

At the Water's Edge: Installation and Optimization of Robotic Sensing Systems

National Institute of Food and Agriculture Grant #2017-67021-25924

Presenter: Justin Bradley

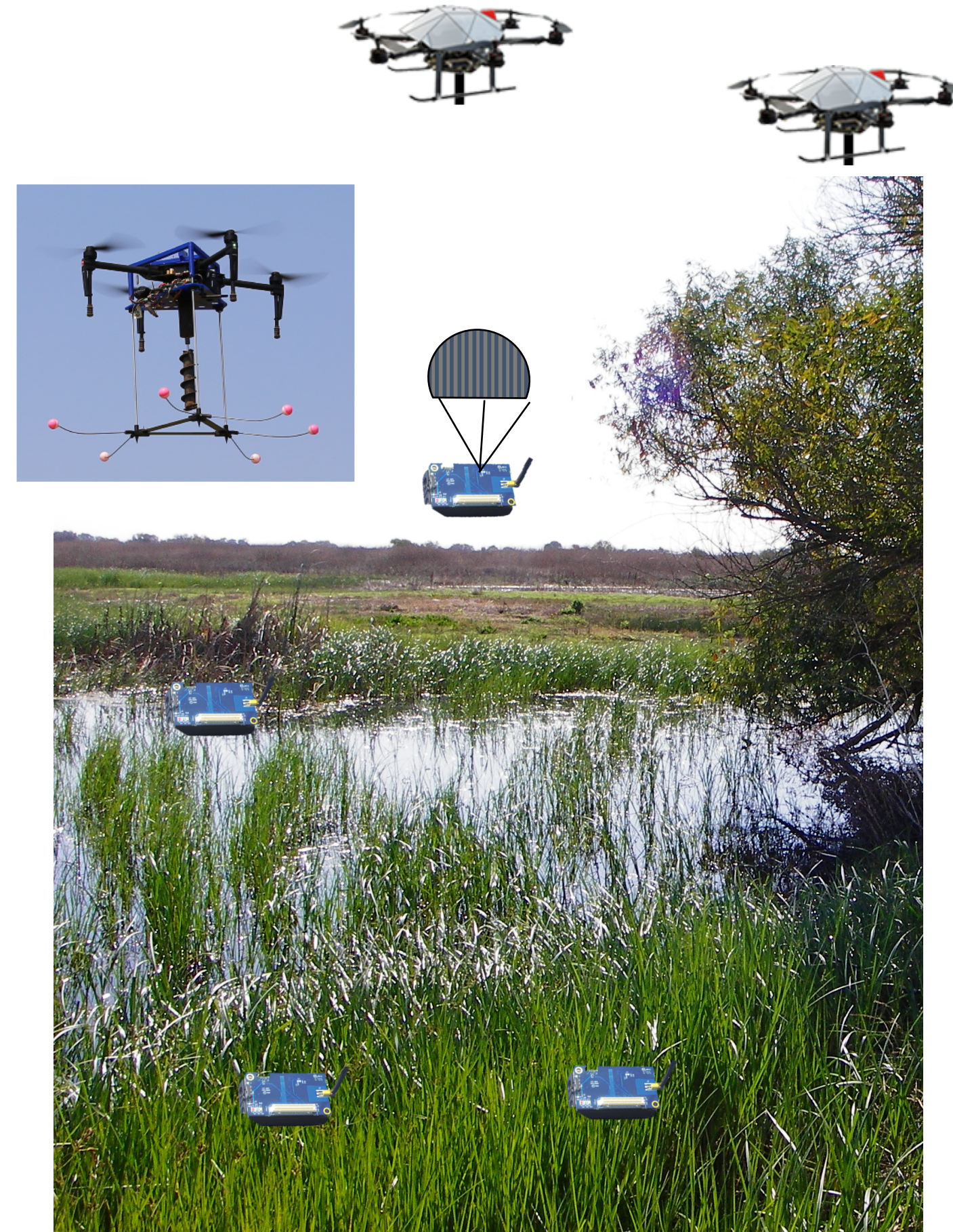
University of Nebraska-Lincoln PIs: Carrick Detweiler, Justin Bradley

University of the Pacific PIs: Elizabeth Basha, Mary Kay Camarillo, William Stringfellow

