

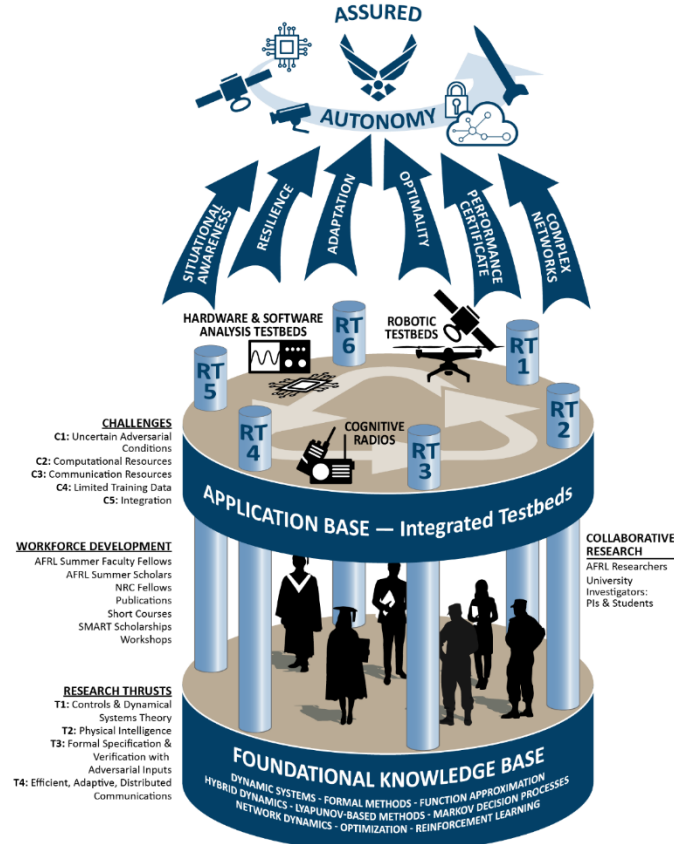
Center Overview



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



Center Overview



AFOSR Center of Excellence in Assured Autonomy in Contested Environments

- >\$8M 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%



- 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

Workforce Dev. AFRL Collaborations Publications





Collaborative Interactions

- Project currently partially supports
 - ~5 postdocs/research scientists, ~50 PhD
- >40 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.
 - >25 PhD
 - RW (x4), (RY/ACT3)
 - Ford, Qualcomm, Intel, Opener, Dematic, DJI, Amazon, Satellogic, Zoox, Aurora Flight Sciences (x2), JPL, Supernal, EpiSci, MIT Lincoln Labs, Mathworks, Samsung Electronics, Raytheon
 - Univ. of the Bio, Purdue University, University of Florida, University of Dayton Research Institute, Univ. of British Columbia, Univ. of Minnesota
 - ~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**), A. Aborizk (**Fitz-Coy**),
- **14 Summer 2024 AFRL/Space Scholar/interns**
 - **RV**: A. Aborizk (**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**)
- **AFRL Summer Faculty Fellows** program
 - Chrispy Petersen (2024 **RY**)
 - Riccardo Bevilacqua (2019 & 2020 **RW**, 2021 **RV**)
 - Matthew Hale (2020 **RW**)



Collaborative Interactions

- Publications
 - ~420 total, >30 published or accepted to appear in 2024
 - Joint publications –
 - >50 w/ multiple PIs,
 - >50 w/ AFRL
- 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 in progress)
 - Collaboration with AFRL/RW for remote (Starlink) connection to Aviary
 - Summer 24 demo: control of UF Autonomy Park UAVs from Eglin Aviary





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
- (C. Petersen with S. Phillips) Two Invited Sessions 2023 American Control Conference:
 - 1) Safe Spacecraft Control
 - 2) Autonomous Control of Satellite Systems
- (C. Petersen) Invited talk on “Cyber Resilience Empowered via Assured Autonomy” at AFRL 2023 Cyber Summit, presented key COE AA results to key government and industry researchers
- (K. Butler and C. Petersen) Started a student-led reading group on problems in the cross domain of space, cyber resilience, privacy, and computation
- (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

