

# Eric W. Frew

767 Nighthawk Cir.  
Louisville, CO 80027  
(303) 890-8212

Eric.frew@colorado.edu  
<http://recuv.colorado.edu/~frew>  
mobile: (303) 746-2362

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## RESEARCH INTERESTS:

My research interests are in the area of autonomous vehicles and field robotics, with an emphasis on unmanned aircraft systems (UAS). Primary focuses are autonomous flight of heterogeneous unmanned aircraft systems (UAS), guidance and control of unmanned aircraft in complex atmospheric phenomena, optimal distributed sensing by mobile robots, controlled mobility in ad-hoc sensor networks, and miniature self-deploying systems.

## EMPLOYMENT:

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| <b>Director, Autonomous Systems Interdisciplinary Research Theme (ASIRT)</b><br>University of Colorado, Boulder                      | Jan 2018-present   |
| <b>Associate Director of Technology, Integrated Remote and In Situ Sensing (IRISS) Initiative</b><br>University of Colorado, Boulder | Jan 2016-present   |
| <b>Director, Research and Engineering Center for Unmanned Vehicles (RECUV)</b><br>University of Colorado, Boulder                    | July 2012-Dec 2017 |
| <b>Associate Professor</b><br>Aerospace Engineering Sciences Department, University of Colorado, Boulder                             | 2011-present       |
| <b>Assistant Professor</b><br>Aerospace Engineering Sciences Department, University of Colorado, Boulder                             | 2004-2011          |

**CITIZENSHIP:** United States of America

## PROFESSIONAL PREPARATION:

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|--|---------------------|
| <b>University of California, Berkeley</b><br>Postdoctoral Research Scientist, Center for Collaborative Control of Unmanned Vehicles (C3UV) | July 2003-July 2004 |
| <b>Stanford University, Stanford, CA</b><br>Ph.D., Department of Aeronautics and Astronautics  | September 2003      |
| M.S., Department of Aeronautics and Astronautics   | May 1996            |
| <b>Cornell University, Ithaca, NY</b><br>B.S., Sibley School of Mechanical and Aerospace Engineering, GPA 4.1                              | May 1995            |

## AWARDS AND HONORS:

Provost's Faculty Achievement Award, 2015  
College of Engineering Faculty Leadership Advancement Group (FLAG), 2015-present  
H. Joseph Smead Fellow, 2014-present  
AIAA Associate Fellow, 2013  
University of Colorado Excellence in Leadership Fellow, 2013-14  
DARPA Computer Science Study Group, 2010  
Provost's Faculty Achievement Award, 2009  
NSF Faculty Early Career Development (CAREER) Award, 2009  
The Chancellor's Award for Excellence in STEM Education, 2009-2010  
2006 Young Engineer of the Year, AIAA Rocky Mountain Section

## TEACHING: (\* indicates courses I created)

|   |   |
|---|---|
| ASEN 2003 Introduction to Dynamics and Systems          | ASEN 3128 Aircraft Dynamics                         |
| ASEN 4018/4028 Senior Projects, Project Advisory Board  | ASEN 4114/5114 Automatic Control Systems            |
| ASEN 5014 Linear Control Systems                        | *ASEN 5519-004 Unmanned Vehicle Systems and Control |
| *ASEN 6519 Cooperative Control of Multi-Vehicle Systems | ASEN 5018/6028 Graduate Projects                    |

## STUDENT, POSTDOCTORAL RESEARCH, AND STAFF SUPERVISION:

### Doctoral Theses, Supervisor

- [1] Holly Borowski, *Performance Tradeoffs in Distributed Control Systems*. Aerospace Engineering Sciences, PhD, May 2016.
- [2] Anthony Carfang, *Cascaded Optimization for a Persistent Data Ferrying Unmanned Aircraft*. Aerospace Engineering Sciences, PhD, December 2015.
- [3] Neeti Wagle, *Transfer Learning for Characterization of Small Unmanned Aircraft Communication*. Computer Science, PhD, May 2015.
- [4] Maciej Stachura, *Cooperative Planning for UAS-based Sensor Networks In Realistic Communication Environments*. Aerospace Engineering Sciences, PhD, December 2013.
- [5] Jack Elston, *Semi-Autonomous Small Unmanned Aircraft Systems for Sampling Tornadoic Supercell Thunderstorms*, Aerospace Engineering Sciences, PhD, May 2011.
- [6] Cory Dixon, *Controlled Mobility of Unmanned Aircraft Chains to Optimize Capacity in Realistic Communication Environments*, Aerospace Engineering Sciences, PhD, August 2010.
- [7] Jason Durrie, PhD candidate, Aerospace Engineering Sciences (passed comps 3/12, never completed degree).
- [8] Sangwoo Moon, PhD candidate, Aerospace Engineering Sciences.
- [9] Andrew Mills, PhD candidate, Aerospace Engineering Sciences.
- [10] Katherine Glasheen, PhD candidate, Aerospace Engineering Sciences.
- [11] Ramya Kanlapuli Rajasekaran, PhD candidate, Aerospace Engineering Sciences.

### Doctoral Theses, Reader

- [1] Ann Dietrich, *Supporting Autonomous Navigation with Flash Lidar Images in Proximity to Small Celestial Bodies*, Aerospace Engineering Sciences Department, University of Colorado, Boulder, August 2017.
- [2] Ben Pearre, *Model-Free in situ Optimisation of Data-Ferried Sensor Networks*, Department of Computer Science, University of Colorado, Boulder, August 2013.
- [3] Michael Otte, *Any-Com Multi-Robot Path Planning*, Department of Computer Science, University of Colorado, Boulder, October 2011.
- [4] William Pisano, *The Development of an Autonomous Gust Insensitive Unmanned Aerial Vehicle*, Aerospace Engineering Sciences Department, University of Colorado, Boulder, May 2009.
- [5] Richard Power, *Track-Loss Detection in the Absence of Truth Data for Target Tracking in Clutter*, Electrical and Computer Engineering Department, University of Colorado, Boulder, August 2007.

### Masters Theses, Supervisor

- [1] Christopher Harnack, expected May 2019. Graduate project option.
- [2] Spencer Watza, *Hybrid Modelling of the Radio Environment*, Expected May 2018.
- [3] Scott Sheahan, May 2017. Graduate project option.
- [4] William Silva, *An Energy-Aware Trajectory Optimization Layer for sUAS*, August 2015.
- [5] Wenceslao Shaw-Cortez, *Energy-Aware Path Planning with UAS for Persistent Sampling and Surveillance*, December 2013.
- [6] Jennifer O'Brien, *Multi-vehicle Aerospace Simulation Environment*, May 2008.
- [7] Tristan Gerritsen, *Particle Filter for UAS Airfield Localization Using Passive Sensors in GPS-denied Environments*, July 2008. (Became project option due to AFRL public release policy)

### Graduate Independent Study, Supervisor

- [1] Young-Young Shen, 2016
- [2] Thomas Lillis, 2015-2016
- [3] William Finamore, 2015-2016
- [4] Peter Merrick 2014-2015
- [5] Frank Erdesz, Fall 2013
- [6] Kevin Rauhauser, Fall 2012-2013
- [7] Eric Brighton, Spring 2011
- [8] Holly Borowski, Fall 2010 – Spring 2011
- [9] Philip Holtzman, May 2010.
- [10] Spencer Riggs, Spring 2009.

[11] Kimberly Kroh, Spring 2009.

#### **IRISS Hourly Students**

- [1] Tom Lillis, 2016
- [2] Will Finamore, 2016
- [3] Michael Cofield, 2016-present
- [4] Amanda Turk, 2016
- [5] Christopher Brown, 2016-present
- [6] Abhilash Manjunat, 2016-2017

#### **Postdoctoral Researcher, Supervisor**

- [1] Vinod Ramaswamy, 2015-2016
- [2] Michael Otte, 2014-2015

#### **RECUV Professional Research Associate**

- [1] James Mack, 2012-2015

#### **IRISS Senior Research Professional**

- [1] Cory Dixon, 2017-present
- [2] Doug Weibel, 2016-2017

#### **IRISS UAS Engineer and Pilot**

- [3] Daniel Hesseliuss, 2016 - present
- [4] Steve Borenstein, 2016 - present

#### **REFEREED JOURNAL PUBLICATIONS: (\* indicates students of mine)**

- [1] Roger J Laurence, Brian M Argrow, and Eric Frew. "Wind Tunnel Results for a Distributed Flush Airdata System." *Journal of Atmospheric and Oceanic Technology*. 34(7):1519-1528, 2017.
- [2] Neeti Wagle\* and Eric W. Frew. "Forward Adaptive Transfer of Gaussian Process Regression for Robot Learning" *AIAA Journal of Aerospace Information Systems*. 14(4): 214-231, 2017.
- [3] Eric W. Frew and Dale Lawrence. "Tracking Expanding Star Curves Using Guidance Vector Fields." *AIAA Journal of Guidance, Control, and Dynamics*. 40(6):1488-1492, June 2017.
- [4] Maciej Stachura\* and Eric W. Frew. "Communication-Aware Information Gathering Experiments with an Unmanned Aircraft System." *Journal of Field Robotics*. 34(4): 736-756, June 2017.
- [5] Anthony J. Carfang\* and Eric W. Frew. "Fast Link Scheduling Policies for Persistent Data Ferrying." *AIAA Journal of Aerospace Information Systems*, 13(12): 433-449, 2016.
- [6] Anthony J. Carfang\*, Neeti Wagle\*, and Eric W. Frew. "Integrating Nonparametric Learning with Path Planning for Data-Ferry Communications", *Journal of Aerospace Information Systems*, Vol. 12: 784-799, 2015.
- [7] Wenceslao Shaw-Cortez\* and Eric W. Frew. "Efficient Trajectory Development for Unmanned Aircraft System Dynamic Soaring." *AIAA Journal of Guidance, Control, and Dynamics*, 38(3): 519-523, 2015.
- [8] Anthony J. Carfang\*, Eric W. Frew, and Derek Kingston. "Cascaded Optimization of Aircraft Trajectories for Persistent Data Ferrying." *AIAA Journal of Aerospace Information Systems*. 11(12): 807-820, 2014.
- [9] Jason Roadman, Jack Elston\*, Brian Argrow, and Eric W. Frew. "Mission Performance of the Tempest UAS in Supercell Storms." *AIAA Journal of Aircraft*, 49(6): 1821-1830, 2012.
- [10] Cory Dixon\* and Eric W. Frew, "Optimizing Cascaded Chains of Unmanned Aircraft acting as Communication Relays." *IEEE Journal on Selected Areas in Communications*, 30(5): 883-898, 2012.

