Center Overview

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

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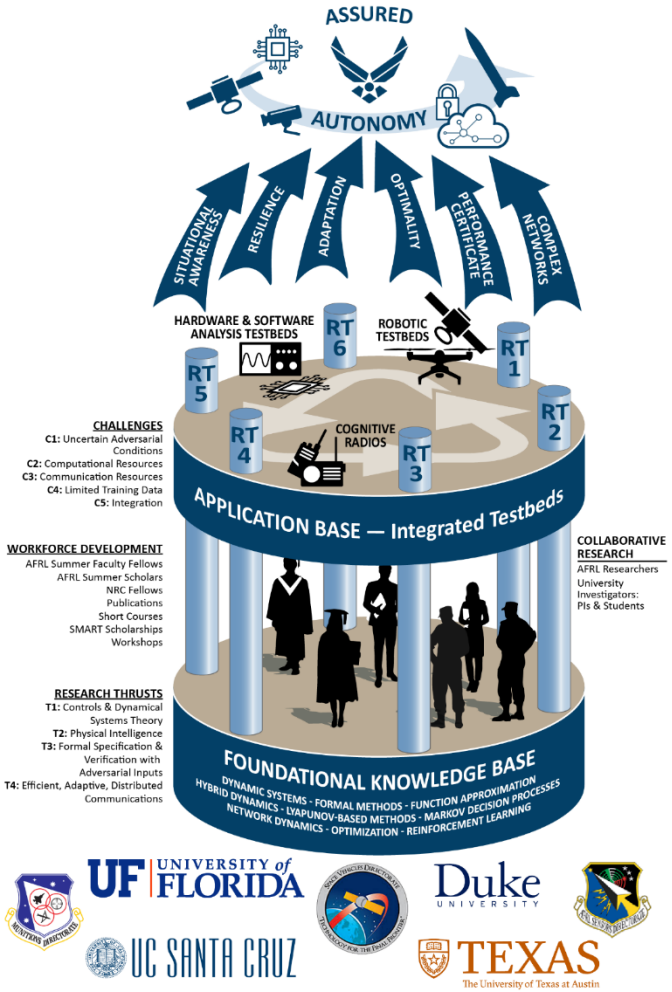
Center Overview



AFOSR Center of Excellence in Assured Autonomy in Contested Environments

- >$9M 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 (GT: 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

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

- AACE has partially supported
  - ~15 postdocs/research scientists and ~100 PhD
  - ~40 PhD students currently

- ~60 Alumni
  - ~10 postdocs – NRC (RW), NVIDIA, Univ. of Sherbrooke, Univ. of Arizona, Apple, Univ. Grenoble Alpes, UC Berkeley, University of Florida (x2), Torch Technologies, Georgia Tech.

  - ~40 PhD
    - (AFRL) RW (x4), RY/ACT3, RV
    - (Industry) Ford, Qualcomm, Intel, Opener, Dematic, DJI, Amazon, Satellogic, Zoox, Aurora Flight Sciences (x2), JPL, Supernal, EpiSci, MIT Lincoln Labs, Mathworks, Samsung Electronics, Raytheon (x2), L3Harris, Johns Hopkins APL, Merlin Industries, Netflix
    - (Academics) Univ. of the Bio, Purdue University, University of Florida, University of Dayton Research Institute, Univ. of British Columbia, Univ. of Minnesota, Duke, University of Maryland

  - ~10 MS – Lockheed Martin (x2), Walmart Labs, UCSC, Zoox, Intel, AgroAI, Rain, Tesla, Aerospace Corp.

Collaborative Interactions

- **SMART Fellows** for C. Nino (Dixon), NSWC: Patrick Amy (Dixon)
- **NRC Postdoc** for RW: A. Isaly (Dixon)
- **NSF Fellow:** Becca Hart (Dixon), Alexander Benvenuti (Hale)
- **AFRL/Space Scholar/interns**
- 10 Summer 2024
  - RV: A. Allen (Fitz-Coy), C. Fedele (Butler), N. Perez (A. Petersen), C. Whitney (C. Petersen)
  - RW: W. Warke (Hale), A. Benvenuti (Hale), G. Behrendt (Hale), Adam Pooley (Hale), C. Nino (Dixon), J. Philor (Dixon), R. Hart (Dixon), Z. Lamb (Sanfelice)
  - RY/Act3: C. Ludden (C. Petersen)
  - RQ: S. Clees (C. Petersen)
- Many applictaions for Summer 2025
- **AFRL Summer Faculty Fellows** program
  - Chrispy Petersen (2024 RY)
  - Riccardo Bevilacqua (2019 & 2020 RW, 2021 RV)
  - Matthew Hale (2020 RW)