Additional Activities

- (W. Dixon) Invited Workshop 2023 Conference on Decision and Control
 - Modern Adaptive Control
- (W. Dixon) Two Invited Sessions 2023 American Control Conference
 - Online Learning, Optimization, and Games (I, II)
- (W. Dixon) Invited Assured Autonomy Seminars
 - AIAA Tech Committee on Space Robotics, Embry Riddle, Auburn, Alabama, ...
- (K. Butler) Invited **keynote address** at IEEE Workshop on Offensive Technology, 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) 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+Topcu) Joined the NATO IST 211 RTG on Designing resilient autonomous vehicles, part of the **NATO Science and Technology Organization**
- (Sanfelice) A co-located workshop of the 2023 CPS-IoT week, May 9-12, 2023: Computation-Aware Algorithmic Design for Cyber-Physical Systems
- (Sanfelice) Plenary Speaker, Colloquium on Discrete Event and Hybrid Systems, 2023 (August 25, 2023, organized by Cinestav and Tecnologico de Monterrey)

Recent Breakthroughs



Recent Breakthroughs

- Fast verification of **control-barrier functions** for **safe learning**
- Lyapunov-based (Lb) implicit and DNN-based control of uncertain nonlinear systems:
 - **Lb-LSTM neural network-based** observer
 - **Lb-LSTM PINN**: deep physics-informed neural networks
 - **DeLb- PINN**: deep physics-informed neural networks
 - **Lb-DNN approximate optimal** indirect regulation of an unknown agent
 - **Lb-DNN-based approximate optimal tracking** of unknown linear systems
 - **Adaptive indirect herding** of **multiple targets with unknown interaction dynamics**
- **Soft-Bellman Equilibrium in Affine Markov Games**: Forward Solutions and **Inverse Learning**
- Privacy-Engineered Value Decomposition **Networks for Cooperative Multi-Agent Reinforcement Learning**
- **Distributed state estimation** with **DNNs for uncertain non-linear systems** under **event-triggered** communication
- **Cooperative Multi-Agent Reinforcement Learning** with Partial Observations
- Spectral Similarity Is All You Need: Transferable **Hypergraph Neural Networks**
- REFORMA: Robust **REinFORceMent Learning via Adaptive** Adversary for Drones Flying under Disturbances

Recent Breakthroughs

- Multiphase **Autonomous Docking** via **Model-Based and Hierarchical Reinforcement Learning**
- 3D underactuated **spacecraft docking** using **Legendre Gauss Radau collocation**
- A Coupled Guidance & Navigation **Optimization** to Improve **Rendezvous and Proximity Operations**
- Autonomous **Satellite Operational Mode Switching** for Anomalies and **Space Weather** Effects Mitigation
- Protecting **Satellite Proximity Operations** via Secure Multi-Party Computation
- Onboard **Space Weather Monitoring** of Energetic Particles
- Capturing a Non-Cooperative **Resident Space Object: A Control Barrier Function** Approach
- Characterizing Computational Resources of **GNC Algorithms**
- Reviewing Known Mitigation Methods for **Space Weather's Effects on Spacecraft**

Recent Breakthroughs

- A **compositional framework** for convex model predictive control
- Characterizing Compositionality of LQR from the **Categorical Perspective**
- Weighted **Prioritization of Constraints** in Optimization-Based Control
- Uniting **Nesterov and Heavy Ball Methods** for Uniform Global Asymptotic Stability of the Set of Minimizers
- Wasserstein Distributionally **Robust Policy Evaluation and Learning** for Contextual Bandits
- Convergence Analysis of the Best Response Algorithm for **Time-Varying Games**
- On Trajectory Augmentations for **Off-Policy Evaluation**
- **Max-Plus Synchronization** in Decentralized Trading Systems
- HySST: An Asymptotically **Near-Optimal Motion Planning** Algorithm for **Hybrid Systems**
- Forward Invariance-Based **Hybrid Control** Using Uncertified Controllers
- 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**

Recent Breakthroughs

- Control of **Misinformation** with Safety and Engagement Guarantees
- Differential Privacy for Stochastic Matrices Using the Matrix Dirichlet Mechanism
- AquaSonic: **Acoustic Manipulation** of Underwater Data Center Operations and Resource Management
- MadRadar A Black-Box **Physical Layer Attack Framework** on mmWave Automotive FMCW Radars
- **Attacks on Perception**-Based Control Systems: Modeling and Fundamental Limits
- RadCloud: Real-Time High-Resolution Point Cloud Generation Using **Low-Cost Radars for Aerial and Ground Vehicles**
- Computation-Aware **Bearings-Only Target Localization and Circumnavigation** in 2D
- **Differentially private** computation of basic reproduction numbers in **networked epidemic models**
- Developing A Channel Emulation System for **Networked Autonomous Vehicles**
- Collaborative **Spectrum Sharing**