- [11] Eric W. Frew, Jack Elston\*, Brian Argrow, Adam Houston, and Erik Rasmussen. "Unmanned Aircraft Systems for Sampling Severe Local Storms and Related Phenomena." *Robotics and Automation Magazine*, 19(1):85-95, 2012.
- [12] A. L. Houston, B. Argrow, J. Elston\*, J. Lahowetz, E. W. Frew and P. C. Kennedy. "The Collaborative Colorado-Nebraska Unmanned Aircraft System Experiment." *Bulletin of the American Meteorological Society*, 93(1):39-54, Jan. 2012.
- [13] Jack Elston\*, Brian Argrow, Eric W. Frew, Adam Houston, and Jerry Straka. "Evaluation of Unmanned Aircraft Systems for Severe Storm Sampling using Hardware-in-the-Loop Simulations" *AIAA Journal of Aerospace Computing, Information, and Communication*, 8(9):269-294, 2011.
- [14] Maciej Stachura\* and Eric W. Frew. "Cooperative Target Localization with a Communication Aware Unmanned Aircraft System." *AIAA Journal of Guidance, Control, and Dynamics*, 34(5), Sept.-Oct. 2011.
- [15] Jack Elston\*, Jason Roadman, Maciej Stachura\*, Brian Argrow, Adam Houston, and Eric W. Frew. "The Tempest Unmanned Aircraft System for In Situ Observations of Tornadic Supercells: Design and Flight Test Results." *Journal of Field Robotics*, 28(4):461-483, July/August 2011.
- [16] Jack Elston\* and Eric W. Frew. "Unmanned Aircraft Guidance for Penetration of Pre-Tornadic Storms." *AIAA Journal of Guidance, Control, and Dynamics*, 33(1):99-107, Jan.-Feb. 2010.
- [17] Jack Elston\*, Eric W. Frew, Dale Lawrence, Peter Gray, and Brian Argrow. "Net-Centric Communication and Control for a Heterogeneous Unmanned Aircraft System." *Journal of Intelligent and Robotic Systems*, 56(1-2):199-232, Sept., 2009.
- [18] Eric W. Frew. "Information-Theoretic Integration of Sensing and Communication for Active Robot Networks." Invited to special issue of *Mobile Networks and Applications (MONET)*, 14(3):267-280 June 2009.
- [19] Cory Dixon\* and Eric W. Frew. "Maintaining Optimal Communication Chains in Robotic Sensor Networks using Mobility Control." Invited to special issue of *Mobile Networks and Applications (MONET)*, 14(3):281-291 June 2009.
- [20] Brian Argrow, Elizabeth Weatherhead, and Eric W. Frew. "Real-Time Participant Feedback from the Symposium for Civilian Applications of Unmanned Aircraft Systems." *Journal of Intelligent and Robotic Systems*, 54:87-103 March 2009.
- [21] Eric W. Frew and Timothy X. Brown. "Networking Issues for Small Unmanned Aircraft Systems." *Journal of Intelligent and Robotic Systems*, 54:21-37, March 2009.
- [22] Eric W. Frew and Timothy X Brown, "Airborne Communication Networks for Small Unmanned Aircraft Systems." *Proceedings of the IEEE, Special Issue on Aviation Information Systems*, 96(12): 2008-2027, Dec. 2008.
- [23] Dale A. Lawrence, Eric. W. Frew, and William J. Pisano, "Lyapunov Vector Fields for Autonomous UAV Flight Control" *AIAA Journal of Guidance, Control, and Dynamics*, 31(5):1220-1229, Sept.-Oct. 2008.
- [24] Eric W. Frew. "Sensitivity of Cooperative Target Geolocalization to Orbit Coordination." *AIAA Journal of Guidance, Control, and Dynamics*, 31(4):1028-1040, July-August 2008.
- [25] Eric W. Frew, Cory Dixon\*, Jack Elston\*, Brian Argrow, and Timothy X. Brown. "Networked Communication, Command, and Control of an Unmanned Aircraft System." *AIAA Journal of Aerospace Computing, Information, and Communication*, 5(4):84-107, 2008.
- [26] Eric W. Frew, Dale A. Lawrence, and Stephen Morris. "Coordinated Standoff Tracking of Moving Targets using Lyapunov Guidance Vector Fields." *AIAA Journal of Guidance, Control, and Dynamics*, 31(2):290-306, March-April 2008.

## UNDER REVIEW OR IN PREPARATION

- [1] Eric Frew, Brian Argrow, Adam Houston, and Chris Weiss. "Toward an Autonomous Airborne Scientist for Studying Severe Local Storms." *AIAA Journal of Aerospace Information Systems*. Under revision.
- [2] Sangwoo Moon\* and Eric Frew. "Distributed Cooperative Control for Joint Optimization of Sensor Coverage and Target Tracking." *Journal of Intelligent and Robotic Systems*. Under review.
- [3] Andrew B. Mills\* and Eric W. Frew. "Energy-Aware Aircraft Trajectory Generation Using Pseudospectral Methods with Differential Flatness." *AIAA Journal of Guidance, Control, and Dynamics*. In preparation.
- [4] Sangwoo Moon\*, Vinod Ramaswamy, Eric W. Frew, Nisar Ahmed. "Mutual Information based communication aware path planning: A game theoretic perspective." *Autonomous Robots*. In preparation.
- [5] Will Silva\*, Michael Otte, and Eric Frew. "Implementing a Trajectory Optimization Layer for Persistent Sampling Missions with Soaring." *Journal of Field Robotics*. Under revision.

## REPORTS:

- [1] Committee on Autonomy Research for Civil Aviation; Aeronautics and Space Engineering Board; Division on Engineering and Physical Sciences; National Research Council. *Autonomy Research for Civil Aviation: Toward a New Era of Flight*. The National Academies Press. 2014.

## BOOK CHAPTERS: (\* indicates students of mine)

- [1] Jack Elston\*, Maciej Stachura\*, Cory Dixon\*, Brian Argrow, and Eric W. Frew. "Layered Approach to Networked Command and Control of Complex UAS." *Handbook of Unmanned Aerial Vehicles*. Edited by Kimon P. Valavanis and George J. Vachtsevanos, 2015, pp. 781 – 811.
- [2] Maciej Stachura\*, Jack Elston\*, Brian Argrow, Eric W. Frew, and Cory Dixon\*. "A Certification Strategy for Small Unmanned Aircraft Performing Nomadic Missions in the U.S. National Airspace System." *Handbook of Unmanned Aerial Vehicles*. Edited by Kimon P. Valavanis and George J. Vachtsevanos, 2015, pp. 2177-2198.
- [3] Cory Dixon\* and Eric W. Frew. "Decentralized Extremum-Seeking Control of Nonholonomic Vehicles to Form a Communication Chain." *Advances in Cooperative Control and Optimization*. Lecture Notes in Computer Science, Vol. 369, Michael J. Hirsch, Panos Pardalos, Robert Murphey, and Don Grundle, Eds. Springer-Verlag, Nov. 2007, pp. 311-322.
- [4] Timothy Brown, Brian Argrow, Eric Frew, Cory Dixon\*, Daniel Henkel, Jack Elston\*, and Harvey Gates. "Experiments Using Small Unmanned Aircraft to Augment a Mobile Ad Hoc Network." *Emerging Technologies in Wireless LANs: Theory, Design, and Deployment*, Edited by Benny Bing, Ch. 28, p. 123-145, 2007.

## CONFERENCE PUBLICATIONS: (\* indicates students of mine)

- [1] Spencer Watza\* and Eric Frew. "Online Hybrid RF Propagation Model for Communication-Aware sUAS Relay Application." *AIAA Science and Technology Forum*. Kissimmee, FL, 8–12 January 2018.
- [2] Katherine Glasheen\*, Andrew Mills\*, and Eric Frew. "Toward an Autonomy Architecture for sUAS Network-Enabled Planning in the Cloud." *AIAA Science and Technology Forum*. Kissimmee, FL, 8–12 January 2018.
- [3] Sangwoo Moon\*, Vinod Ramaswamy Pillai, Eric W. Frew, and Nisar Ahmed. "Co-optimization of Communication, Sensing, and Computation for Information Gathering using Cloud Computing." *1st IEEE Conference on Control Technology and Applications*. Kohala Coast, Hawaii, Aug. 27-30, 2017.
- [4] Andrew B. Mills\*, Daniel Kim, and Eric W. Frew. "Energy-Aware Aircraft Trajectory Generation Using Pseudospectral Methods with Differential Flatness". *1st IEEE Conference on Control Technology and Applications*. Kohala Coast, Hawaii, Aug. 27-30, 2017.