Collaborative Interactions

- Publications
  - ~500 total, >80 published or accepted to appear in 2024 (>paper/week for 6 years)
  - Joint publications –
    >60 w/ multiple PIs,
    >70 w/ AFRL (~paper/month for 6 years)

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

- Testbed Development
  - Starlink Connection established
  - Transitioned all assets to ROS2
  - Upgraded sensing and computational capabilities
  - Focus on 5G/LTE (microhard radio communication now possible)
  - Collaboration with AFRL/RW for remote (Starlink) connection to Aviary
    - Summer 24 demo: control of UF Autonomy Park UAVs from Eglin Aviary
    - Summer 24 demo: Jam and anti Jam network control
    - Summer 24 demo: Fully on-line DNN drone flight
  - Completing build of 25 custom drones in collaboration with AFRL
    - GPS RTK, microhard mesh radios, Starlink connectivity, Nvidia Jetson Orin, Zed 2i stereo cameras, LIDAR
    - ~30 min hover time

Additional Activities

- (C. Petersen with S. Phillips and A. Soderlund) Two Invited Sessions 2024 American Control Conference:
  - 1) Autonomy, Learning, and Optimization for Spacecraft
  - 2) Multi-Agent Spacecraft Control
- (K. Butler and C. Petersen) Started a student-led reading group on problems in the cross domain of space, cyber resilience, privacy, and computation
- (K. Butler) PCAST working group to review federal R&D activities in information technology including cybersecurity, AI and communication investments.
- (C. Petersen) Invited to give a talk to UF AF ROTC, engaged with cadets on COE research and how to assure autonomy when they specifically operate complex satellites. (Two undergrads working on COE related projects, one is now a summer scholar)
- (C. Petersen) lead author on American Control Conference **Tutorial Session**
  - "Safe and Constrained Rendezvous and Proximity Operations"
- (M. Hale) Invited Assured Autonomy Seminars at Auburn and UIUC
- (W. Dixon) Invited Assured Autonomy Seminars
  - AIAA Tech Committee on Space Robotics, Embry Riddle, Auburn, Alabama, Rutgers, UIUC…
- (J. Shea) Book: *Foundations of Data Science with Python*, published by CRC Press, 484 pages, 2024

Recent Breakthroughs

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Recent Breakthroughs

- Lyapunov-based (Lb) DNN control of uncertain nonlinear systems:
  - Lb-LSTM neural network-based observers and control
  - Lb-DNN approximate optimal indirect regulation of an unknown agent
  - Lb-DNN-based approximate optimal tracking of unknown systems
  - Lb-PINN: deep physics-informed neural networks
  - Lb-DNN Approximate Dynamic Programming
  - Lb-GNN Graphical Neural Networks
  - Adaptive indirect herding of multiple targets with unknown interaction dynamics
- Transferable Hypergraph Neural Networks via Spectral Similarity
- Multiphase Autonomous Docking via Model-Based and Hierarchical Reinforcement Learning
- REFORMA: Robust REinFORceMent Learning via Adaptive Adversary for Drones Flying under Disturbances
- Steering Decision Transformers via Temporal Difference Learning
- Wasserstein Distributionally Robust Policy Evaluation and Learning for Contextual Bandits
- Distributed State Estimation of Linear Systems under Jointly Connected Directed Switching Networks
- Robust Parameter Estimation for Hybrid Dynamical Systems with Linear Parametric Uncertainty
- Hybrid Persistency of Excitation in Adaptive Estimation for Hybrid Systems
- Parameter Estimation for Hybrid Dynamical Systems with Delayed Jump Detection
- Robust Synergistic Hybrid Feedback
- Switching of Asymptotically Stable and Uniformly Ultimately Bounded Systems With Applications to Machine Vision
- A Hybrid Observer for Linear Systems under Delayed Sporadic Measurements
- Semiglobal High-Gain Hybrid Observer for a Class of Hybrid Dynamical Systems with Unknown Jump Times
- A Switched System Dwell-time Update Mechanism For Path Following With Intermittent State Feedback Constraints
- Towards Gluing KKL Observer for Hybrid Systems with Unknown Jump Times
- Stochastic Approximations of Hybrid Inclusions
- Robust Global Hybrid Passive Complementary Filter on SO(2)
- HyRRT-Connect: A Bidirectional Rapidly-Exploring Random Trees Motion Planning Algorithm for Hybrid Systems
- A Switched Reference Governor for High-Performance Trajectory Tracking Control under State and Input Constraints