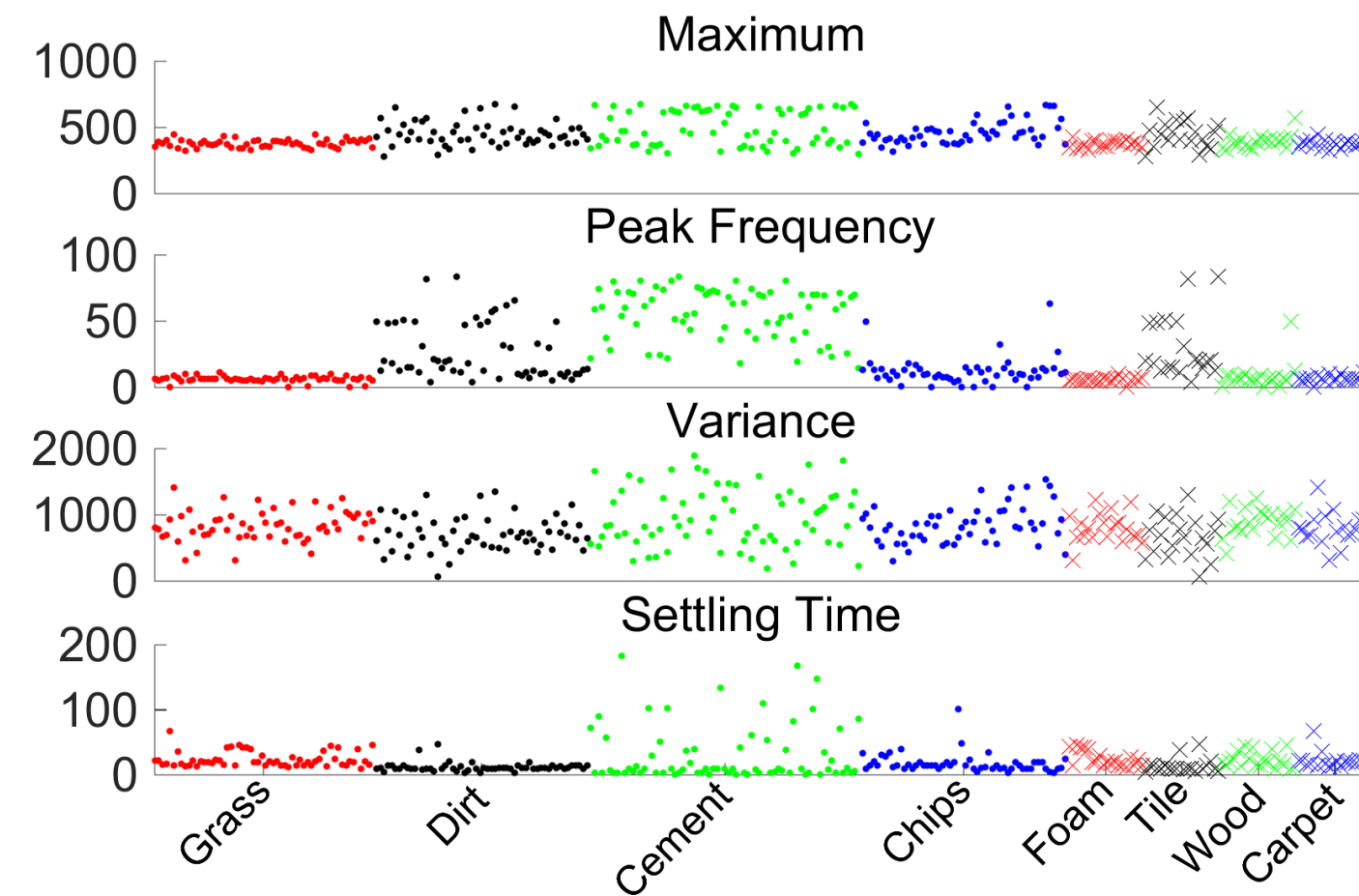
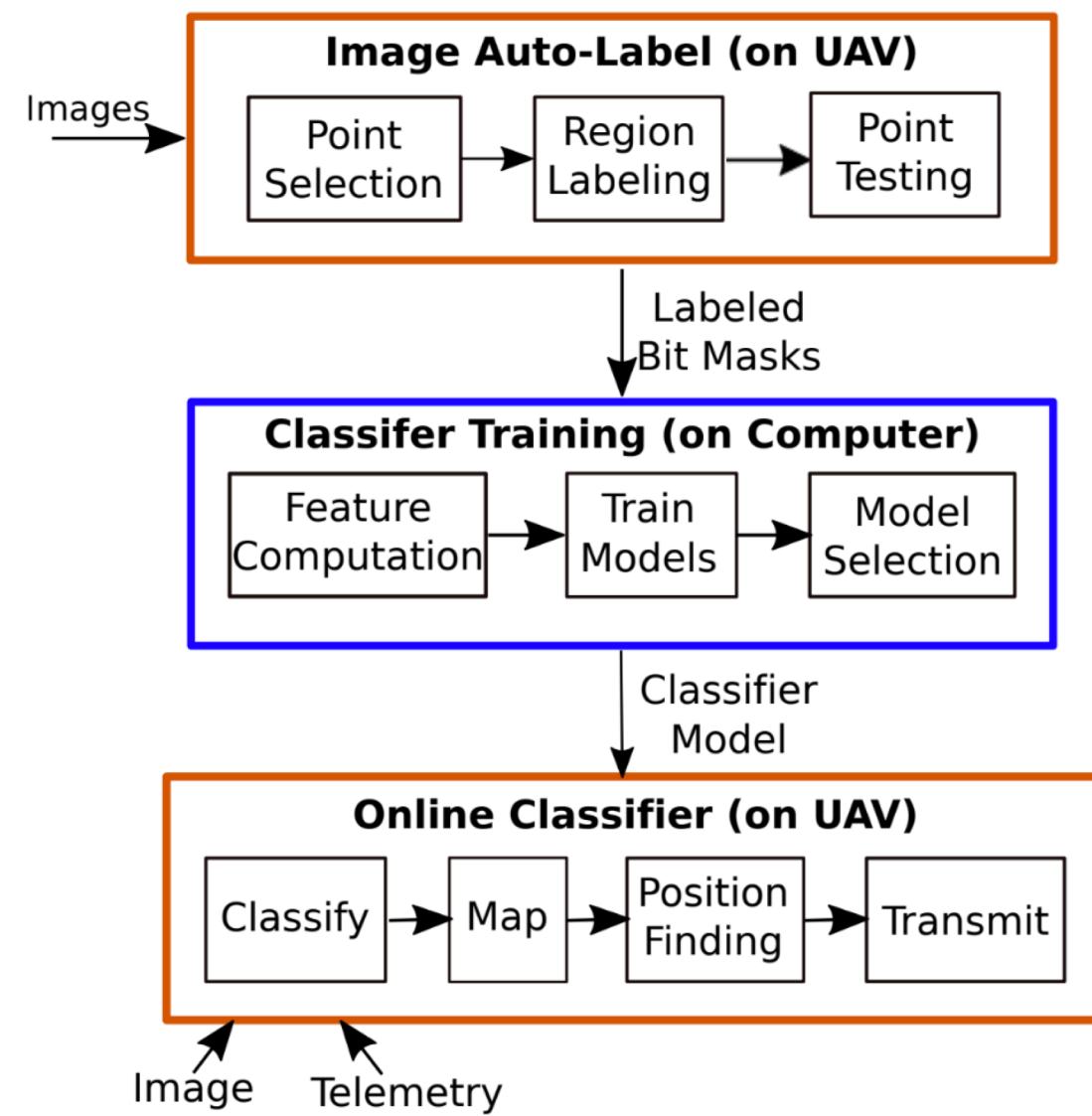
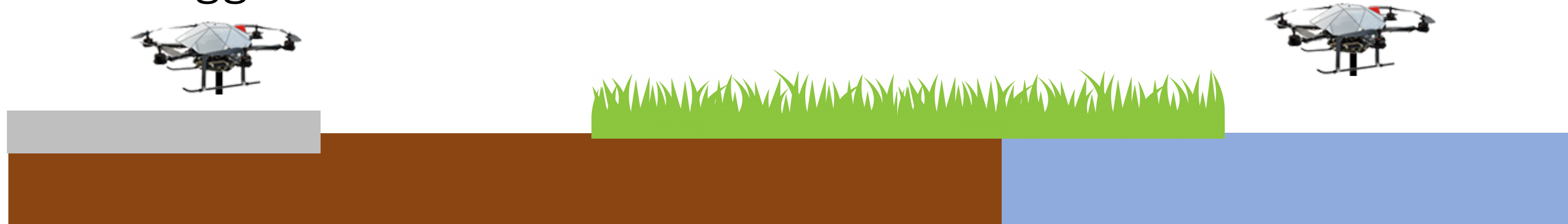