- [5] Ramya Kanlapuli Rajasekaran\* and Eric Frew. “Cyber-security challenges for wireless networked aircraft.” *Integrated Communications, Navigation and Surveillance Conference (ICNS)*, Herndon, VA, Aug. 18-20, 2017.
- [6] Sangwoo Moon\* and Eric Frew. “Distributed Cooperative Control for Joint Optimization of Sensor Coverage and Target Tracking.” *The 2017 International Conference on Unmanned Aircraft Systems*. Miami, FL, June 13-16, 2017.
- [7] Young-Young Shen\*, Megan Cattau, Steve Borenstein, Eric Frew, and Doug Weibel. “Toward an Architecture for Subalpine Forest Monitoring Using Commercial Off-the-Shelf Unmanned Aircraft Systems and Sensors.” *17th AIAA Aviation Technology, Integration, and Operations Conference*, Denver, CO, June 5-9, 2017.
- [8] Ben Mccamish, Arash Termehchy, Behrouz Touri, Vinod Ramaswamy, Eric Frew and Liang Huang. “A Signaling Game Approach to Databases Querying and Interaction.” *ACM SIGMOD International Conference on Management of Data (SIGMOD 2017)*, Raleigh, NC, May 14-19, 2017.
- [9] Andrew Mills\*, Scott Sheahan\*, and Eric Frew. “Sensitivity Analysis for Energy-Aware Path Optimization.” *AIAA Science and Technology Forum*, San Diego, CA, Jan. 2017.
- [10] Scott Sheahan\*, Andrew Mills\*, and Eric Frew. “Kernel Function Evaluation for Gaussian Process Wind Regression.” *AIAA Science and Technology Forum*, San Diego, CA, Jan. 2017.
- [11] Vinod Ramaswamy, Sangwoo Moon, Eric W. Frew, Nisar Ahmed. “Mutual Information based communication aware path planning: A game theoretic perspective.” *2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. Daejeon, Korea , October 9-14, 2016.
- [12] Eric Frew, Brian Argrow, Roger Laurence, Tevis Nichols, Andrew Mills\*, and Scott Sheahan\*. “Energy-Aware Airborne Dynamic Data Driven Application Systems for Persistent Surveillance and Sampling.” *1st International Conference on InfoSymbiotics / DDDAS (Dynamic Data Driven Applications Systems)*, Hartford, Connecticut, August 9-12, 2016.
- [13] Nisar Ahmed, William Whitacre, Sangwoo Moon\*, and Eric Frew. “Factorized Covariance Intersection for Scalable Partial State Decentralized Data Fusion.” *19th International Conference on Information Fusion*, Heidelberg, Germany, July 2016.
- [14] Eric Frew, Brian Argrow, Adam Houston, and Chris Weiss. “Toward an Autonomous Airborne Scientist for Studying Severe Local Storms.” *AIAA 8th Atmospheric and Space Environments Conference*, Washington, DC, June 2016.
- [15] Roger Laurence, III, Brian Argrow, and Eric Frew. “In-Situ Wind Sensing from a Small UAS with Distributed Pressure Sensors”. *AIAA 8th Atmospheric and Space Environments Conference*, Washington, DC, June 2016.
- [16] Michael Otte, Will Silva\*, and Eric Frew. “Any-Time Path-Planning: Time-Varying Wind Field + Moving Obstacles.” *International Conference on Robotics and Automation*, Stockholm, Sweden, May 2016.
- [17] Will Silva\* and Eric Frew. “Experimental Assessment of Online Dynamic Soaring Optimization for Small Unmanned Aircraft.” *AIAA SciTech Forum*, San Diego, CA, January 2016.
- [18] Nisar R. Ahmed, William Whitacre, Sangwoo Moon\*, and Eric W. Frew. “Scalable Decentralized Target Localization with Ownship Uncertainties Using Factorized Data Fusion.” *AIAA SciTech Forum*, San Diego, CA, January 2016.
- [19] Woldt W., Frew, E., Meyer, G., Freiburger, R., and Stachura, M. “Flight characteristics of a fixed wing unmanned aircraft system for aerial surveillance of agricultural systems”, 2015 ASABE Annual International Meeting, New Orleans, LA, Paper No. 152190195, 15pp. 2015.
- [20] Will Silva\*, Eric W. Frew, and Wenceslao Shaw-Cortez. “Implementing Path Planning and Guidance Layers for Dynamic Soaring and Persistence Missions.” *International Conference on Unmanned Aircraft Systems*, Denver, CO, June 2015.

- [21] Austin Anderson\*, Eric W. Frew, and Dirk Grunwald. "Cognitive Radio Development for UAS Applications." *International Conference on Unmanned Aircraft Systems*, Denver, CO, June 2015.
- [22] Anthony Carfang\*, Neeti Wagle\* and Eric W. Frew. "Improving Data Ferrying by Iteratively Learning the Radio Frequency Environment." *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Chicago, IL, Sept 14-18, 2014.
- [23] Wayne E. Woldt, Eric W. Frew, George E. Meyer, Maciej Stachura, James Mack. "Performance Measures for Autonomous Navigation System in a Fixed Wing Unmanned Aircraft System Flying Production Agriculture Missions." *American Society of Agricultural and Biological Engineers*. Montreal, Quebec Canada July 13 – July 16, 2014.
- [24] Wenceslao Shaw-Cortez\* and Eric W. Frew. "Efficient Trajectory Development for UAS Dynamic Soaring Applications." *AIAA Guidance, Navigation, and Control Conference*, National Harbor, MD, January 2014.
- [25] Anthony J. Carfang\* and Eric W. Frew. "Fast Bandwidth Allocation Policies for Persistent Data Ferrying." 4<sup>th</sup> *International Workshop on Wireless Networking and Control for Unmanned Autonomous Vehicles*, Atlanta, GA, Dec. 2013.
- [26] H. Borowski\*, J. R. Marden, D. S. Leslie, and E. W. Frew, "Coarse Resistance Tree Methods for Stochastic Stability Analysis," *IEEE Conference on Decision and Control*, 2013.
- [27] H. Borowski\*, J. R. Marden, and E. W. Frew, "Fast Convergence in Semi-Anonymous Potential Games," *IEEE Conference on Decision and Control*, 2013.
- [28] Anthony J. Carfang\*, Eric W. Frew, and Derek Kingston. "A Cascaded Approach to Optimal Aircraft Trajectories for Persistent Data Ferrying." *AIAA Guidance, Navigation, and Control Conference*, Boston, MA, August 2013.
- [29] Eric W. Frew, Brian Argrow, Dale Lawrence, Jack Elston\*, and Maciej Stachura\*. "Unmanned Aircraft Systems for Communication and Atmospheric Sensing Missions." *American Control Conference*, Washington DC, June 2013.
- [30] Eric W. Frew, Brian Argrow, Adam Houston, Chris Weiss, Jack Elston. "An Energy-Aware Airborne Dynamic Data-Driven Application System for Persistent Sampling and Surveillance." *International Conference on Computational Science, ICCS 2013*, Barcelona, Spain, June 2013.
- [31] Neeti Wagle\* and Eric W. Frew. "Online Evaluation of Communication Models Derived via Transfer Learning" *Wireless Networking for Unmanned Autonomous Vehicles (WiUAV '12)*, Anaheim, CA, Dec. 2012.
- [32] Holly Borowski\* and Eric W. Frew. "An Evaluation of Path Planners for Guidance With Vision Based Simultaneous Localization and Mapping." In *AIAA Guidance, Navigation, and Control Conference*, Minneapolis, MN, August, 2012.
- [33] Eric W. Frew and Dale Lawrence. "Tracking Expanding Star Curves Using Guidance Vector Fields." In *Proceedings 2012 American Control Conference*, Montreal, Canada, June 2012.
- [34] Neeti Wagle\* and Eric W. Frew. "Transfer Learning for Dynamic RF Environments." In *Proceedings 2012 American Control Conference*, Montreal, Canada, June 2012.
- [35] Anthony Carfang\* and Eric W. Frew. "Real-Time Estimation of Wireless Ground-to-Air Communication Parameters." *International Conference on Computing, Networking and Communications, Wireless Ad Hoc and Sensor Networks Symposium*, Maui, Hawaii, Jan/Feb, 2012.
- [36] Neeti Wagle\* and Eric W. Frew. "Spatio-temporal Characterization of Airborne Radio Frequency Environments." *Wireless Networking for Unmanned Autonomous Vehicles (GC'11 Workshop - Wi-UAV)*, Houston, TX, Dec. 2011.

