



The National Science Foundation's

C-UAS

CENTER FOR UNMANNED AIRCRAFT SYSTEMS

In this issue:

- Texas A&M Joins C-UAS
- February 2020 IAB Meeting
- Noteworthy News
- Center Statistics
- Recent Publications

C-UAS continues to grow and prosper in its 8th year of funding as an I-UCRC. C-UAS now includes 22 industry members with 24 total industry memberships.



THE NATIONAL SCIENCE FOUNDATION
CENTER FOR UNMANNED AIRCRAFT SYSTEMS



INDUSTRY MEMBERS



Texas A&M Joins C-UAS!

In March, Texas A&M received their award from the National Science Foundation. John Valasek, TAMU's Site Director, said **"A big thank you to all of you for your assistance and support in making this two year journey a reality. We are looking forward to getting started."** TAMU will add a variety of resources to C-UAS, including excellent facilities and world-class faculty and students. Manoranjan Majji will be the Co-Site Director at TAMU.



February 2020 IAB Meeting Recap

The February 2020 IAB Meeting was held at Brigham Young University. At this meeting, faculty researchers presented updates on 22 projects to the Industry Advisory Board. 42 PhD, graduate, and undergraduate students attended and participated in the interactive sessions. Invited guests from 14 prospective member organizations attended, including 17 individual representatives. We are hopeful that several of these guest organizations will join in the coming months.

Randy Beard, Center Director, led a discussion on exploring the idea of submitting a new Phase 1 Proposal for a NSF IUCRC focused on UAS. A straw vote was taken (unanimous, unopposed).

Tim McLain, Site Director, BYU, discussed an NSF AccelNet proposal for International Collaboration that was submitted with C-UAS university sites and other international UAS research organizations.

A Center operations discussion was led by Jim DeBoer. Members discussed plans for interaction between POCs and faculty members.

A member information session was held for member representatives to present their organizations to students and other attendees.

A new project feedback session was used to allow faculty and members to discuss LIFE feedback in small groups.

More details about February's meeting can be found on c-uas.org.

Noteworthy News

Virginia Tech:

- ◇ Kevin Kochersberger launches the African Drone and Data Academy in Malawi.
- ◇ Virginia Tech hosted the AUVSI Ridge & Valley Chapter's 3rd annual conference "The Power of Partnership." Special guest speakers included:
 - * Dr. Ryan Eustice, Senior VP of Automated Driving, Toyota Research Institute (TRI),
 - * Dr. Bala Ganesh, VP, Advanced Technology Group, UPS,
 - * Ms. Catherine McGhee, Director of Research and Innovation, Virginia Transportation Research Council, and
 - * Mr. Brad Whitby, Managing Director, Center for Unmanned Aircraft Systems.
- ◇ Craig Woolsey was re-elected to a second term as AUVSI Ridge & Valley chapter president.
- ◇ Project Wing has partnered with Virginia Tech's Mid-Atlantic Aviation Partnership (MAAP) to test delivery by unmanned aircraft.

University of Colorado Boulder

- ◇ Smead Aerospace UAS research teams, working primarily with NOAA, are simultaneously supporting research near the North Pole in Project MOSAiC and from the Caribbean island-nation of Barbados in Project ATOMIC, while preparing for the year-2 deployment over the Great Plains of the U.S. for Project TORUS.
- ◇ Smead Aerospace, and our C-UAS site, welcomes Assistant Professor Zach Sunberg. Zach's specialties include:
 - * Practical safety for autonomous vehicles
 - * Partially observable Markov decision processes
 - * Decision making under uncertainty
 - * Artificial intelligence
 - * Helicopter and fixed-wing aircraft control
 - * Autonomous vehicle interaction with humans
 - * Self-driving cars
 - * Active information gathering for state estimation

Brigham Young University

- ◇ The Safe2Ditch project (part of BYU 20.06) was given a NASA group achievement award from the NASA LaRC Center Director. (Randy Beard, Parker Lusk, Thane Downing)

Center Statistics

- ◆ Over \$10 Million in funding to date
- ◆ Over 400 student years funded
- ◆ 141 Projects funded
- ◆ 172 Publications
- ◆ 210 Presentations

2019-2020 Project Year:

- * 118 students funded (24 Doctoral, 28 Masters, and 39 Undergraduates)
- * 27 degrees awarded (6 Doctorates, 11 Masters, 10 Bachelors)



"A big thank you to all of you for your assistance and support in making this two year journey a reality. We are looking forward to getting started."