Goals and Objectives

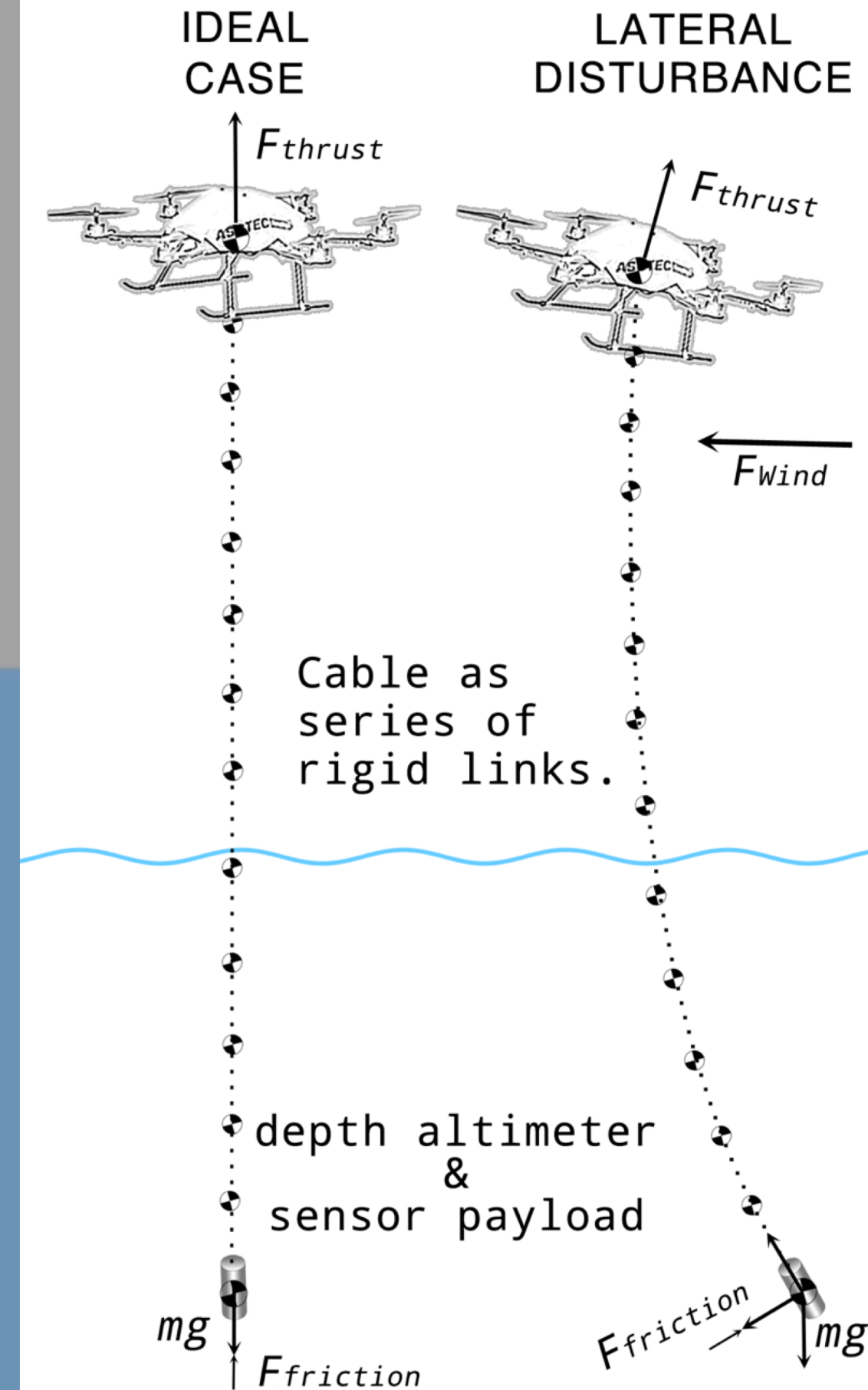
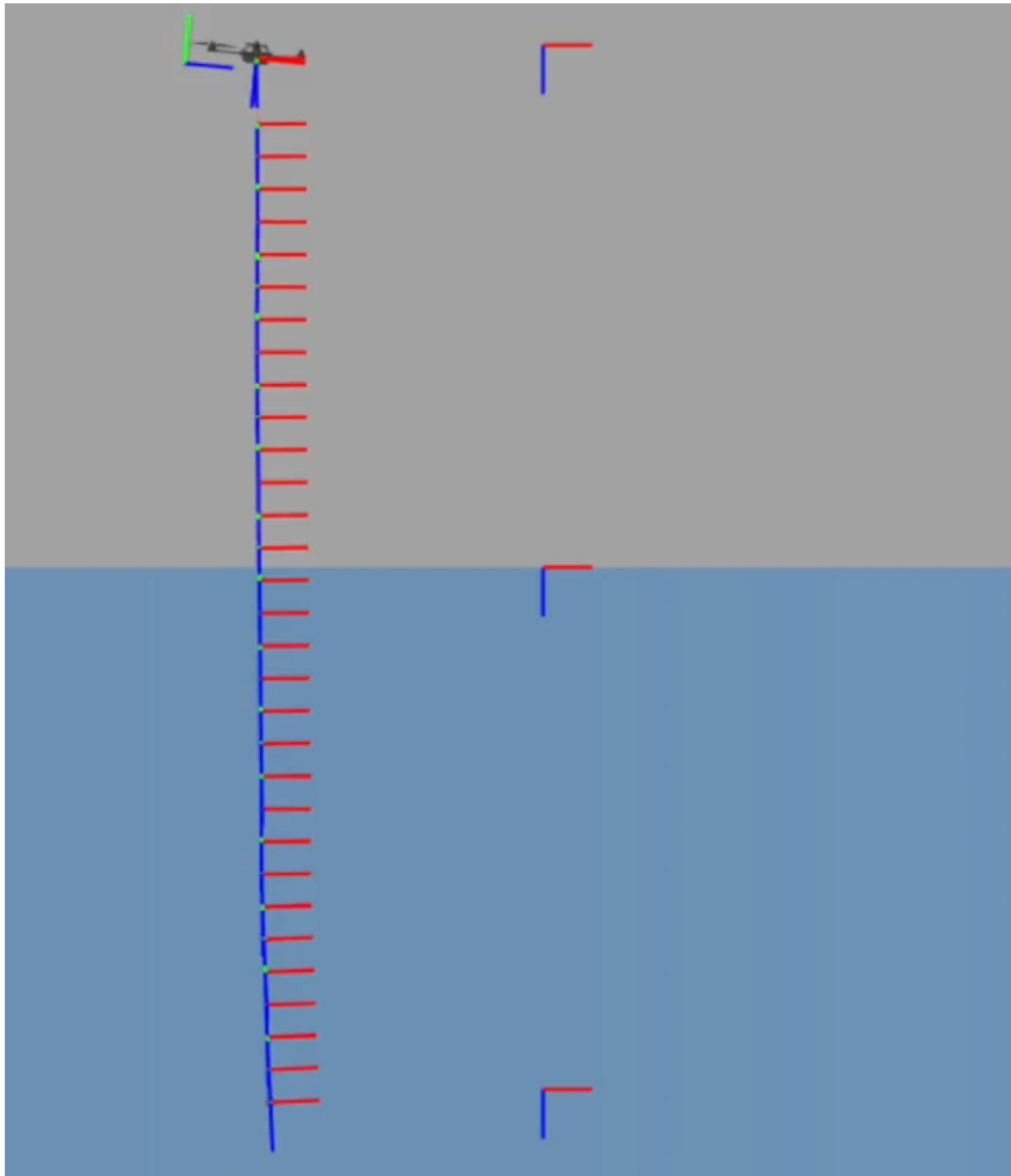
- Design and implement UAV-based systems that measure wetlands channels
- Develop algorithms and approaches to ensure sensing repeatability independent of environmental conditions.
- Develop UAV-based sensor emplacement and deployments, including verification of sensor node installation.
- Develop multi-agent controllers that maximize science data collection while balancing resources over multiple flights.
- **Will be starting year 3 in Nov**