- [37] Maciej Stachura\* and Eric W. Frew. "WiFi Localization Experiments with an Unmanned Aircraft." In *AIAA Guidance, Navigation, and Control Conference*, Portland, OR, August 2011.
- [38] Brian Argrow, Eric Frew, Jack Elston\*, Maciej Stachura\*, Jason Roadman, Adam Houston, and Jamie Lahowetz. "The Tempest UAS: The VORTEX2 Supercell Thunderstorm Penetrator." In *AIAA Infotech@Aerospace*, St. Louis, MS, March 2011.
- [39] Jack Elston\*, Maciej Stachura\*, Brian Argrow, Eric Frew, and Cory Dixon\*. "Guidelines and Best Practices for FAA Certificate of Authorization Applications for Small Unmanned Aircraft." In *AIAA Infotech@Aerospace*, St. Louis, MS, March 2011, 10 pages.
- [40] Jack Elston\*, Brian Argrow, Adam Houston, and Eric Frew. "Design and Validation of a System for Targeted Observations of Pre-Tornadic Supercells Using Unmanned Aircraft." In *2010 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Taipei, Taiwan, October 2010, 6 pages.
- [41] Maciej Stachura\* and Eric W. Frew. "Cooperative Target Localization with a Communication Aware Active Sensor Network." In *AIAA Guidance, Navigation, and Control Conference*, Toronto, Canada, August 2010, 15 pages.
- [42] Anthony J. Carfang\*, Eric W. Frew, and Timothy X Brown. "Improved Delay-Tolerant Communication by Considering Radio Propagation in Planning Data Ferry Navigation." In *AIAA Guidance, Navigation, and Control Conference*, Toronto, Canada, August 2010, 14 pages.
- [43] Neeti Wagle\* and Eric W. Frew. "A Particle Filter Approach to WiFi Target Localization." In *AIAA Guidance, Navigation, and Control Conference*, Toronto, Canada, August 2010, 12 pages.
- [44] Jack Elston\*, Brian Argrow, Eric W. Frew, and Adam Houston. "Evaluation of UAS Concepts of Operation for Severe Storm Penetration using Hardware-in-the-Loop Simulations." In *AIAA Guidance, Navigation, and Control Conference*, Toronto, Canada, August 2010, 15 pages.
- [45] Eric W. Frew and Brian Argrow. "Embedded Reasoning for Atmospheric Science Using Unmanned Aircraft Systems." In *AAAI 2010 Spring Symposium on Embedded Reasoning: Intelligence in Embedded Systems*, Palo Alto, CA, March 2010, 5 pages.
- [46] Eric W. Frew, Cory Dixon\*, Jack Elston\*, and Maciej Stachura\*. "Active Sensing by Unmanned Aircraft Systems in Realistic Communication Environments." *IFAC Workshop on Networked Robotics*, Golden, CO, October 2009, 6 pages.
- [47] Jack Elston\* and Eric W. Frew. "Reduction of Computational Complexity for Guidance of Unmanned Aircraft through Strong Wind Fields." In *AIAA Guidance, Navigation, and Control Conference*, Chicago, IL, August 2009, 6 pages.
- [48] Maciej Stachura\*, Anthony Carfang\*, and Eric W. Frew. "Cooperative Target Tracking with a Communication Limited Active Sensor Network." *International Workshop on Robotic Wireless Sensor Networks*, Marina Del Rey, CA, June 2009, 6 pages.
- [49] Eric W. Frew. "Providing Quality of Service of Information through Mobility." In *Proceedings 2009 American Control Conference*, St. Louis, MO, June 2009, pp. 2160-2165.
- [50] Eric W. Frew. "Combining Area Patrol, Perimeter Surveillance, and Target Tracking Using Ordered Upwind Methods." In *Proceedings of the 2009 IEEE International Conference on Robotics and Automation*, Kobe, Japan, May 12-17, 2009, pp. 3123-3128.
- [51] Jason Durrie\*, Tristan Gerritsen\*, Eric W. Frew, and Stephen Pledgie. "Vision-Aided Inertial Navigation on an Uncertain Map Using a Particle Filter." In *Proceedings of the 2009 IEEE International Conference on Robotics and Automation*, Kobe, Japan, May 12-17, 2009, pp. 4189-4194.



- [52] Jack Elston\*, Maciej Stachura\*, Eric W. Frew, and Ute C. Herzfeld. "Toward Model Free Atmospheric Sensing by Heterogeneous Aerial Robot Networks in Strong Wind Fields." In *Proceedings of the 2009 IEEE International Conference on Robotics and Automation*, Kobe, Japan, May 12-17, 2009, pp. 3090-3095.
- [53] Eric W. Frew. "Approximating Information Content for Active Sensing Tasks Using the Unscented Transform." In *IEEE/RSJ International Conference on Intelligent Robots and Systems*, Nice, France, Sept. 2008, pp. 2559-64.
- [54] Jack Elston\* and Eric W. Frew. "Unmanned Aircraft Guidance for Penetration of Pre-Tornadic Storms." In *AIAA Guidance, Navigation, and Control Conference*, Honolulu, HI, August 2008, 14 pages.
- [55] Eric W. Frew, Tristan Gerritsen\*, Stephen Pledgie, Chris Brinton, Shivang Patel, and Bonnie Schwartz. "Vision-Based Navigation for Airfield Surface Operation." In *AIAA Guidance, Navigation, and Control Conference*, Honolulu, HI, August 2008, pp. 4189-94.
- [56] Brian Argrow, Elizabeth Weatherhead, and Eric W. Frew. "Real-Time Participant Feedback from the Symposium for Civilian Applications of Unmanned Aircraft Systems." In *International Symposium on Unmanned Aerial Vehicles*, Orlando, FL, June 2008, 13 pages.
- [57] Eric W. Frew and Timothy X. Brown. "Airborne Communication Networks for Small Unmanned Aircraft Systems." In *International Symposium on Unmanned Aerial Vehicles*, Orlando, FL, June 2008, 17 pages.
- [58] Eric W. Frew and Jack Elston\*. "Target Assignment for Integrated Search and Tracking by Active Robot Networks." In *Proceedings of the 2008 IEEE International Conference on Robotics and Automation*, Pasadena, CA, May 2008, pp. 2354-2359.
- [59] Jack Elston\* and Eric W. Frew. "Hierarchical Distributed Control for Search and Tracking by Heterogeneous Aerial Robot Networks." In *Proceedings of the 2008 IEEE International Conference on Robotics and Automation*, Pasadena, CA, May 2008, pp. 170-175.
- [60] Cory Dixon\* and Eric W. Frew. "Maintaining Optimal Communication Chains in Robotic Sensor Networks using Mobility Control." In *Proceedings of the First International Conference on Robot Communication and Coordination (Robocomm)*, Athens, Greece, October 2007, 8 pages.
- [61] Eric W. Frew. "Information-Theoretic Integration of Sensing and Communication for Active Robot Networks." In *Proceedings of the First International Conference on Robot Communication and Coordination (Robocomm)*, Athens, Greece, October 2007, 8 pages.
- [62] Eric W. Frew, Jack Langelaan, and Maciej Stachura\*. "Adaptive Planning Horizon Based on Information Velocity for Vision-Based Navigation." Invited to *AIAA Guidance, Navigation, and Control Conference*, Hilton Head, SC, August 2007, pp. 3822-3841.
- [63] Eric W. Frew. "Sensitivity of Cooperative Geolocalization to Orbit Coordination." *AIAA Guidance, Navigation, and Control Conference*, Hilton Head, SC, August 2007, pp. 3869-3892.
- [64] Dale A. Lawrence, Eric W. Frew, and William J. Pisano, "Lyapunov Vector Fields for Autonomous UAV Flight Control" *AIAA Guidance, Navigation, and Control Conference*, Hilton Head, SC, August 2007, pp. 78-99.
- [65] Cory Dixon\* and Eric W. Frew. "Cooperative Electronic Chaining Using Small Unmanned Aircraft". In *AIAA Infotech@Aerospace*, Rohnert Park, CA, May 2007, pp. 339-346.
- [66] Jack Elston\* and Eric W. Frew. "Net-centric Cooperative Tracking of Moving Targets." In *AIAA Infotech@Aerospace*, Rohnert Park, CA, May 2007, pp. 1931-1938.
- [67] Eric W. Frew, Dale A. Lawrence, Cory Dixon\*, Jack Elston\*, and William J. Pisano. "Lyapunov Guidance Vector Fields for Unmanned Aircraft Applications." Invited to *Proceedings 2007 American Control Conference*, New York, NY, June 2007, pp. 371-376.