-John Valasek,

TAMU Site Director

Recent Publications

- Akagi, John and Moon, Brady and Chen, Xingguang and Peterson, Cameron K.. (2019). Gesture Commands for Controlling High-Level UAV Behavior. *2019 International Conference on Unmanned Aircraft Systems (ICUAS)*. 1023 to 1030. [doi:10.1109/ICUAS.2019.8797743](https://doi.org/10.1109/ICUAS.2019.8797743)
- Bai, He and Beard, Randal W.. (2019). Relative Heading Estimation and Its Application in Target Handoff in GPS-Denied Environments. *IEEE Transactions on Control Systems Technology*. 27 (1) 74 to 85. [doi:10.1109/TCST.2017.2773027](https://doi.org/10.1109/TCST.2017.2773027)
- Bidstrup, Craig C. and Moore, Jared J. and Peterson, Cameron K. and Beard, Randal W.. (2019). Tracking Multiple Vehicles Constrained to a Road Network from a UAV with Sparse Visual Measurements. *2019 American Control Conference (ACC)*. 3817 to 3822. [doi:10.23919/ACC.2019.8815384](https://doi.org/10.23919/ACC.2019.8815384)
- Castagno, J., Yao, Y. and Atkins, E., 2019. Realtime Rooftop Landing Site Identification and Selection in Urban City Simulation. arXiv preprint arXiv:1903.03829. <https://arxiv.org/abs/1903.03829>
- C. Kang & C. Woolsey, "Visual pose estimation and model-based path prediction for fixed-wing unmanned aircraft" (In review.)
- C. Kang, H. Chaudhry, C. Woolsey & K. Kochersberger, "Development of a peripheral-central vision system for small UAS tracking", SciTech 2019. <https://doi.org/10.2514/6.2019-2074>
- Craig Bidstrup, Jared More, Cameron Peterson, Randal W. Beard, "Tracking Multiple Vehicles Constrained to a Road Network from a UAV with Sparse Visual Measurements," American Control Conference (ACC), 2019.
- D. Abou Jaoude, D. Muniraj, and M. Farhood, "Robustness analysis of uncertain time-varying interconnected systems using integral quadratic constraints," Proceedings of the American Control Conference, 2019. DOI: 10.23919/ACC.2019.8814360
- D. Abou Jaoude and M. Farhood, "Guaranteed output bounds using performance integral quadratic constraints," Proceedings of the American Control Conference, 2020.
- D. Abou Jaoude, M.C. Palframan, and M. Farhood, "An oracle for the discrete-time integral quadratic constraint problem," Automatica, vol. 107, pp. 112-118, 2019. <https://doi.org/10.1016/j.automatica.2019.05.023>
- D. Abou Jaoude, M.C. Palframan, and M. Farhood, "On the analytic center cutting plane method for the discrete-time integral quadratic constraint problem," Proceedings of the IEEE Conference on Decision and Control, 2019. doi: 0.1109/CDC40024.2019.9029528
- Das, Arun and Woolsey, Craig A.. (2019). Workspace Modeling and Path Planning for Truss Structure Inspection by Unmanned Aircraft. *Journal of Aerospace Information Systems*. 16 (1) 37 to 51.
- Derricott, Jeffrey C. and Willis, Jacob B. and Peterson, Cameron K. and Franke, Kevin W. and Hedengren, John D.. (2019). Disaster Reconnaissance Using Multiple Small Unmanned Aerial Vehicles. *Mechanical Engineering*. 141 (06) S7 to S11. [doi:10.1115/1.2019-JUN5](https://doi.org/10.1115/1.2019-JUN5)
- D. Muniraj, D. Abou Jaoude, and M. Farhood, "On using composability tools for reliability analysis of unmanned multi-aircraft systems: A case study," IEEE Access, vol. 8, pp. 16331-16349, 2020. DOI: 10.1109/ACCESS.2020.2966763
- D. Muniraj, J.M. Fry, and M. Farhood, "Towards compositional reasoning for verified design of unmanned aircraft systems," submitted.
- Ellingson, Jaron and Ellingson, Gary and McLain, Tim. (2019). Deep RC: Enabling Remote Control through Deep Learning. *International Conference on Unmanned Aircraft Systems*. 1161 to 1167. [doi:10.1109/ICUAS.2019.8798325](https://doi.org/10.1109/ICUAS.2019.8798325)

Franke, K.W., Candia, G., Mayoral, J., Wood, C.M., Montgomery, J., Hutchinson, T., Morales-Velez, A.C., and Dashti, S. (2019). *Observed Building Damage Patterns and Foundation Performance in Mexico City following the 2017 M7.1 Puebla-Mexico City Earthquake*. Franke, K.W., Candia, G., Mayoral, J., Wood, C.M., Montgomery, J., Hutchinson, T., Morales-Velez, A.C., and Dashti, S. (2019). *Observed Building Damage Patterns and Foundation Performance in Mexico City following the 2017 M7.1 Puebla-Mexico City Earthquake*. *Soil Dynamics and Earthquake Engineering*, Elsevier, Volume 125, October 2019, 105708.