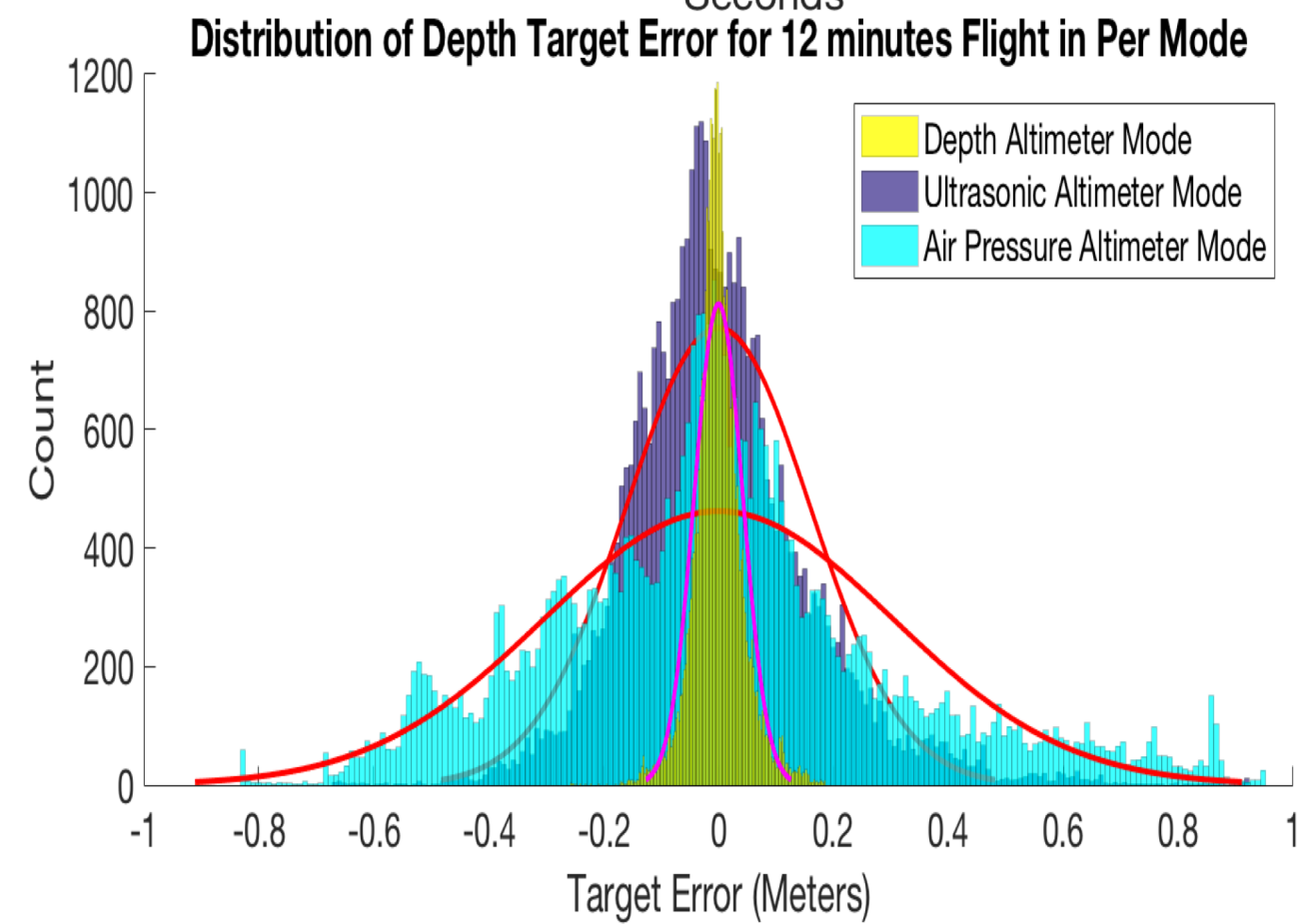
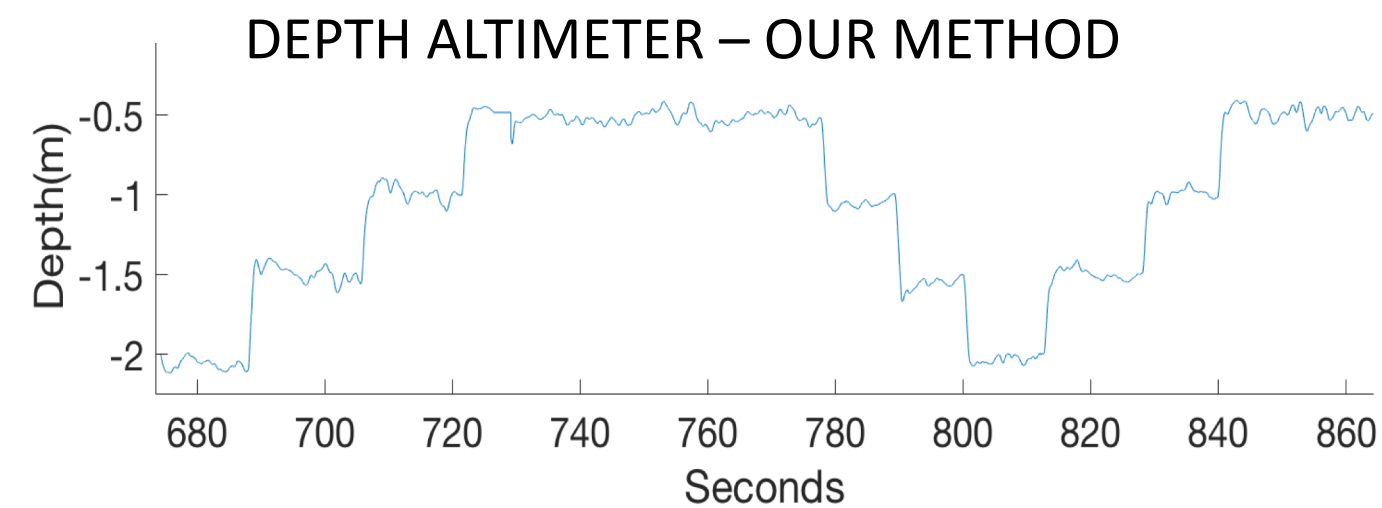
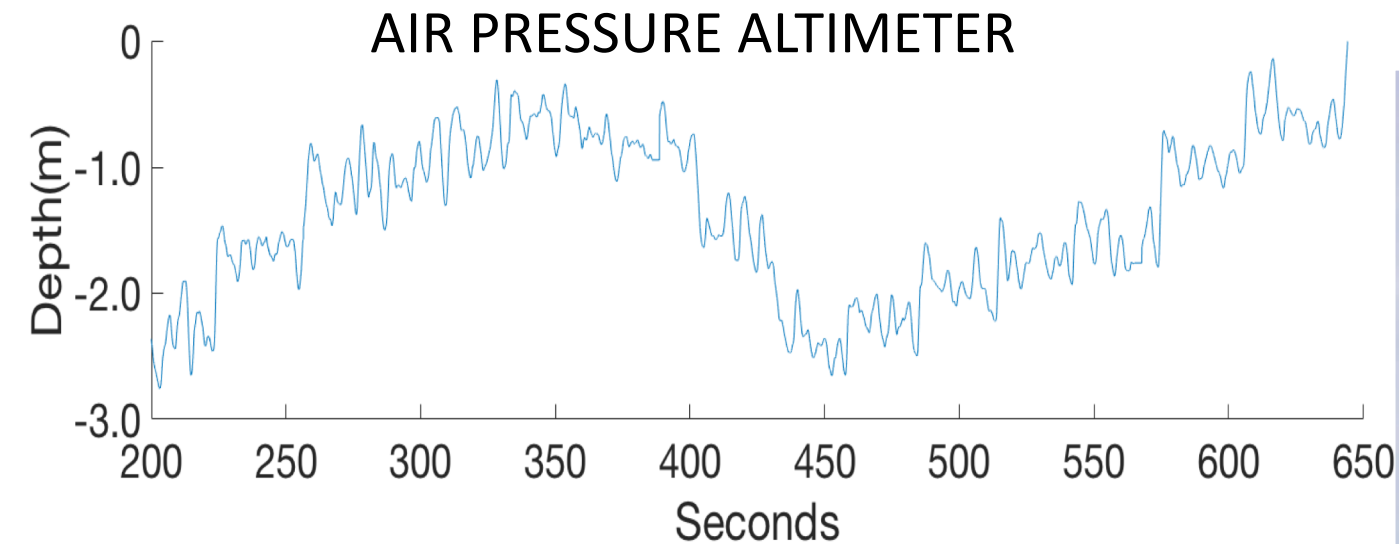
Technical Nugget #1: Surface detection and classification



