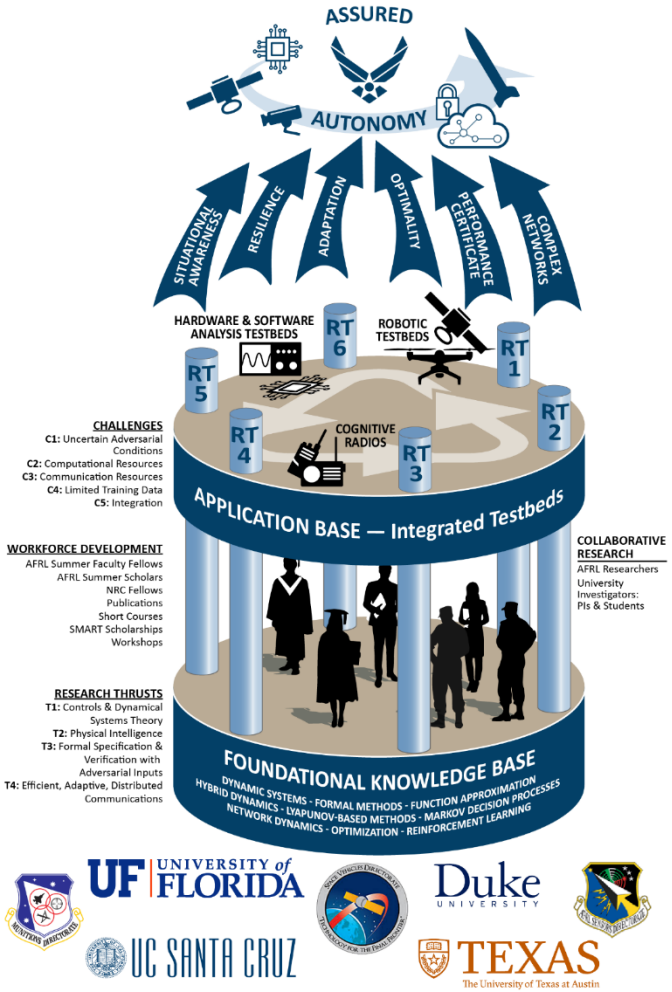
# Center Overview




**AFOSR Center of Excellence in Assured Autonomy in Contested Environments**

- >$7M over 6 years (3 x 2 year increments)
- 9 PIs @ 4 Universities:
  - K. Butler (UF: cyber resiliency/privacy)
  - W. Dixon (UF: ADP, networks, hybrid)
  - N. Fitz-Coy (UF: optimal, games)
  - M. Hale (UF: networks, privacy)
  - M. Pajic (Duke: cyber resiliency/privacy)
  - R. Sanfelice (UCSC: hybrid, networks)
  - J. Shea (UF: networks, privacy)
  - U. Topcu (UT: formal, hybrid, optimal)
  - M. Zavlanos (Duke: ADP, networks, formal)
  - C. Petersen (UF: Space GNC)
  - A. Petersen (Space weather/physics)
- AFOSR provides 50% of funding
- AFRL (RV, RW, RY) provide 50%

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# Center Motivation

- Innovation & technology dominance and strong economy have allowed for exquisite systems that for decades have operated in largely uncontested environments
  - Remote piloted vehicles (RPV) and monolithic satellites provide various strategic and tactical advantages
  - Intelligence, surveillance, and reconnaissance (ISR) in close proximity with RPVs or from protected space assets, while simultaneously striking from distances and with speeds beyond the capability of countermeasures
- These advantages are mitigated as the technology gap closes and as other world economies become near peers and risks to the warfighter and financial costs increase and tactical capabilities become stressed when military operations are in contested or denied environments (i.e., anti-access/area denial (A2AD) environments)
- Increased stand-off distance, persistence, and scaled projection of power have resulted in an urgency for development and fielding of human-in-the loop/semiautonomous systems

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# Center Motivation

- As these advantages are taken to the limit, coupled with the resultant need for rapid decision-making capabilities, emerging technology will move along a spectrum towards greater automation with less human intervention
- In contested environments, autonomous systems are even further motivated by the potential desire to complete mission execution when communication with a human operator is unavailable
- Autonomous systems must execute high level missions plans with verifiable assurances despite uncertain adversarial environments where the integrity and availability of sensor information and communications are challenged
- Key innovations include analysis, design and synthesis tools that enable autonomous mission execution despite uncertainty within complex dynamics while accounting for the integrity and privacy of information on computationally constrained resources

# Center Goals & Vision

- Networks of autonomous systems will require information exchanges of many data types, including high-level mission specifications and sensor feedback for navigation and control
- The goal of assuring autonomy is complicated by the interplay between dynamics of autonomous agents and the stochastic and intermittent dynamics of network traffic
- This challenge is further amplified by delays and asynchrony in information flows
- Information perturbations can also emanate from adversarial actors in unique and complex ways, requiring security-aware design and analysis methods
- For example, we will develop techniques to protect mission-critical information and prevent information disruption/corruption
- These challenges must be addressed considering resource limitations and quantitative tradeoffs.