- [68] Eric W. Frew. "Cooperative Stand-off Tracking of Uncertain Moving Targets using Active Robot Networks." *Proceedings of the 2007 IEEE International Conference on Robotics and Automation*, Rome, Italy, April 2007, pp. 3277 - 3282.
- [69] Eric W. Frew. "Receding Horizon Control under Uncertainty Using Optimal Input Design and the Unscented Transform." In *45th IEEE Conference on Decision and Control*, San Diego, CA, December 2006, 6 pages.
- [70] Cory Dixon\* and Eric W. Frew. "Controlling the Mobility of Network Nodes using Decentralized Extremum Seeking." In *45th IEEE Conference on Decision and Control*, San Diego, CA, December 2006, pp. 1291-1296.
- [71] Cory Dixon\*, Dan Henkel, Eric W. Frew, and Timothy X. Brown. "Phase Transitions for Controlled Mobility in Wireless Ad hoc Networks." *AIAA Guidance, Navigation, and Control Conference*, Keystone, CO, August 2006, pp. 3346-3356.
- [72] Cory Dixon\* and Eric W. Frew. "Maintaining a Linked Network Chain Utilizing Decentralized Mobility Control." *AIAA Guidance, Navigation, and Control Conference*, Keystone, CO, August 2006, pp. 3338-3345.
- [73] Jack Elston\*, Eric W. Frew, and Brian Argrow. "Networked UAV Communication, Command, and Control." *AIAA Guidance, Navigation, and Control Conference*, Keystone, CO, August 2006, pp. 3357-3365.
- [74] Eric W. Frew, Jack Langelaan, and Sungmoon Joo. "Adaptive Receding Horizon Control for Vision-Based Navigation of Small Unmanned Aircraft." Invited to *Proceedings 2006 American Control Conference*, Minneapolis, MN, June 2006, pp. 2160-2165.
- [75] Eric W. Frew. "Comparison of Lateral Controllers for Following Linear Structures Using Computer Vision." Invited to *Proceedings 2006 American Control Conference*, Minneapolis, MN, June 2006, pp. 2154-2159.
- [76] Eric W. Frew, Tim X. Brown, Cory Dixon\*, and Dan Henkel. "Establishment and Maintenance of a Delay Tolerant Network through Decentralized Mobility Control." Invited to *IEEE International Conference On Networking, Sensing and Control (ICNSC)*, Ft. Lauderdale, FL, April 2006, pp. 584-589.
- [77] Cory Dixon\*, Eric W. Frew, Brian Argrow. "Electronic Leashing of an Unmanned Aircraft to a Radio Source." *44th IEEE Conference on Decision and Control*, Seville, Spain, December 2005, pp. 3560-3565.
- [78] Eric W. Frew, Cory Dixon\*, Brian Argrow, and Timothy Brown. "Radio Source Localization by a Cooperating UAV Team." Invited to *AIAA Infotech@Aerospace*, Arlington, VA, September 2005, pp. 10-20.
- [79] Cory Dixon\*, Eric Frew, and Brian Argrow. "Radio Leashing Unmanned Aircraft." *AIAA Infotech@Aerospace*, Arlington, VA, September 2005, pp. 1093-1102.
- [80] Jack Elston\*, Brian Argrow, and Eric Frew. "A Distributed Avionics Package for Small UAVs." *AIAA Infotech@Aerospace*, Arlington, VA, September 2005, pp. 733-742.
- [81] Eric W. Frew. "Receding Time Horizon Control Using Random Search for UAV Navigation with Passive, Non-cooperative Sensing." *AIAA Guidance, Navigation, and Control Conference*, San Francisco, CA, August 2005, pp. 553-565.
- [82] Eric W. Frew and Dale A. Lawrence. "Cooperative Stand-off Tracking of Moving Targets by a Team of Autonomous Aircraft." *AIAA Guidance, Navigation, and Control Conference*, San Francisco, CA, August 2005, pp. 4885-4895.
- [83] Eric W. Frew and Raja Sengupta. "Obstacle Avoidance with Sensor Uncertainty for Small Unmanned Aircraft." In *43rd IEEE Conference on Decision and Control*, Paradise Island, Bahamas, December 2004, pp. 614-619.
- [84] Eric Frew, Xiao Xiao, Stephen Spry, Tim McGee, ZuWhan Kim, Jack Tisdale, Raja Sengupta, and J. Karl Hedrick. "Flight Demonstrations of Self-Directed Collaborative Navigation of Small Unmanned Aircraft." *AIAA 3rd Unmanned Unlimited Technical Conference, Workshop, & Exhibit*, Chicago, IL, September 2004, 14 pages.

- [85] Eric Frew, Tim McGee, ZuWhan Kim, Xiao Xiao, Stephen Jackson, Michael Morimoto, Sivakumar Rathinam, Jose Padiar, and Raja Sengupta. "Vision-Based Road Following Using a Small Autonomous Aircraft." In *Proceedings of the 2004 IEEE Aerospace Conference*, Big Sky, MT, March 2004, pp. 3006-3015.
- [86] Christopher M. Clark, Eric W. Frew, Henry L. Jones, and Stephen M. Rock. "An Integrated System for Command and Control of Cooperative Robotic Systems", In *Proceedings of the 11th International Conference on Advanced Robotics*, Portugal, June, 2003, pp. 459-464.
- [87] Eric W. Frew and Stephen M. Rock. "Trajectory Generation for Monocular Vision-Based Tracking of a Constant Velocity Target." In *Proceedings of the 2003 IEEE International Conference on Robotics and Automation*, Taipei, Taiwan, September 2003, pp. 461-465.
- [88] Andreas Huster, Eric W. Frew, and Stephen M. Rock. "Relative Position Estimation for AUVs by Fusing Bearing and Inertial Rate Sensor Measurements." In *Proceedings of the Oceans 2002 Conference*, Biloxi, MS, October 2002, pp. 1857-1864.
- [89] Eric W. Frew and Stephen M. Rock. "Exploratory Motion Generation for Monocular Vision-Based Target Localization." In *Proceedings of the 2002 IEEE Aerospace Conference*, Big Sky, MT, March 2002, 7:3633-3643.
- [90] Henry L. Jones, Eric W. Frew, Bruce R. Woodley, and Stephen M. Rock. "Human-Robot Interaction for Field Operation of an Autonomous Helicopter." In *Proc. SPIE, Mobile Robots XIII and Intelligent Transportation Systems*, Boston MA, November 1998, 3525:244-252.
- [91] Steve M. Rock, Eric W. Frew, Henry L. Jones, Bruce Woodley, and Ed LeMaster. "Combined CDGPS and Vision-Based Control of a Small Autonomous Helicopter." In *Proceedings 1998 American Control Conference*, Philadelphia, June 1998, 2:694-698.
- [92] Bruce Woodley, Henry Jones, Eric W. Frew, Ed LeMaster, and Dr. Stephen Rock. "A Contestant in the 1997 International Aerial Robotics Competition. Aerospace Robotics Laboratory Stanford University." In *AUVSI '97 Proceedings*, Orlando FL, July 1997, 8 pages.
- [93] Bruce Woodley, Hank Jones, Eric Frew, Ed LeMaster, and Dr. Stephen Rock. "A Contestant in the 1996 International Aerial Robotics Competition." In *AUVSI '96 Proceedings*, Orlando FL, July 1996, pp. 939-946.
- [94] Bruce Woodley, Henry L. Jones, Ed LeMaster, Eric W. Frew, and Dr. Stephen M. Rock. "Carrier Phase GPS and Computer Vision for the Control of an Autonomous Helicopter." In *Proceedings of the Institute of Navigation GPS-96 Conference*, Kansas City MO, September 1996, pp. 461-465.

## CONFERENCE AND WORKSHOP PRESENTATIONS: (\* indicates students of mine)

- [1] Spencer Watz, Ramya Kanlapuli, Eric Frew. "Hybrid RF Propagation Model using ITM and Gaussian Processes for Communication-Aware Planning." *RSS 2017 Workshop on Robot Communication in the Wild*. Cambridge, MA, July 2017.
- [1] Matthew Aitken, Nisar Ahmed, Dale Lawrence, Brian Argrow and Eric Frew. "Assurances and Machine Self-Confidence for Enhanced Trust in Autonomous Systems", *RSS 2016 Workshop on Social Trust in Autonomous Robots*, June 2016, Ann Arbor, MI.
- [2] Eric Frew. The Center for Unmanned Aircraft Systems. *The Ohio UAS Conference*. Dayton, OH, August, 2016.
- [3] Eric Frew, Austin Lillard, Brian Argrow, and Dale Lawrence. Assurances for Enhanced Trust in Autonomous Systems. *AAAI Fall Symposium on Self-confidence in Autonomous Systems*, Nov. 12-14, 2015, Arlington, VA.
- [4] Eric Frew. The Center for Unmanned Aircraft Systems. *The Ohio UAS Conference*. Dayton, OH, Aug. 25-26, 2015.
- [5] Jack Elston, Tevis Nichols, Brian Argrow, Eric Frew, Dale Lawrence, John Cassano, Melissa Nigro, Gijs de Boer, Adam Houston, Alexander Schueth, Chris Weiss, Norman Wildmann and Phil Chilson." Multi-sUAS Evaluation of

Techniques for Measurement of Atmospheric Properties.” *International Society for Atmospheric Research using Remotely Piloted Aircraft*. Norman, OK, May 2015.