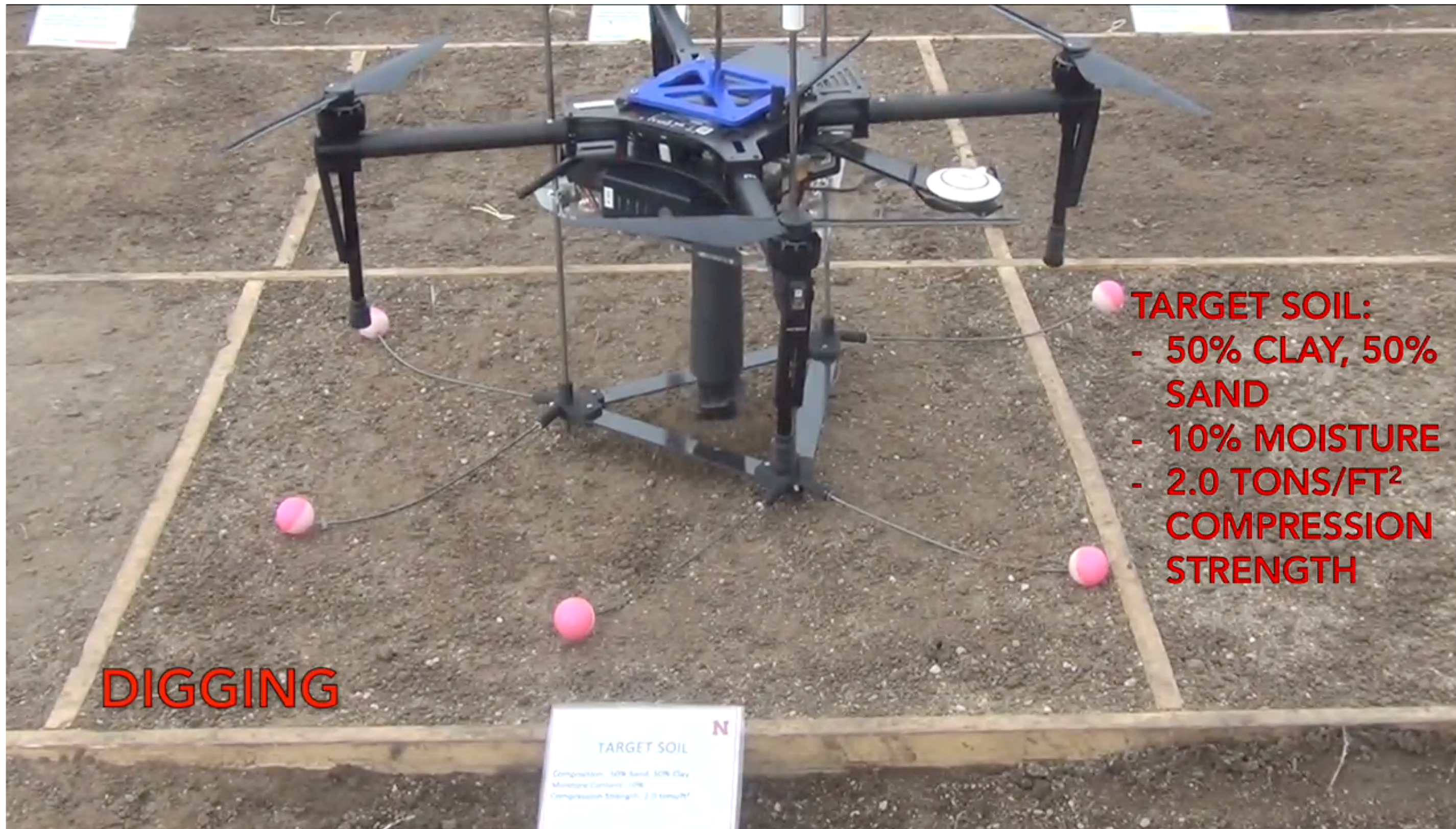
Technical Nugget #2: Sub-surface sampling



Technical Nugget #2: Sub-surface sampling



Technical Nugget #3: UAV sensor emplacement platform



Technical Nugget #4: Co-regulated information consensus for multi-agent systems

- Start with information consensus
 - easy to apply feedback-style control
- Discrete information consensus

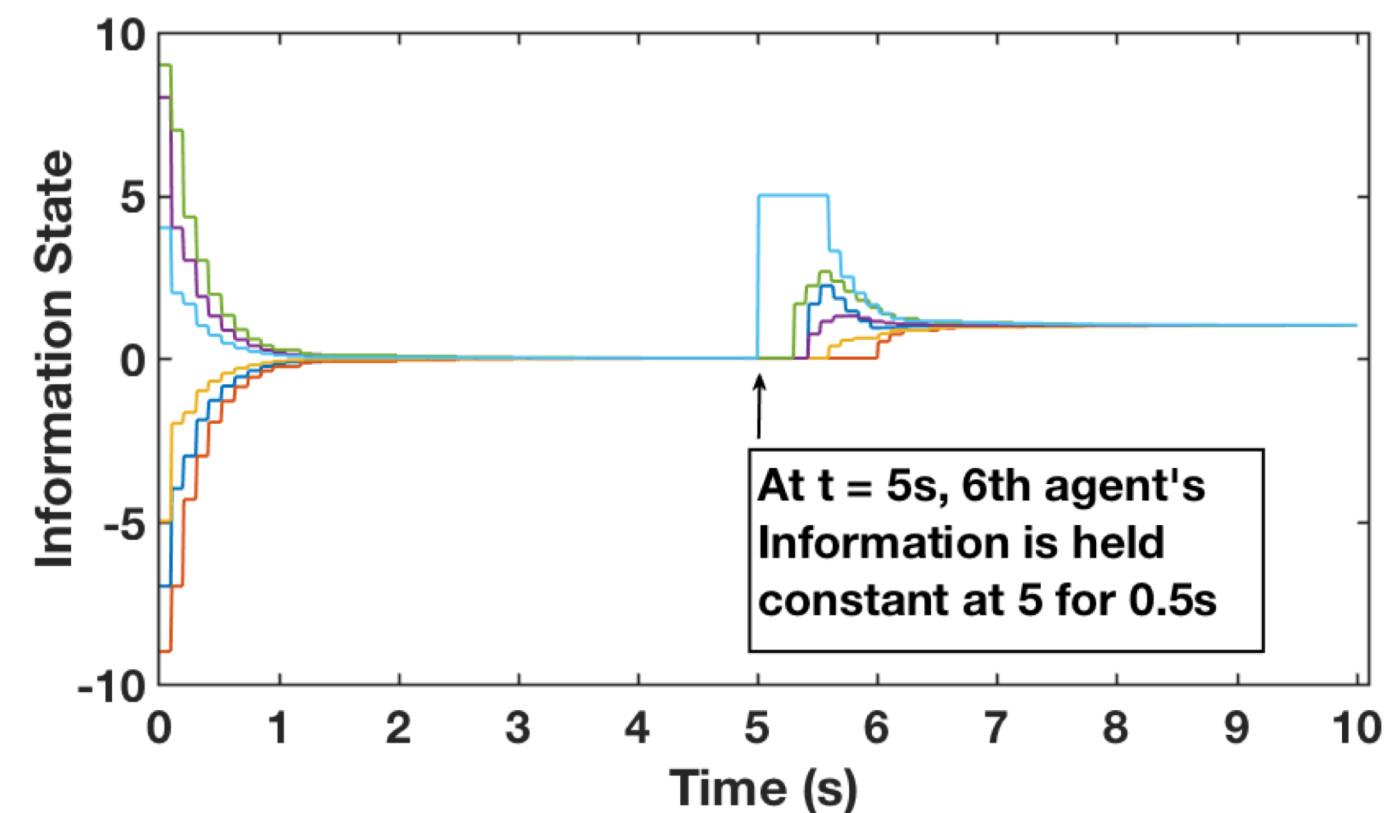
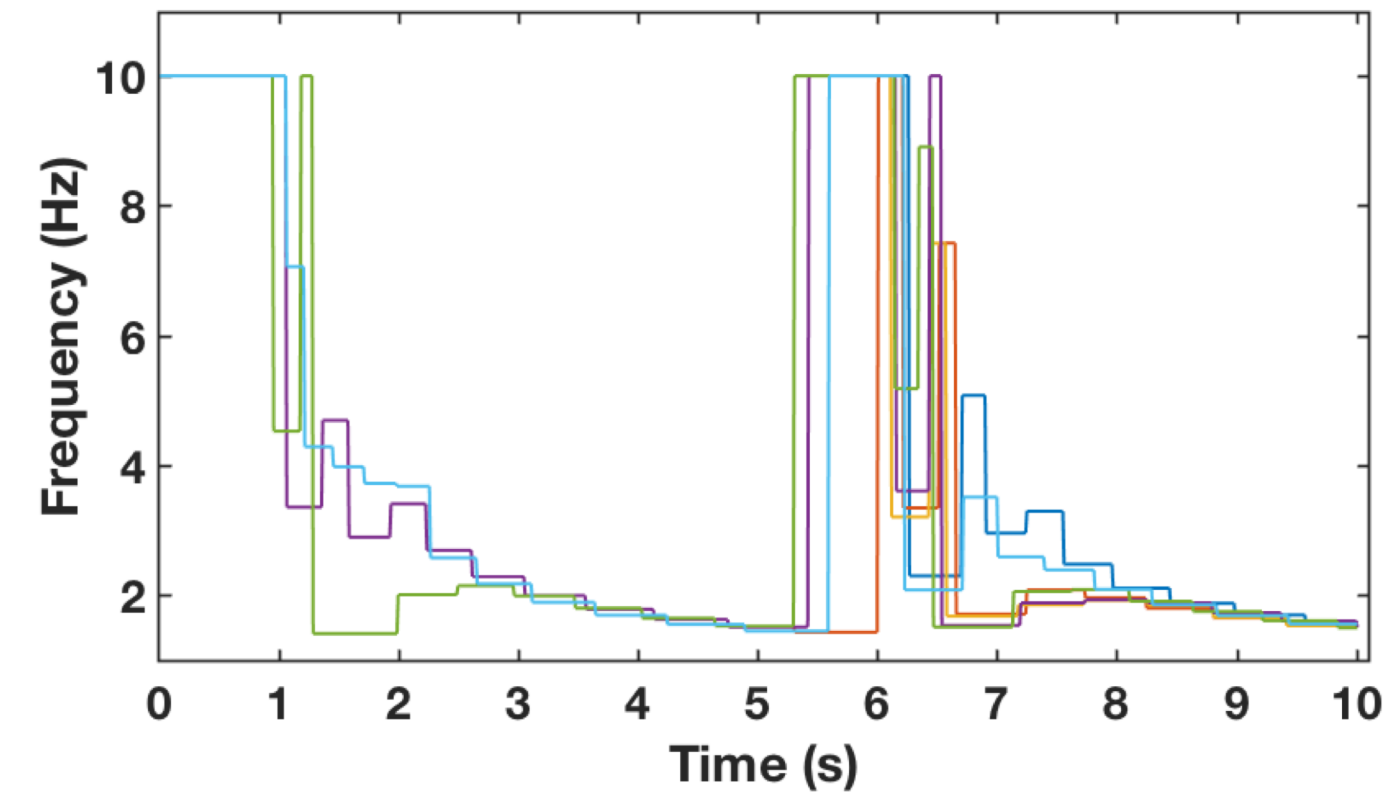
$$x_i^I[k+1] = \frac{1}{\sum |M_i|} \sum_{j \in M_i} x_j^I[k]$$