Recent Breakthroughs

- A Hybrid Systems Formulation for a Capture-the-Flag Game
- Event-Triggered Multi-Agent System Rendezvous with Graph Maintenance in Varied Hybrid Formulations
- Pointwise Exponential Stability of State Consensus with Intermittent Communication
- Conical Transition Graphs: A New Tool to Analyze Asymptotic Stability for Hybrid Systems
- On the Optimal Cost and Asymptotic Stability in Two-Player Zero-Sum Set-Valued Hybrid Games
- Developing A Channel Emulation System for Networked Autonomous Vehicles
- Network Preference Dynamics using Lattice Theory
- Learning of Nash Equilibria in Risk-Averse Games
- Cooperative Multi-Agent Reinforcement Learning with Partial Observations
- A Totally Asynchronous Nesterov's Accelerated Gradient Method for Convex Optimization (I)
- Cooperative Navigation: From Single-Agent Navigation Fields to Graph-Maintaining Distributed MAS Controllers
- Learning Optimal Strategies for Temporal Tasks in Stochastic Games
- On the uniqueness of solution for the Bellman equation of LTL objectives
- A Data-Driven Approach for Certifying Asymptotic Stability and Cost Evaluation for Hybrid Systems
- Boosting One-Point Derivative-Free Online Optimization via Residual Feedback
- Uniting Nesterov and Heavy Ball Methods for Uniform Global Asymptotic Stability of the Set of Minimizers
- Constrained Optimization with Decision-Dependent Distributions
- Pose Graph Optimization over Planar Unit Dual Quaternions: Improved Accuracy with Provably Convergent Riemannian Optimization
- On Minimizing Total Discounted Cost in MDPs Subject to Reachability Constraints
- An On-Line Global Search Approach to Underactuated Docking Operations Via Model Predictive Control and the Cross-Entropy Method
- A Coupled Guidance & Navigation Optimization to Improve Rendezvous and Proximity Operations
- Outlier-Robust Distributionally Robust Optimization via Unbalanced Optimal Transport
- 3D underactuated spacecraft docking using Legendre Gauss Radau collocation
- On Trajectory Augmentations for Off-Policy Evaluation
- Off-Policy Selection for Initiating Human-Centric Experimental Design

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Recent Breakthroughs

- Control of compositional systems (model predictive control)
- Differentially Private Reward Functions for Markov Decision Processes
- Differentially Private computation of basic reproduction numbers in networked epidemic models
- The bounded Gaussian mechanism for differential privacy
- Guaranteed Feasibility in Differentially Private Linearly Constrained Convex Optimization
- Identity Concealment Games: How I Learned to Stop Revealing and Love the Coincidences
- Defining and Measuring Deception in Sequential Decision Systems: Application to Network Defense
- AquaSonic: Acoustic Manipulation of Underwater Data Center Operations and Resource Management
- Control of Misinformation with Safety and Engagement Guarantees
- Attacks on Perception-Based Control Systems: Modeling and Fundamental Limits
- Robust exploration with adversary via Langevin Monte Carlo
- Randomized Exploration in Cooperative Multi-Agent Reinforcement Learning
- Bayesian Methods for Trust in Collaborative Multi-Agent Autonomy
- Black-box Stealthy GPS Attacks on Unmanned Aerial Vehicles
- Protecting Satellite Proximity Operations via Secure Multi-Party Computation
- MadRadar A Black-Box Physical Layer Attack Framework on mmWave Automotive FMCW Radars
- MultiHyRL: Robust Hybrid RL for Obstacle Avoidance against Adversarial Attacks on the Observation Space
- Autonomous Satellite Operational Mode Switching for Anomalies and Space Weather Effects Mitigation
- Reviewing Known Mitigation Methods for Space Weather's Effects on Spacecraft
- Onboard Space Weather Monitoring of Energetic Particles
- Capturing a Non-Cooperative Resident Space Object: A Control Barrier Function Approach
- Computation-Aware Bearings-Only Target Localization and Circumnavigation in 2D
- Some Converse Lyapunov-Like Results for Strong Forward Invariance
- Understanding computational resources for GNC methods
- Safe controllers for uncertain nonlinear systems using multiple control barrier functions and adaptive barrier functions