- [6] Reinhart, A. E., C. C. Weiss, A. Houston, E. W. Frew and B. Argrow. “Real-time dual-Doppler wind synthesis applied to the support of research using unmanned aircraft systems.” *31st Conference on Environmental Information Processing Technologies*, Phoenix, AZ, 2015.
- [7] Adam Houston, Brian Argrow, Eric Frew, and Chris Weiss. “Application of UAS towards tornado research and forecasting.” *American Geophysical Union Fall Meeting*, San Francisco CA, Dec. 2014.
- [8] Eric Frew, Brian Argrow, Adam Houston, and Chris Weiss. “Initial Results from an Energy-Aware Airborne Dynamic, Data-Driven Application System Performing Sampling in Coherent Boundary-Layer Structures.” *American Geophysical Union Fall Meeting*, San Francisco CA, Dec. 2014.
- [9] Brian Argrow, Eric Frew, Adam Houston, and Chris Weiss. “Recent Advances in the Tempest UAS for In-Situ Measurements in Highly-Dynamic Environments.” *American Geophysical Union Fall Meeting*, San Francisco CA, Dec. 2014.
- [10] George Limpert, N. A. Lock, A. L. Houston, E. W. Frew, J. Elston, and C. C. Weiss. “An Approach for Identification, Tracking, and Prediction of Convective Planetary Boundary Layer Phenomena.” *12th Conference on Artificial and Computational Intelligence and its Applications to the Environmental Sciences*, 2014.
- [11] Eric Frew. “Nomadic UAS Operation for Studying Severe Convective Storms.” *Drones and Aerial Robotics Conference*, NYC, New York, October 12, 2013.
- [12] Brian Argrow, Eric Frew, Adam Houston, Christopher Weiss, and Conrad Zeigler. “In Situ Sensing in Convective Storms and Air Masses with Small Unmanned Aircraft System.” 16th Aviation, Range, and Aerospace Meteorology (ARAM) Conference, 2012.
- [13] Jason Durrie\* and Eric W. Frew. “Coordinated Persistent Surveillance with Guaranteed Target Bounds.” *Robotics: Science and Systems 2011 Workshop on 3D Exploration, Mapping, and Surveillance with Aerial Robots*, Los Angeles, CA, July 1, 2011.
- [14] Maciej Stachura\* and Eric W. Frew. “Information Gathering With An Aerial Robotic Sensor Network in Realistic Communication Environments.” *First Southwest Workshop on Theory and Applications of Cyber-Physical Systems*, Tucson, AZ, March 10-11, 2011.
- [15] Jason Durrie\* and Eric W. Frew. “Mothership/Daughtership Architectures for Persistent Sensing and Surveillance Tasks.” *First Southwest Workshop on Theory and Applications of Cyber-Physical Systems*, Tucson, AZ, March 10-11, 2011 (poster).
- [16] Brian Argrow, Adam Houston, and Eric W. Frew, “VORTEX2 Unmanned Aircraft System (UAS).” *Hot Topics, AUVSI’s Unmanned Systems North America 2010*, Denver, CO, August 23, 2010.
- [17] Adam Houston, Brian Argrow, and Eric W. Frew. “Unmanned Aircraft in VORTEX2.” *25<sup>th</sup> Conference on Severe Local Storms*, Denver CO, Oct. 2010.
- [18] Adam Houston, Brian Argrow, and Eric W. Frew. “Observing Supercells with Unmanned Aircraft: Results from the UAS Component of VORTEX-2.” *American Geophysical Union Fall Meeting*, San Francisco CA, Dec. 2010.

## **DISSERTATION:**

**Trajectory Design for Target Motion Estimation Using Monocular Vision**

August 2003

*Advisor: Professor Stephen Rock*

*Reading Committee: Professor Robert Cannon, Professor Claire Tomlin*

## INVITED PRESENTATIONS:

- [1] Eric W. Frew, "Trajectory Design for Target Motion Estimation Using Monocular Vision." *Mechanical Engineering Seminar*, Case Western Reserve University, July 1, 2003.
- [2] Eric W. Frew, "Trajectory Design for Target Motion Estimation Using Monocular Vision." *Mechanical Engineering Seminar*, Yale University, July 8, 2003.
- [3] Eric W. Frew, "Self-directed Navigation of Small Unmanned Aircraft." *Aerospace Engineering Seminar*, University of Colorado at Boulder, March 29, 2004.
- [4] Eric W. Frew, "Self-directed Navigation of Small Unmanned Aircraft." *Aerospace Engineering Seminar*, Texas A&M University, April 15, 2004.
- [5] Eric W. Frew, "Stereo-Vision-Based Control of a Small Autonomous Aircraft Following a Road." *Second Annual Swarming Conference*, Crystal City, MD, June 2004.
- [6] Eric W. Frew, "Networked Communication, Command, and Control (C3) of a Team of Unmanned Aircraft." *Engineering Seminar*, Colorado School of Mines, Jan. 2005.
- [7] Eric W. Frew, "Networked Communication, Command, and Control (C3) of a Team of Unmanned Aircraft." *GNC Seminar*, Stanford University, Aug. 19, 2005.
- [8] Eric W. Frew, "Networked Communication, Command, and Control (C3) of a Team of Unmanned Aircraft." *System Engineering Seminar*, University of California, Berkeley, Aug. 20, 2005.
- [9] Eric W. Frew, "Networked Communication, Command, and Control (C3) of a Team of Unmanned Aircraft." United States Air Force Academy, Oct. 4, 2005.
- [10] Eric W. Frew, "Networked Communication, Command, and Control (C3) of a Team of Unmanned Aircraft." Cornell University, Aug. 16, 2006.
- [11] Eric W. Frew, "Networked Communication, Command, and Control (C3) of a Team of Unmanned Aircraft." Air Force Institute of Technology, Nov. 16, 2007.
- [12] Eric W. Frew, "Planning and Control of Unmanned Aircraft Systems in Realistic Communication Environments." *Electrical Engineering Department Seminar*, University of New Mexico, Nov. 14, 2008.
- [13] Eric W. Frew, "Planning and Control of Unmanned Aircraft Systems in Realistic Communication Environments." *Mechanical Engineering Department Seminar*, Tufts University, March 5, 2009.
- [14] Eric W. Frew, "Planning and Control of Unmanned Aircraft Systems in Realistic Communication Environments." MIT, March 6, 2009.
- [15] Eric W. Frew, "Control of Unmanned Aircraft Systems for Communication and Atmospheric Sensing Applications." Texas A&M University, Sept. 28, 2009.
- [16] Eric W. Frew, "Control of Unmanned Aircraft Systems for Communication and Atmospheric Sensing Applications." *Aeronautics and Astronautics Department Seminar*, Stanford University, February 3, 2010.
- [17] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." University of Maryland, October 8, 2010.
- [18] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." Rocky Mountain Chapter AUVSI, January 12, 2011.
- [19] Eric W. Frew, "Net-Centric Control of Unmanned Aircraft Systems for Communication and Sensing Applications." Northrop Grumman Electronic Systems, September 8, 2011.

- [20] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." Korea Advanced Institute of Science and Technology (KAIST), November 14, 2011.
- [21] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." Korea Aerospace Research Institute (KARI), November 15, 2011.
- [22] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." Korean Agency for Defense Development (ADD), November 15, 2011.
- [23] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." Seoul National University, November 17, 2011.
- [24] Eric W. Frew, "Net-Centric Control of Unmanned Aircraft Systems for Communication and Sensing Applications." The Australian Center for Field Robotics, University of Sydney, February 23, 2012.
- [25] Eric W. Frew, "Sampling Tornadoic Supercell Thunderstorms Using Unmanned Aircraft Systems." RMIT University, Melbourne, Australia, March 30, 2012.
- [26] Eric W. Frew, "Net-Centric Control of Unmanned Aircraft Systems for Communication and Sensing Applications." Control Science Center of Excellence, Air Force Research Laboratory, July 24, 2012.
- [27] Eric W. Frew, "Exploiting Controlled Mobility for Airborne Communication and Surveillance Networks." Chief of Naval Operations Strategic Studies Group, Boulder, CO, November 7, 2012.
- [28] Eric W. Frew, "Unmanned Aircraft Systems for Atmospheric Science Applications." CU-Boulder Denver Alumni Association, Saturday, August 14, 2013.
- [29] Eric W. Frew, "Unmanned Aircraft Systems for Atmospheric Science Applications." CU-Boulder Alumni Association Directors Club Winter Meeting, Saturday, January 25, 2014.
- [30] Eric W. Frew, "Unmanned Aircraft Systems for Communication and Atmospheric Sensing Missions." University of Colorado, Colorado Springs, April 2014.
- [31] Eric W. Frew, "Net-Centric Control of Unmanned Aircraft Systems for Communication and Sensing Applications." Georgia Institute of Technology, May 9, 2014.
- [32] Eric W. Frew, "Net-Centric Control of Unmanned Aircraft Systems for Communication and Sensing Applications." University of Minnesota, May 10, 2014.
- [33] Eric W. Frew, "UAS in Academia." Panel, Civil Applications of UAS, AUVSI North America Meeting, May 13, 2014.
- [34] Eric W. Frew, "Unmanned Aircraft Systems for Communication and Atmospheric Sensing Missions." University of Nebraska – Lincoln, June 25, 2014.
- [35] Eric W. Frew, "In-Situ Meteorological Measurements Using Small Unmanned Aircraft Systems." 3D Robotics, Berkeley, CA, March 2, 2015.
- [36] Eric W. Frew, "Energy-Aware Airborne Dynamics Data-Driven Application System for Persistent Sensing." NASA Ames Research Center, March 18, 2015.
- [37] Eric Frew, "Net-Centric Control of Unmanned Aircraft Systems for Communication and Sensing Applications." United Technology Research Center, Hartford, CT, May 5, 2015.
- [38] Eric Frew, "Unmanned Systems Research at the University of Colorado: Mobile Sensing Systems to Observe the World in 4-D." Jet Propulsion Laboratory, Pasadena, CA, July 27, 2015.

- [39] Eric W. Frew, “Energy-Aware Unmanned Aircraft Systems: Enabling Persistent Atmospheric Sampling.” University of Washington, November 16, 2015.
- [40] Eric Frew, “Unmanned Aircraft Systems (Drones) at the University of Colorado Boulder.” Boulder County Parks and Open Space Public Open House, Longmont, CO, Jan. 13, 2016.
- [41] Invited Speaker, Army Science Planning and Strategy Meeting: Distributed and Collaborative Intelligent Systems, December 3-4, 2015.