- Communication period evolves as

$$T_i[k+1] = T_i[k] + x_i^F[k] u_i^F[k]$$

- Proposed controller

$$u_i^F[k] = - \underbrace{\alpha_1^F \sum_{j \in M_i} |x_i^I[k] - x_j^I[k]|}_{\text{Pushes comm rate toward } x_{i,\max}^F} + \underbrace{\alpha_2^F |x_i^F[k] - x_{i,\min}^F|}_{\text{Pushes comm rate toward } x_{i,\min}^F}$$

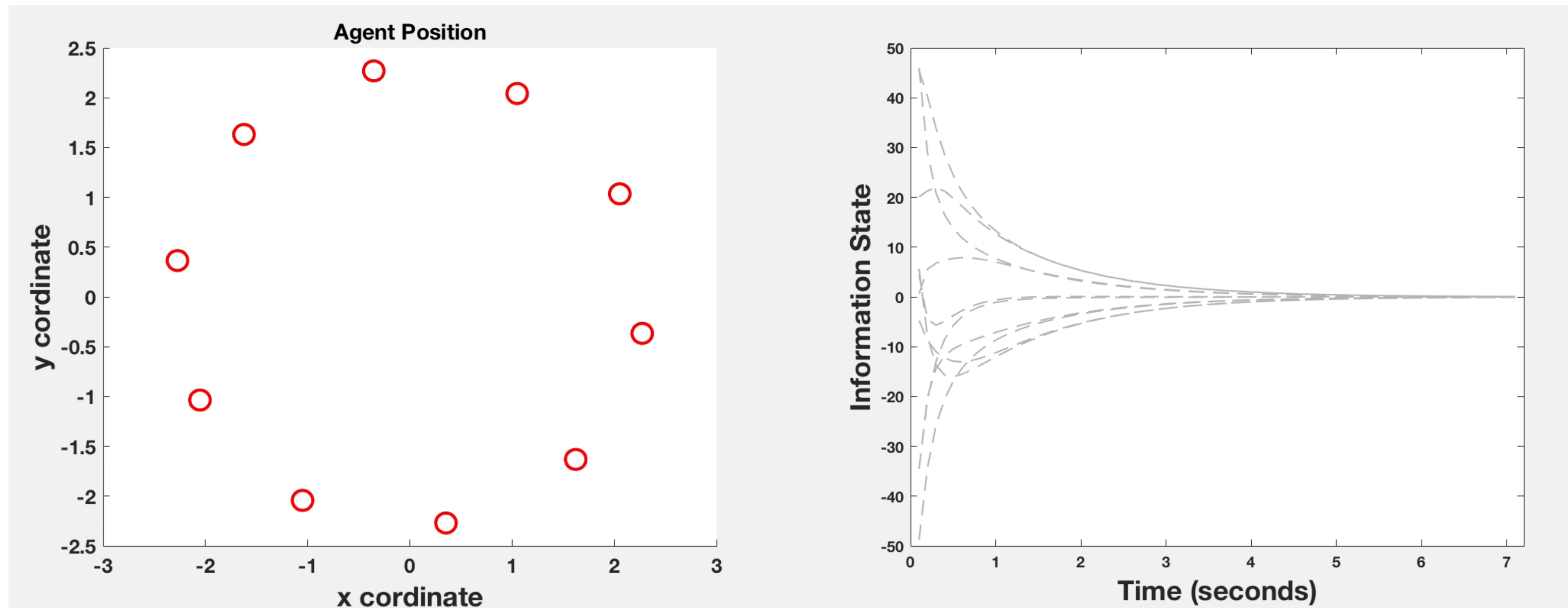


C. Fernando, C. Detweiler, and J. Bradley, "Co-Regulating Communication for Asynchronous Information Consensus," in *57th IEEE Conference on Decision and Control*, 2018. to appear