Freeman, M., Vernon, C., Berrett, B., Hastings, N., Derricott, J., Pace, J., Horne, B., Hammond, J., Janson, J., Chiabrando, F., Hedengren, J.D., Franke, K. (2019). *Sequential Earthquake Damage Assessment Incorporating Optimized sUAV Remote Sensing at Pescara del Tronto*. Freeman, M., Vernon, C., Berrett, B., Hastings, N., Derricott, J., Pace, J., Horne, B., Hammond, J., Janson, J., Chiabrando, F., Hedengren, J.D., Franke, K., *Sequential Earthquake Damage Assessment Incorporating Optimized sUAV Remote Sensing at Pescara del Tronto*, Special Issue: Remote Sensing Applications for Earthquake and Tsunami Damage Assessment, *Geosciences*, 2019.

Jackson, James and Brink, Kevin and Forsgren, Brendon and Wheeler, David and McLain, Timothy. (2019). Direct Relative Edge Optimization, A Robust Alternative for Pose Graph Optimization. *IEEE Robotics and Automation Letters*. 4 (2) 1932 to 1939. [doi:10.1109/LRA.2019.2896478](https://doi.org/10.1109/LRA.2019.2896478)

Jackson, James and Nielsen, Jerel and McLain, Tim and Beard, Randal. (2019). Improving the Robustness of Visual-Inertial Extended Kalman Filtering. *2019 International Conference on Robotics and Automation (ICRA)*. 4703 to 4709. Status = Deposited in NSF-PAR [doi:10.1109/ICRA.2019.8794164](https://doi.org/10.1109/ICRA.2019.8794164)

Jackson, J., Nielsen, J., McLain, T. and Beard, R. Improving the robustness of visual-inertial extended Kalman filtering, *International Conference on Robotics and Automation*, May 2019.

Jerel Nielsen, Randal W. Beard, "Relative Moving Target Tracking and Circumnavigation," *American Control Conference (ACC)*, 2019.

J. Kunzler and K. F. Warnick (2019). *Developing High Isolation Planar Rx-Tx Ku Band Phases Arrays for Unmanned Aerial Systems*. J. Kunzler and K. F. Warnick, "Developing high isolation planar Rx-Tx Ku band phased arrays for unmanned aerial systems (UAS)," *USNC-URSI Radio Science Meeting*, Atlanta, GA, July 7-12, 2019.

J.M. Fry, D. Abou Jaoude, and M. Farhood, "Robustness analysis of uncertain time-varying systems using integral quadratic constraints with time-varying multipliers," to be submitted (finalizing illustrative example)..



Joseph Stamenkovich, Lakshman Maalolan and Cameron Patterson, "Formal Assurances for Autonomous Systems Without Verifying Application Software", 2019 International Workshop on Research, Education and Development on Unmanned Aerial Systems, Nov 25-27, 2019, Cranfield, UK. DOI: 10.1109/REDUAS47371.2019.8999690

Kang, Changkoo and Chaudhry, Haseeb and Woolsey, Craig A. and Kochersberger, Kevin B.. (2019). Development of a Peripheral-Central Vision System for Small UAS Tracking. AIAA SciTech.

Lusk, Parker C. and Glaab, Patricia C. and Glaab, Louis J. and Beard, Randal W.. (2019). Safe2Ditch: Emergency Landing for Small Unmanned Aircraft Systems. *Journal of Aerospace Information Systems*. 16 (8) 327 to 339. [doi:10.2514/1.1010706](https://doi.org/10.2514/1.1010706)

M. Farhood, "LPV control and analysis under uncertain initial conditions," submitted.

Muniraj, Devaprakash and Farhood, Mazen. (2019). Detection and mitigation of actuator attacks on small unmanned aircraft systems. *Control Engineering Practice*. 83 (C) 188 to 202.

Muniraj, D and Vamvoudakis, K. G and Farhood, M.. (2019). Enforcing Signal Temporal Logic Specifications in Multi-Agent Adversarial Environments: A Deep Q-Learning Approach. 2018 IEEE Conference on Decision and Control (CDC). 4141-4146.