## **SCIENTIFIC AND PROFESSIONAL SOCIETIES**

- Associate Fellow, American Institute of Aeronautics and Astronautics (AIAA)
- Institute of Electrical and Electronic Engineers (IEEE)

## **INSTITUTIONAL AND PROFESSIONAL SERVICE**

### **A. Professional**

- Associate Editor, AIAA Journal of Aerospace Information Systems, January 1, 2017 – present.
- Member, Board of Directors, The Centre for Aerial Robotics Research and Education (CARRE), University of Toronto Institute for Aerospace Studies, 2016-present.
- Invited Participant, NSF DHS Policy for Autonomy Workshop, January 7-8, 2016.
- Workshop Chair, 2016 American Control Conference Operating Committee.
- Member, Research Council, Rocky Mountain UAS, 2013 – 2016.
- Member, National Research Council Committee on Autonomy Research for Civil Aviation, 2013-2014.
- Registration Chair, 2013 American Control Conference Operating Committee.
- Education Co-Chair, AIAA Guidance, Navigation, and Control Technical Committee, Aug. 2010-2012.
- Member, AIAA Guidance, Navigation, and Control Technical Committee, Aug. 2008-2012.
- Member, International Program Committee, 2009 IFAC Workshop on Networked Robotics, October 6-8, 2009.
- Member, Program Committee, 2009 International Workshop on Robotic Wireless Sensor Networks, June 10, 2009.
- Member, Organizing Committee, 2nd International Symposium on Unmanned Aerial Vehicles, June 8-10, 2009.

### **B. Institutional**

- Director, Autonomous Systems Interdisciplinary Research Theme, 2018-present
- Member, CU Unmanned Aircraft System Committee, 2016-present
- Associate Director, Integrated Remote and In Situ Sensing (IRISS) Initiative, 2015 - present
- Faculty Research Council, College of Engineering, 2013-2015
- Director, Research and Engineering Center for Unmanned Aircraft, 2012 - 2017

### **C. Department**

- AES Building Committee, Department of Aerospace Engineering Sciences, 2016-present.
- Executive Committee, Department of Aerospace Engineering Sciences, 2013-present.
- Chair, AES Distinguished Lecture & Visiting Faculty Selection Committee. 2013-2015.
- Vehicle Systems Focus Area lead, AES Department, 2008 – 2010.
- Member, Graduate Committee, Aerospace Engineering Sciences Department, 2005-2010.
- Dynamics and Control Lead, Curriculum and Teaching Committee, AES Department, 2005-2008.
- AES Department Program Lead, CU High School Summer Honors Institute, 2006-2008.

## **FUNDED PROJECTS** (\$10.9 M as PI; \$16.6 M in total external awards with \$11.4 M as Frew's share)

### ***A. In Progress, Externally Funded***

Targeted observation and seeding using autonomous unmanned aircraft systems

Source of Support: UAE Rain Enhancement Program; **Eric W. Frew**

Total Award Amount and Period Covered: \$1,500,000; 3/1/18 - 2/28/21

CUAS User-Adaptive Assurances for Enhancing Trust

Source of Support: Center for UAS; Nisar Ahmed (PI), **Eric Frew**, Dale Lawrence, and Brian Argrow

Total Award Amount and Period Covered: \$60,000; /1/17 - 8/31/18

Frew's Share: \$15,000 (25%)

CUAS Robust Communication Services in Complex Environments

Source of Support: Center for Unmanned Aircraft Systems; **Eric W. Frew**

Total Award Amount and Period Covered: \$70,000; 9/1/17 - 8/31/18

CUAS Robust Fault Detection and Mitigation for Small UAS

Source of Support: Center for Unmanned Aircraft Systems; Dale Lawrence (PI), Nisar Ahmed, and **Eric W. Frew**

Total Award Amount and Period Covered: \$75,000; 9/1/17 - 8/31/18

Frew's Share: \$25,000 (33%)

CUAS Verification and Validation of Autonomous Systems: Systematic Quantification of Failure Risks

Source of Support: Center for Unmanned Aircraft Systems; Sriram Sankaranarayanan (PI) and **Eric W. Frew**

Total Award Amount and Period Covered: \$80,000; 9/1/17 - 8/31/18

Frew's Share: \$40,000 (50%)

CUAS Multiple Aircraft Sensing System

Source of Support: Center for Unmanned Aircraft Systems; **Eric W. Frew (PI)** and Nisar Ahmed

Total Award Amount and Period Covered: \$96,000; 9/1/17 - 8/31/18

I/UCRC Phase 2: Center for Unmanned Aircraft Systems: I/UCRC for Unmanned Aircraft Systems

Source of Support: NSF I/UCRC (CISE Directorate); **Eric W. Frew (PI)**, Brian Argrow, Dale Lawrence, and Nisar Ahmed

Total Award Amount and Period Covered: \$500,000; 3/1/2017 - 2/28/2022

Improving Variable Rate Irrigation Efficiency using a Real-time Soil Moisture Adaptive Control Model Informed by Sensors Deployed on Unmanned Aircraft Systems

Source of Support: USDA AFRI; **Eric W. Frew**

Collaborators: Chris Neale (UNL), Wayne Woldt (UNL), + others. Total project = \$500K.

Total Award Amount and Period Covered: \$66,345; 5/01/2017 - 4/31/2020

Convection Initiation Measurements at Oklahoma Mesonet Sites

Source of Support: NOAA OAR; Brian Argrow (PI) and **Eric W. Frew**

Total Award Amount and Period Covered: \$245,084; 10/01/2016 - 9/30/2018

Frew's Share: \$122,542 (50%)

Coordinated Persistent Airborne Information Gathering: Cloud Robotics in the Clouds

Source of Support: AFOSR Dynamic Data Driven Application Systems; **Eric W. Frew (PI)** and Brian Argrow

Total Award Amount and Period Covered: \$711,856; 9/01/2016 - 8/31/2020

NRI: Collaborative Research: Targeted Observation of Severe Local Storms Using Aerial Robots

Source of Support: NSF National Robotics Initiative; **Eric W. Frew (PI)** and Brian Argrow

Collaborators: Adam Houston (UNL), Chris Weiss (TTU), Volkan Isler (UMN), and Dezhen Song (TAMU)

Total Award Amount and Period Covered: \$653,000 (Total Award = \$1,900,000); 1/1/16 - 12/31/18



***B. In Progress, Internally Funded***

Integrated Remote and In Situ Sensing Initiative (IRISS) – Base Funding

Source of Support: University of Colorado; Brian Argrow (Director) and **Eric W. Frew**

Total Award Amount and Period Covered: \$3,240,457; 1/1/16-8/31/19

Frew's Share: \$1,620,229 (50%)

Project Forest

Source of Support: IRISS; **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$229,591; 1/1/16-8/31/18

Project Autonomy

Source of Support: IRISS; **Eric W. Frew (PI)** and Jill Dupre

Total Award Amount and Period Covered: \$84,648; 9/1/16-8/31/18

***C. Completed (non CUAS)***

Persistent Information-Gathering with Airborne Surveillance and Communication Networks in Fading Environments

Source of Support: Korean Agency for Defense Development (ADD); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$200,699; 9/01/2014 - 8/31/2017

CU Boulder Summer of Innovation

Source of Support: AFRL Summer of Innovation; S. Sankaranarayanan (PI), D. Grunwald, C. Heckman, and **Eric W. Frew**

Total Award Amount and Period Covered: \$90,175; 5/8/17 – 8/30/17

Frew's Share: \$22,544 (25%)

Efficient Reconfigurable Cockpit Design and Fleet Operations using Software Intensive, Networked and Wireless Enabled Architecture (ECON)

Source of Support: NASA LEARN; **Eric W. Frew (PI)**; Collaboration with Parimal Kopardekar (NASA ARC) et. al.

Total Award Amount and Period Covered: \$29,500; 6/1/15 - 2/29/16

NOAMAD

Source of Support: Aurora Flight Sciences (NASA SBIR); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$134,000; 4/1/2016 - 3/31/2017

Collaborative Research: RAPID: Integration of Unmanned Aircraft System (UAS) into the Program for Research on Elevated Convection with Intense Precipitation

Source of Support: NSF PDM Rapid; **Eric W. Frew (PI)**; Collaboration with Adam Houston at UNL

Total Award Amount and Period Covered: \$54,555; 6/1/15 - 5/31/16

Solar UAS Assessment

Source of Support: Sunlight Photonics; **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$19,592; 3/5/15 - 11/31/15

Energy-Aware Aerial Systems for Persistent Sampling and Surveillance

Source of Support: AFOSR Dynamic Data-Driven Application Systems; **Eric W. Frew (PI)** and Brian Argrow

Total Award Amount and Period Covered: \$1,512,757; 9/1/12 - 8/31/15

RI: Small: Providing Quality of Information in Robot Sensor Networks

Source of Support: NSF Robust Intelligence (CISE Directorate); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$500,000; 8/1/2011 - 7/31/2015

CAREER: Mothership/Daughtership Architectures for In Situ Science by Robotic Sensor Networks

Source of Support: NSF CAREER (CISE Directorate); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$571,495 (\$498,589 from NSF and \$60,000 matching from CU; \$7,906 through REU supplement; \$5,000 through Hazards on Hill supplement); 5/1/09-4/30/14

RAPID: Multi-sUAS Evaluation of Techniques for Measurement of Atmospheric Properties (MET MAP)

Source of Support: NSF PDM; Brian Argrow (PI) and Eric Frew

Total Award Amount and Period Covered: \$18,519; 8/01/2014 - 12/31/2014

Observations of Wind Turbine Wakes Using Unmanned Aircraft Systems

Source of Support: CIRES IRP; John Cassano (PI), Julie Lundquist, Brian Argrow, Katja Friedrich, and Eric Frew