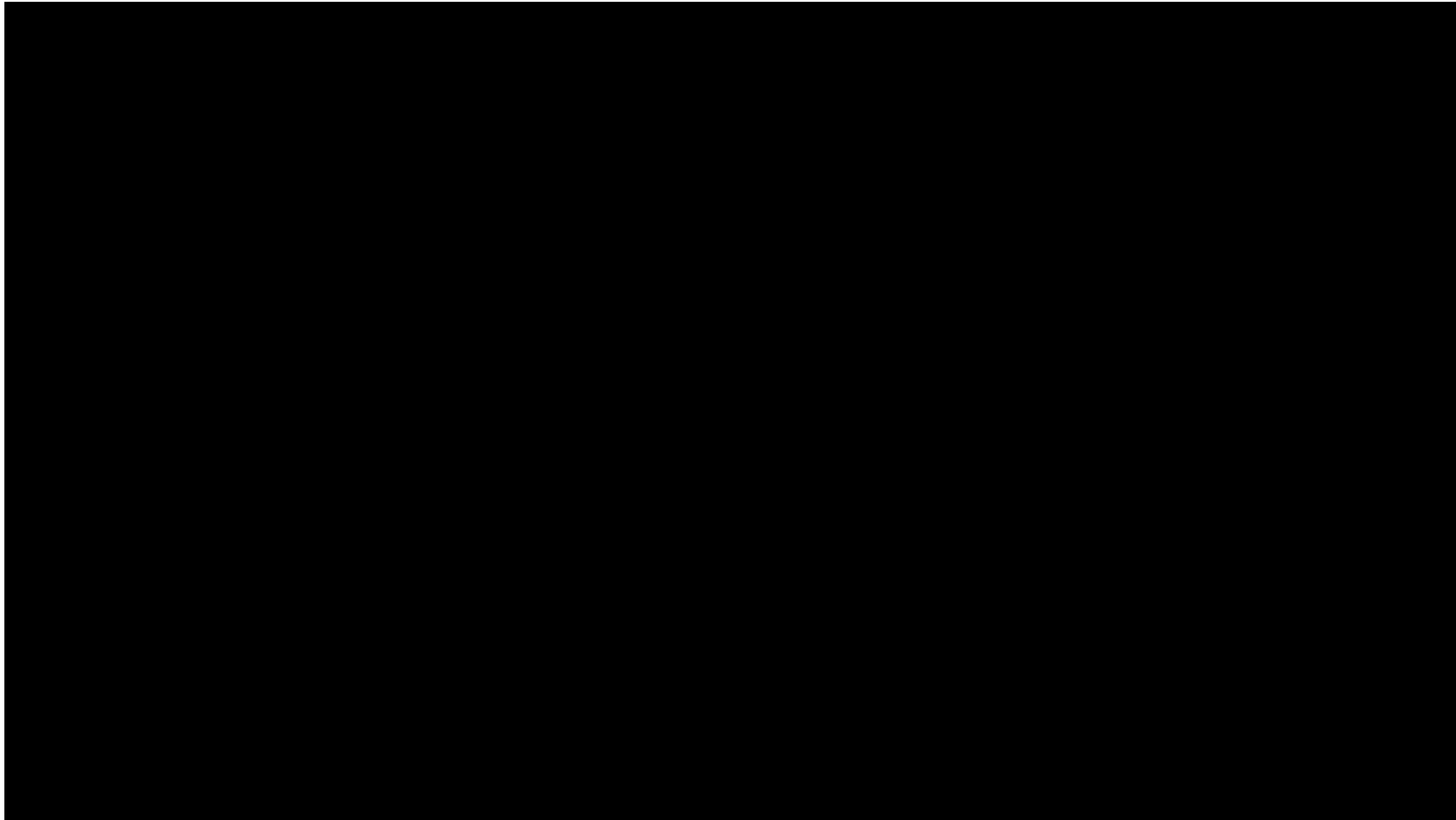


Technical Nugget #4: Co-regulated information consensus for multi-agent systems

$$u_i^P = \underbrace{-\alpha_1 K \left(x_i^P - x_{center}^P \right) \left(\sum_{j \in M_i} |x_i^I - x_j^I| w_{ij} \right)}_{\text{Pushes agents toward each other based on information state error}} \underbrace{-\alpha_2 K \left(x_i^P - x_{i,initial}^P \right)}_{\text{Pushes agents back out}}$$

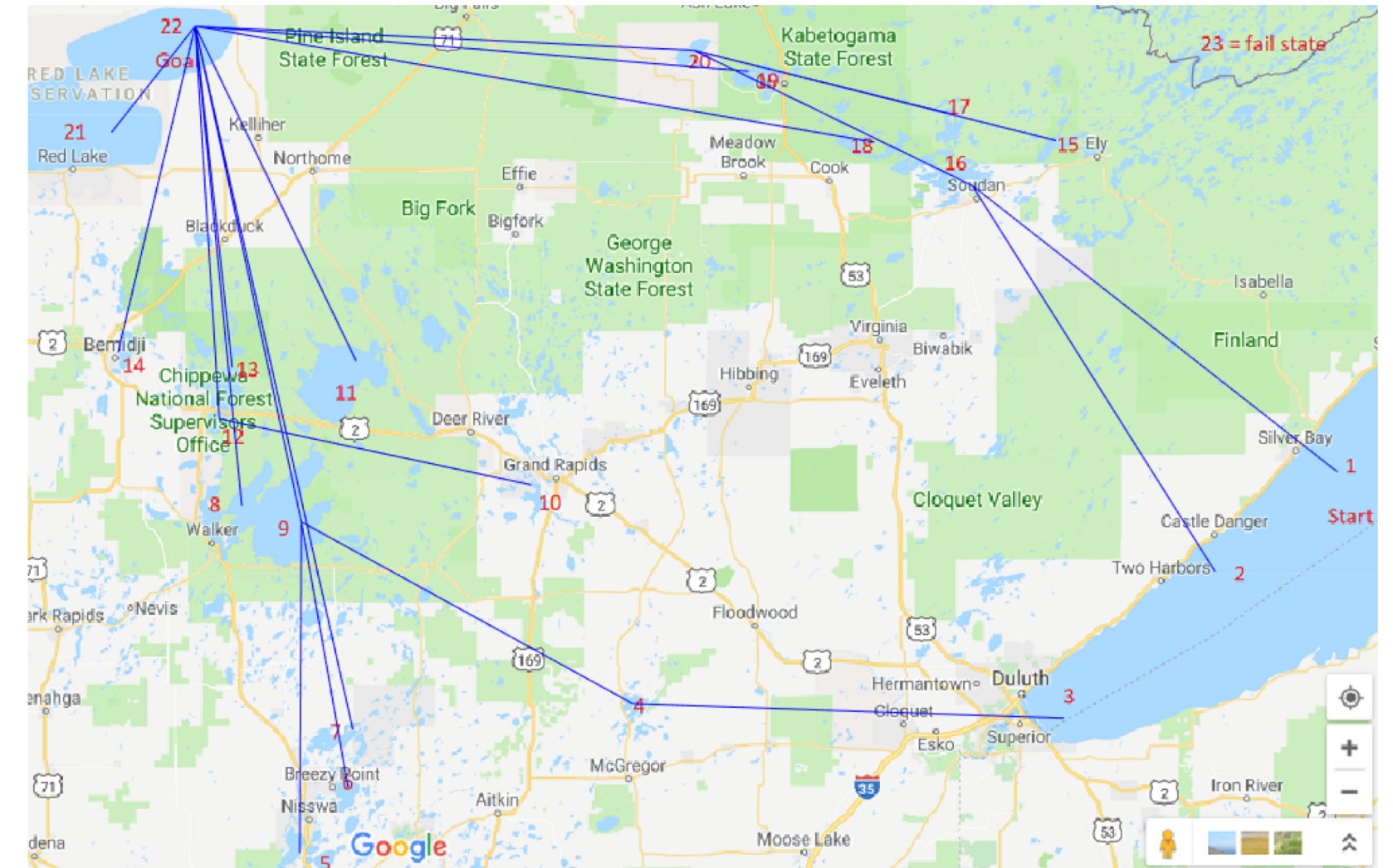


Technical Nugget #5: Multi-drone release for multi-agent sensing



Next

- Full system testing
 - Implement multi-agent co-regulated consensus and MDP algorithms
 - Continued testing and integration of surface classification and bathymetry systems
 - Deploy ground and water sensors
- Single-agent multi-flight co-optimization
 - Solar-supplemented UAV
 - Co-optimize energy, time, landing location, time of day
- Continue work with stakeholders (wetlands scientists)
 - Conduct joint field test with University of the Pacific team
 - Perform testing comparing automated techniques with prior strategies used by environmental scientists (quantity and quality of data collected about wetlands)