**Research Topics**

- Nonsmooth Systems
- Adaptation, Optimality, and Synthesis
- Network Systems
- Asynchronous Information
- Attack-Resilient Design
- Protecting Information

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# Workforce Dev. AFRL Collaborations Publications

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# Collaborative Interactions

- Project partially supports
  - 4 postdocs/research scientists, >40PhD
- ~40 Alumni
  - 9 postdocs – NRC (RW), NVIDIA, Univ. of Sherbrooke, Univ. of Arizona, Apple, Univ. Grenoble Alpes, UC Berkeley, University of Florida
  - 20 PhD – RW (x2), Ford, Qualcomm, Intel, Univ. of the Bio, Opener, Purdue University, Dematic, DJI, Amazon, Satellogic, University of Florida, Zoox, University of Dayton Research Institute (RY/ACT3)
  - 8 MS – Lockheed Martin (Orlando), Walmart Labs, UCSC, Zoox, Intel, AgroAI, Rain
- **SMART Fellows** for RV: S. Edwards (Dixon), RW: C. Makumi (Dixon), C. Nino (Dixon), NSWC: Patrick Amy (Dixon)
- **NRC Postdoc** for RW: A. Isaly (Dixon)
- **NSF Fellow:** Becca Hart (Dixon)
- 10 Summer 2023 **AFRL/Space Scholar/interns**
  - RV: A. Allen (Fitz-Coy)
  - RW: W. Warke (Hale), A. Benvenuti (Hale), G. Behrendt (Hale), C. Makumi (Dixon), C. Nino (Dixon), J. Philor (Dixon), Z. Lamb (Sanfelice)
  - RY/Act3: C. Hawkins (Hale), C. Fedele (Butler)
- **AFRL Summer Faculty Fellows** program
  - Riccardo Bevilacqua (2019 & 2020 RW, 2021 RV)
  - Matthew Hale (2020 RW)

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# Collaborative Interactions

- Publications
  - >335 total, ~30 published or accepted to appear so far in 2023
  - Joint publications –
    >40 w/ PIs,
    >40 w/ AFRL

- International collaborations (Pontifical Catholic University of Rio de Janeiro (PUC-RIO) in Rio de Janeiro, Brazil)

- Testbed Development
  - Initial demonstration completed-ish
  - Investigating expansion
  - Certification courses and other educational outcomes **via remote access**
  - Initial industrial collaborations (e.g., Northrup Grumman) and government interactions

# Additional Activities

- (C. Petersen) Two **Invited Sessions** American Control Conference:
  - 1) Safe Spacecraft Control
  - 2) Autonomous Control of Satellite Systems
- (W. Dixon) Two Invited Sessions American Control Conference
  - Online Learning, Optimization, and Games (I, II)
- (C. Petersen) lead author on American Control Conference **Tutorial Session**
  - "Safe and Constrained Rendezvous and Proximity Operations"
- (K. Butler) Invited **keynote address** at IEEE Workshop on Offensive Technology, May 2023
- (Pajic) Presented the project's results to industry and DoD labs, such as Galois, Intel, SRC, as well as a number of government officials including General Quinton Brown Jr., the Air Force Chief of Staff
- (Pajic) Invited **keynote address** at 2022 Euromicro Conference on Real-Time Systems
- (Pajic) Collaboration with NATO partners from the **NATO Centre for Maritime Research and Experimentation (CMRE)** on transitioning this technology into real-world systems, mostly focusing on security-aware analysis of autonomous unmanned underwater systems
- (Pajic) Joined the new NATO IST-122-ET RTG on Designing resilient autonomous vehicles, part of the **NATO Science and Technology Organization**, where he is working with partners from several countries on a new standard for development of secure autonomous systems

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# Recent Breakthroughs

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# Recent Breakthroughs

- Considerations for space weather impacts on spacecraft
- Randomized greedy algorithms for sensor selection in large-scale satellite constellations
- Autonomous satellite rendezvous and proximity operations with time constrained sub-optimal model predictive control
- Safe and constrained redezvous, proximity operations, and docking
- On the converse safety problem for differential inclusions: solutions, regularity, and time-varying barrier functions
- Fast verification of CBF via linear programming
- Optimal safety for constrained differential inclusions using nonsmooth cbfs
- Distributed hybrid algorithms for time synchronization
- A switched systems approach to multi-agent system consensus: A relay-explorer perspective
- Explaining the mystery of periodicity in inter-transmission times in two-dimensional event-triggered controlled system
- Robust output feedback control design in the presence of sporadic measurements
- Secure control design for networked control systems with nonlinear dynamics under time-delay-switch attacks
- Consensus over clustered networks using output feedback and asynchronous inter-cluster communication
- Totally asynchronous algorithm for time-varying convex optimization problems

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# Recent Breakthroughs

- Distributed asynchronous large-scale mixed-integer linear programming via saddle point computation
- Target tracking subject to intermittent measurements using attention deep neural networks
- Hierarchical reinforcement learning-based supervisory control of unknown nonlinear systems
- Deep recurrent NN-based observer for uncertain nonlinear systems
- Hierarchical reinforcement learning and gain scheduling-based control of a hypersonic vehicle
- Variational latent branching for off-policy evaluation
- On the privacy risks of deploying recurrent neural networks in machine learning models
- Differential privacy for symbolic systems with application to markov chains
- Privacy-preserving datasets of eye-tracking samples
- Solving the validation problem by enabling first-of-a-kind trade studies on datasets and physics-based simulators
- Stealthy perception-based attacks on UAV
- Regularizing a function with a linear term enforces the strict saddle property
- Dimension reduction finds on-manifold adversarial examples in hard-label attacks
- A novel first-order method for conic optimization that automatically detects infeasibility

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