Total Award Amount and Period Covered: \$24,768; 7/1/13 - 6/30/14

Frew's Share: \$4,954 (20%)

Indoor Flying Robot Lab

Source of Support: CU Engineering Excellence Fund; **Eric W. Frew (PI)**, James Mack, Nikolaus Correll, Trudy Schwartz

Total Award Amount and Period Covered: \$52,623; 7/1/13 - 6/30/14

Exploiting Controlled Mobility in Aerial Communication and Surveillance Networks

Source of Support: DARPA Computer Science Study Group Phase 2; **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$400,000; 4/1/11 - 8/30/13

Investigations of Spatial and Temporal Variability of Ocean and Ice Conditions In and Near the Marginal Ice Zone (MIZOPEX)

Source of Support: NASA: ROSES 2010: Airborne Science: UAS Enabled Earth Science; Jim Maslanik (PI) + others

Total Award Amount and Period Covered: \$3,494,784; 8/1/2011 - 7/31/2013

Frew's Share: \$37,609 (1%)

GAANN Fellowships in Aerospace Systems

Source of Support: DOE Graduate Assistance in Areas of National Need (GAANN) Program; George Born (PI) + 11

Total Award Amount and Period Covered: \$510,000; 8/15/2009 - 8/14/2012

Frew's Share: \$42,500 (8.33%)

RI: Information-theoretic Control of Robotic Sensor Networks

Source of Support: NSF Robust Intelligence (CISE Directorate); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$280,361 (\$11,875 through REU supplement); 9/1/07 – 8/31/11

Forge FCMS

Source of Support: Forge Aeronautics; Brian Argrow (PI) and Eric W. Frew

Total Award Amount and Period Covered: \$9,600; 9/1/10 – 4/1/11

SQUAD: Smart Quad-Rotor Unmanned Autonomous Demonstrator

Source of Support: CU Engineering Excellence Fund (EEF); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$8,000; 5/1/10 – 4/31/11

Control of Self-Deploying Robotic Systems

Source of Support: DARPA Computer Science Study Group; **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$100,000; 4/1/10 - 3/31/11

Supplement to a Pilot Program for the Use of UAS in VORTEX2

Source of Support: Merage Foundation; Brian Argrow (PI) and Eric W. Frew

Total Award Amount and Period Covered: \$38,319; 1/1/2010 – 08/31/2010

Frew's Share: \$19,160 (50%)

Collaborative Research: Development of Unmanned Aircraft System for Research in a Severe Storm Environment and Deployment within the VORTEX 2

Source of Support: NSF Atmospheric Sciences (GEO Directorate); Brian Argrow (PI) and Eric W. Frew

Total Award Amount and Period Covered: \$289,566; 10/1/2008 – 09/31/2010

Frew's Share: \$144,783 (50%)

The Sky's the Limit: An Unmanned Aircraft Lab Module (Chancellor's Faculty Award for Excellence in STEM Education)

Source of Support: CU Innovation through Institutional Integration (I3); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$9,600, 7/1/07 – 5/31/10

Unmanned Aerial Vehicle Ground Operations Positioning System

Source of Support: Phase I/II Air Force SBIR with Mosaic ATM; **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$228,000 (out of \$750,000 total); 6/1/06 – 5/31/09

An Integrated Framework for Controlled Mobility in Ad Hoc Networks

Source of Support: AFOSR – Software and System Program; **Eric W. Frew (PI)** and Tim Brown

Total Award Amount and Period Covered: \$450,000; 02/01/06 – 05/31/09

Networked System Test Bed Integration and Test Phase 1

Source of Support: L3 Comcept / USAF; Tim Brown (PI), Brian Argrow, and Eric W. Frew

Total Award Amount and Period Covered: \$343,462; 10/01/07 – 03/27/09

Frew's Share: \$114,476 (33.33%)

Remote Management of a Heterogeneous UAV Team

Source of Support: Raytheon IIS; **Eric W. Frew (PI)**, Brian Argrow, and Dale Lawrence

Total Award Amount and Period Covered: \$135,000; 7/1/06 – 10/31/07

UAV Sensor Data Collection

Source of Support: L3 Comcept / USAF; Tim Brown (PI), Brian Argrow, and Eric W. Frew

Total Award Amount and Period Covered: \$367,000; 09/22/05 – 09/30/07

Frew's Share: \$122,321 (33.33%)

Collaborative Tracking of Moving Targets by Teams of Autonomous Unmanned Air Vehicles

Source of Support: Phase I AFOSR STTR with MLB Company; **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$50,000; 11/1/04 – 7/30/05

**D. Completed – Center for Unmanned Aircraft Systems**

CU16-04 User-Adaptive Assurances for Enhancing Trust

Source of Support: Center for UAS; **Eric W. Frew (PI)**, Nisar Ahmed, Dale Lawrence, and Brian Argrow

Total Award Amount and Period Covered: \$40,000; 9/1/16 - 8/31/17

CU16-12 Scalable Cooperative Tracking of Moving RF Ground Targets

Source of Support: Center for Unmanned Aircraft Systems; Nisar Ahmed (PI) and Eric W. Frew,

Total Award Amount and Period Covered: \$40,000; 9/1/16 - 8/31/17

Frew's Share: \$20,000 (50%)

CU16-06 Robust Communication Services in Complex Environments

Source of Support: Center for Unmanned Aircraft Systems; Eric W. Frew,

Total Award Amount and Period Covered: \$60,000; 9/1/16 - 8/31/17

I/UCRC Phase 1: Center for Unmanned Aircraft Systems: I/UCRC for Unmanned Aircraft Systems

Source of Support: NSF I/UCRC (CISE Directorate); **Eric W. Frew (PI)**, Brian Argrow, Dale Lawrence, and Tim Brown

Total Award Amount and Period Covered: \$275,000; 2/1/2012 - 1/31/2017

Collaborative Research: IUCRC: FRP: Network Enabled Airborne Autonomy

Source of Support: NSF IUCRC Fundamental Research Program; **Eric W. Frew (PI)** and Nisar Ahmed

Collaborators: Tim McLain and Randy Beard (BYU)

Total Award Amount and Period Covered: \$120,000 (Total Award = \$200,000); 1/1/16 - 12/31/16

I/UCRC Phase 1: Center for Unmanned Aircraft Systems: REU Supplement

Source of Support: NSF I/UCRC (CISE Directorate); **Eric W. Frew (PI)**

Total Award Amount and Period Covered: \$15,500

CU15-04 User-Adaptive Assurances for Enhancing Trust

Source of Support: Center for UAS; **Eric W. Frew (PI)**, Nisar Ahmed, Dale Lawrence, and Brian Argrow

Total Award Amount and Period Covered: \$60,000; 9/1/15 - 8/31/16

CU15-12 Scalable Cooperative Tracking of Moving RF Ground Targets

Source of Support: Center for Unmanned Aircraft Systems; Nisar Ahmed (PI) and Eric W. Frew,  
Total Award Amount and Period Covered: \$80,000; 9/1/15 - 8/31/16

CU14-06 Guidance and Control for a UAS Providing Communication Services

Source of Support: Center for Unmanned Aircraft Systems; **Eric W. Frew (PI)**, Tim Brown, and Jason Marden  
Total Award Amount and Period Covered: \$131,000; 9/1/14 - 8/31/15

CU14-01 Information and Distributed Optimization

Source of Support: Center for Unmanned Aircraft Systems; Jason Marden (PI) and Eric W. Frew,  
Total Award Amount and Period Covered: \$60,000; 9/1/14 - 8/31/15

CU14-04 Assured Autonomy Technology

Source of Support: Center for Unmanned Aircraft Systems; **Eric W. Frew (PI)**, Brian Argrow and Dale Lawrence  
Total Award Amount and Period Covered: \$50,000; 9/1/14 - 8/31/15

I/UCRC Phase 1: Center for Unmanned Aircraft Systems: REU and VRS Supplements

Source of Support: NSF I/UCRC (CISE Directorate); **Eric W. Frew (PI)**  
Total Award Amount and Period Covered: \$25,500

CU13-06A Guidance and Control for a UAS Providing Communication Services

Source of Support: Center for Unmanned Aircraft Systems; **Eric W. Frew (PI)**, Tim Brown, and Jason Marden  
Total Award Amount and Period Covered: \$80,000; 9/1/13 - 8/31/14

CU12-06A Guidance and Control for a UAS Providing Communication Services

Source of Support: Center for Unmanned Aircraft Systems; **Eric W. Frew (PI)**, Tim Brown  
Total Award Amount and Period Covered: \$50,805; 7/1/12 - 6/31/13

CU12-06B Guidance and Control for a UAS Providing Communication Services

Source of Support: Center for Unmanned Aircraft Systems; Tim Brown (PI), Eric Frew  
Total Award Amount and Period Covered: \$40,000; 7/1/12 - 6/31/13  
Frew's Share: \$20,000 (50%)

Collaborative Research: Planning Grant: I/UCRC for Unmanned Aircraft Systems

Source of Support: NSF I/UCRC (CISE Directorate); Brian Argrow (PI), Eric W. Frew, Dale Lawrence, and Tim Brown  
Total Award Amount and Period Covered: \$10,000; 2/15/10 - 8/31/11  
Frew's Share: \$2,500 (25%)