Selected Publications

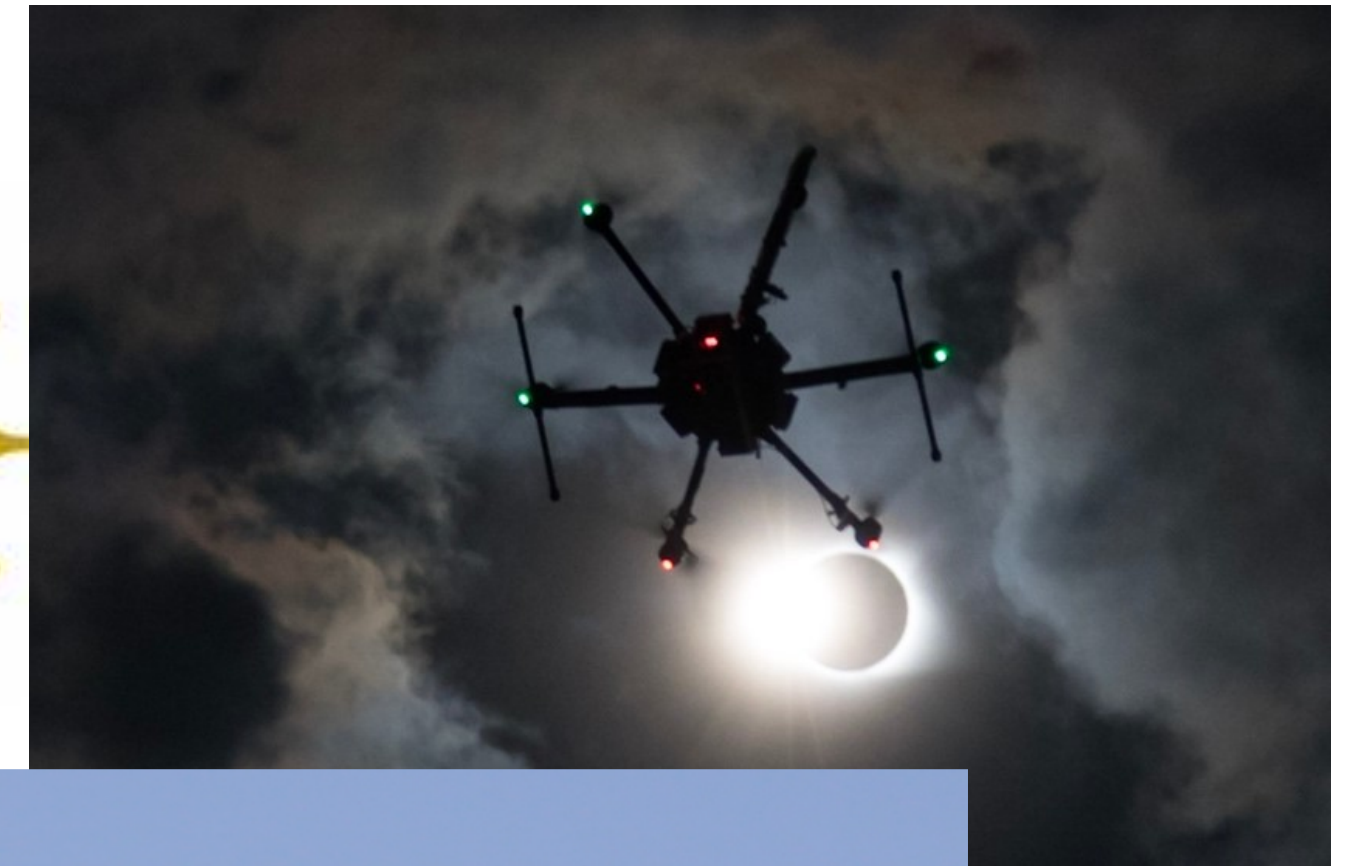
- C. Fernando, C. Detweiler, and J. Bradley, "Co-Regulating Communication for Asynchronous Information Consensus," in *57th IEEE Conference on Decision and Control*, 2018.
- L. Kruse and J. Bradley, A Hybrid, Actively Compliant Manipulator/Gripper for Aerial Manipulation With a Multicopter. In 16th IEEE International Symposium on Safety, Security, and Rescue Robotics, Philadelphia, PA, 2018
- X. Zhang, S. Doebbeling, and J. Bradley, Co-regulation of Computational and Physical Effectors in a Quadrotor Unmanned Aircraft System. In Proceedings of the 9th ACM/IEEE International Conference on Cyber-Physical Systems, Porto, Portugal, 2018, pp. 119-129.
- J.-P. Ore and C. Detweiler, Sensing Water Properties at Precise Depths from the Air. *Journal of Field Robotics*, 2018.
- Y. Sun, A. Plowcha, M. Nail, S. Elbaum, B. Terry, and C. Detweiler, Unmanned Aerial Auger for Underground Sensor Installation. In Proceedings of IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Madrid, Spain, 2018.
- N. Najeeb and C. Detweiler, UAV Based Wireless Charging of Sensor Networks without Prior Knowledge. In Proceedings of IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Madrid, Spain, 2018.
- A. Plowcha, Y. Sun, C. Detweiler, and J. Bradley, Predicting Digging Success for Unmanned Aircraft System Sensor Emplacement. In Proceedings of International Symposium on Experimental Robotics (ISER), Buenos Aires, Argentina, 2018.
- K. Song, A. Brewer, S. Ahmadian, A. Shankar, C. Detweiler, and A. Burgin. Using unmanned aerial vehicles to sample aquatic ecosystems. *Limnology and Oceanography: Methods*, 15(12), 1021-1030, 2017.
- E. Basha, T. Watts-Willis, and C. Detweiler. Autonomous Meta-Classifer for Surface Hardness Classification from UAV Landings. In Proceedings of IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Vancouver, Canada, 2017.
- T. Medeiros, T. Watts-Willis, and E. Basha. Online Visual Water Differentiation Using Unmanned Aerial Vehicles. Poster at IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Vancouver, Canada, 2017.
- S. Doebbeling, A. Shankar, and J. Bradley. Toward a Cyber-Physical Quadrotor: Characterizing Trajectory Following Performanc. *International Conference on Unmanned Air Systems (ICUAS)*, 2017
- N. Najeeb and C. Detweiler. Extending Wireless Rechargeable Sensor Network Life without Full Knowledge. *Sensors*. 2017; 17(7):1642.
- J.-P. Ore, C. Detweiler, and S. Elbaum. Dimensional Inconsistencies in Code and ROS Messages: a Study of 5.9M Lines of Code. In Proceedings of IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS), Vancouver, Canada, 2017.
- J.-P. Ore, and C. Detweiler. Sensing Water Properties at Precise Depths from the Air. In Proceedings of International Conference on Field and Service Robotics, Zurich, Switzerland, 2017.
- J.-P. Ore, C. Detweiler, and S. Elbaum. Lightweight Detection of Physical Unit Inconsistencies without Program Annotations. In Proceedings of the 2017 International Symposium on Software Testing and Analysis (ISSTA), Santa Barbara, CA, 2017
- D. Anthony, and D. Detweiler. (2017), UAV Localization in Row Crops, *J. Field Robotics*, 34:1275-1296. doi:10.1002/rob.21706



Available Opportunities

- **REU: Unmanned Systems Foundations and Applications**

- Summer 2019
- Have room for 10-13 undergraduate researchers
- NSF sponsored with competitive stipend
- <https://www.unl.edu/summerprogram/unmanned>



- **Postdocs: 2 openings**

- Postdoc with **mechanical engineering** skills including SolidWorks, field testing, multicopter construction
- Postdoc interested in the intersection of **control** and **real-time computing** in multi-agent UAS applications

- For more information, or to apply:
nimbus-directors@cse.unl.edu