Nielsen, Jerel and Beard, Randal. (2019). Relative Moving Target Tracking and Circumnavigation. *2019 American Control Conference (ACC)*. 1122 to 1127. [doi:10.23919/ACC.2019.8815178](https://doi.org/10.23919/ACC.2019.8815178)

Okeson, T.J., Barrett, B.J., Arce, S., Vernon, C.A., Franke, K.W, Hedengren, J.D. (2019). *Achieving Tiered Model Quality in 3D Structure from Motion Models Using a Multi-Scale View-Planning Algorithm for Automated Targeted Inspection*. Okeson, T.J., Barrett, B.J., Arce, S., Vernon, C.A., Franke, K.W, Hedengren, J.D., *Achieving Tiered Model Quality in 3D Structure from Motion Models Using a Multi-Scale View-Planning Algorithm for Automated Targeted Inspection*, Sensors, MDPI, 19 (12), 2703, [doi: 10.3390/s19122703](https://doi.org/10.3390/s19122703)

Peterson, John and Li, Weilin and Cesar Tondreau, Brian and Bird, John and Kochersberger, Kevin and Czaja, Wojciech and McLean, Morgan. (2019). Experiments in unmanned aerial vehicle/unmanned ground vehicle radiation search. *Journal of Field Robotics*. 36 (4) p. 818-845.

Sangwoo Moon and Eric Frew, "Distributed Optimization of Nonlinear, Non-Gaussian, Communication-Aware Information using Particle Methods," IEEE International Conference on Robotics and Automation (ICRA), May 2020, Paris, France (accepted).

Sangwoo Moon, John Bird, Steve Bernstein, and Eric Frew, "A Gazebo/ROS-based Communication-Realistic Simulator for Networked sUAS," International Conference on Unmanned Aircraft Systems (ICUAS), Jun 2020, Athens, Greece (submitted).

Wheeler, D.. (2020). Relative Navigation of Autonomous GPS-degraded Micro Air Vehicles. *Autonomous robots*. [doi:DOI: 10.1007/s10514-019-09899-4](https://doi.org/10.1007/s10514-019-09899-4)

Wheeler, David O. and Koch, Daniel P. and Jackson, James S. and Ellingson, Gary J. and Nyholm, Paul W. and McLain, Timothy W. and Beard, Randal W. (2020). Relative navigation of autonomous GPS-degraded micro air vehicles. *Autonomous Robots*. [doi:10.1007/s10514-019-09899-4](https://doi.org/10.1007/s10514-019-09899-4)

Yoon H., Chou Y., Chen X., Frew E., Sankaranarayanan S. (2019) Predictive Runtime Monitoring for Linear Stochastic Systems and Applications to Geofence Enforcement for UAVs. In: Finkbeiner B., Mariani L. (eds) Runtime Verification. RV 2019. Lecture Notes in Computer Science, vol 11757. Springer, Cham. DOI: [10.1007/978-3-030-32079-9_20](https://doi.org/10.1007/978-3-030-32079-9_20)

Thesis/Dissertations

A. J. Wagner. Online Unmanned Ground Vehicle Mission Planning using Active Aerial Vehicle Exploration. (2019). Virginia Tech.

Ellingson, Gary James. Cooperative navigation of fixed-wing micro air vehicles in GPS-denied environments. (2019). Brigham Young University.

Eric Bianchi. COCO-Bridge: Common Objects in Context Dataset and Benchmark for Structural Detail Detection of Bridges. (2019). Virginia Tech.

Fulda, Nancy Ellen. Semantically aligned sentence-level embeddings for agent autonomy and natural language understanding. (2019). Brigham Young University.

J. A. Stamenkovich. Enhancing Trust in Autonomous Systems without Verifying Software. (2019). Virginia Tech.

J. J. Donnelly. Semi-Dense Stereo Reconstruction from Aerial Imagery for Improved Obstacle Detection. (2019). Virginia Tech.

Marsh, David Moyle. Phased array digital beamforming algorithms and applications. (2019). Brigham Young University.

Newcomb, Jenna Elisabeth. Trajectory Optimization and Design for a Large Number of Unmanned Aerial Vehicles. (2019). Brigham Young University.

Nielsen, Jerel Bendt. Robust Visual-Inertial Navigation and Control of Fixed-Wing and Multirotor Aircraft. (2019). Brigham Young University.

Olson, Jacob Moroni. Collaborative UAV planning, mapping, and exploration in GPS-denied environments. (2019). Brigham Young University.

White, Jacob Harley. Real-time visual multi-target tracking in realistic tracking environments. (2019). Brigham Young University.

