Bringing Aerial Robots Closer to the Ground: Sensing, Sampling, and Safety

nimbus.unl.edu

Carrick Detweiler

Computer Science and Engineering Department

University of Nebraska-Lincoln

carrick@cse.unl.edu cse.unl.edu/~carrick nimbus.unl.edu

youtu.be/nm8MhcBkYDw

Use Cases: Fly High

youtu.be/tFi8YbE9M6k

Use Cases: Fly Low

What can else can UAVs do?

- Low Flight for Close Inspection
  - Determine cost/effort of aerial imaging for monitoring Swallows along Platte River
  - Investigate reaction of birds to small drones
  - Examine quality of captured images

Collaborators: Mary Brown and TJ Fontaine

youtu.be/LWn9WNidpnM

What can else can UAVs do?

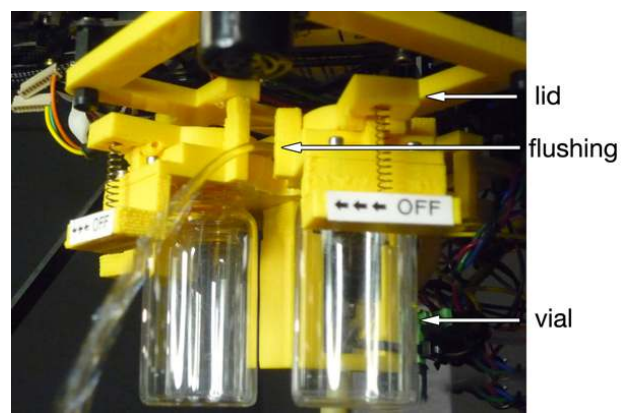
Collect Samples?

Vision, Capabilities, and Requirements

- Fly close to the environment
- Interact with environment
- Autonomy to increase success
- Reliability to lower cost
- Safety to enable adoption

UAV Water Sampling
Interacting with Environment

- Goals
  - Collect water samples with UAV
  - Partial Autonomy
- Research Challenges
  - Staying safe and dry
  - Integrating ultrasound, altimeter, and water sensor data
  - Easy and robust user interface



Student: J-P Ore; Collaborator: S. Elbaum, A. Burgin

Why Water Sampling?

How is it Done Now?
Fixed Samplers

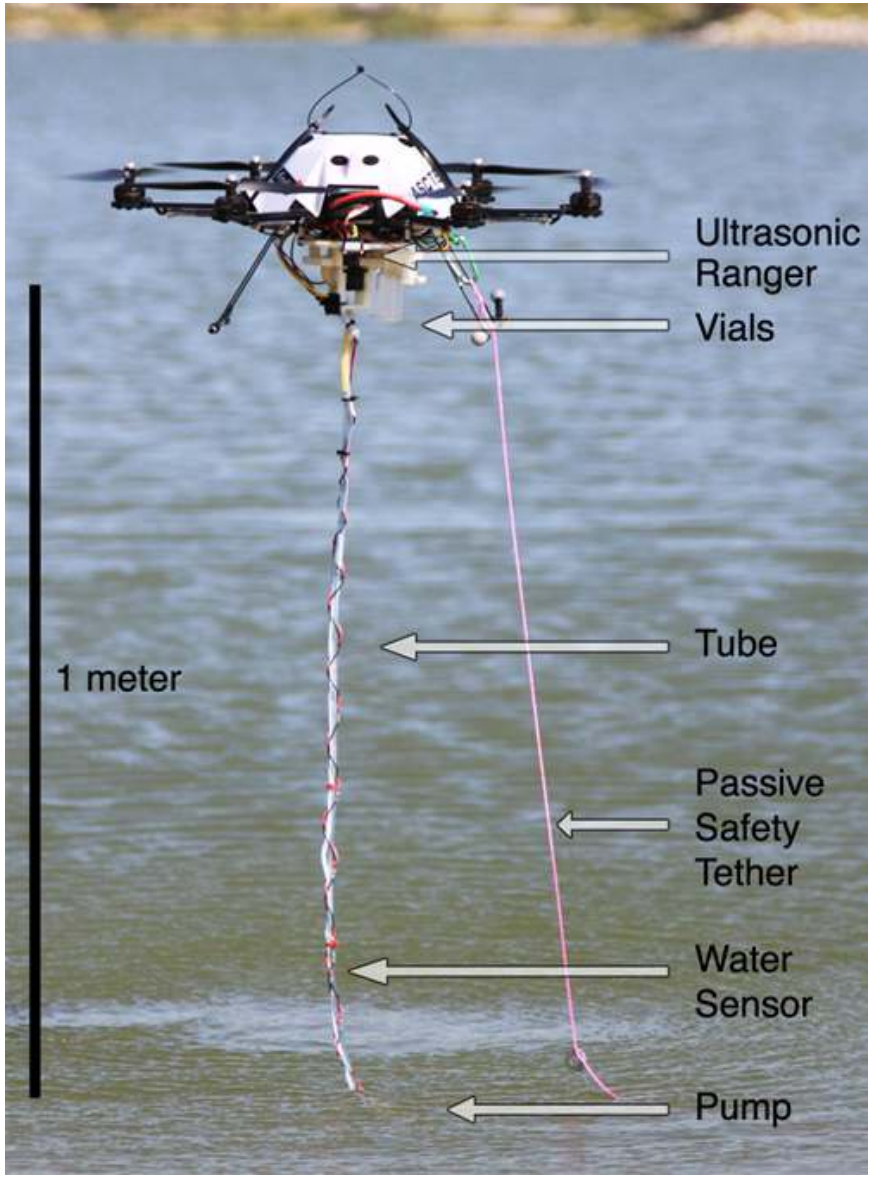
How is it Done Now? Autonomous Systems

- J. Manley, A. Marsh, W. Cornforth, and C. Wiseman, “Evolution of the Autonomous Surface Craft AutoCat,” Proceedings of Oceans 2000, MTS/IEEE Providence, RI, October, 2000.
- H. Ferreira, A. Martins, A. Dias, C. Almeida, J. M. Almeida, E. P. Silva, “ROAZ Autonomous Surface Vehicle Design and Implementation”, Encontro Científico - Robótica 2006, Pavilhão Multi-usos, Guimarães, Portugal, 28 Abril, 2006
- R. Hine and P. McGillivary, “Wave powered autonomous surface vessels as components of ocean observing systems,” Proceedings of PACON 2007, Honolulu, HI June 2007
- Curcio, Joseph, John Leonard, and Andrew Patrikalakis. "SCOUT - A low cost autonomous surface platform for research in cooperative autonomy." OCEANS, 2005. Proceedings of MTS IEEE. IEEE, 2005.

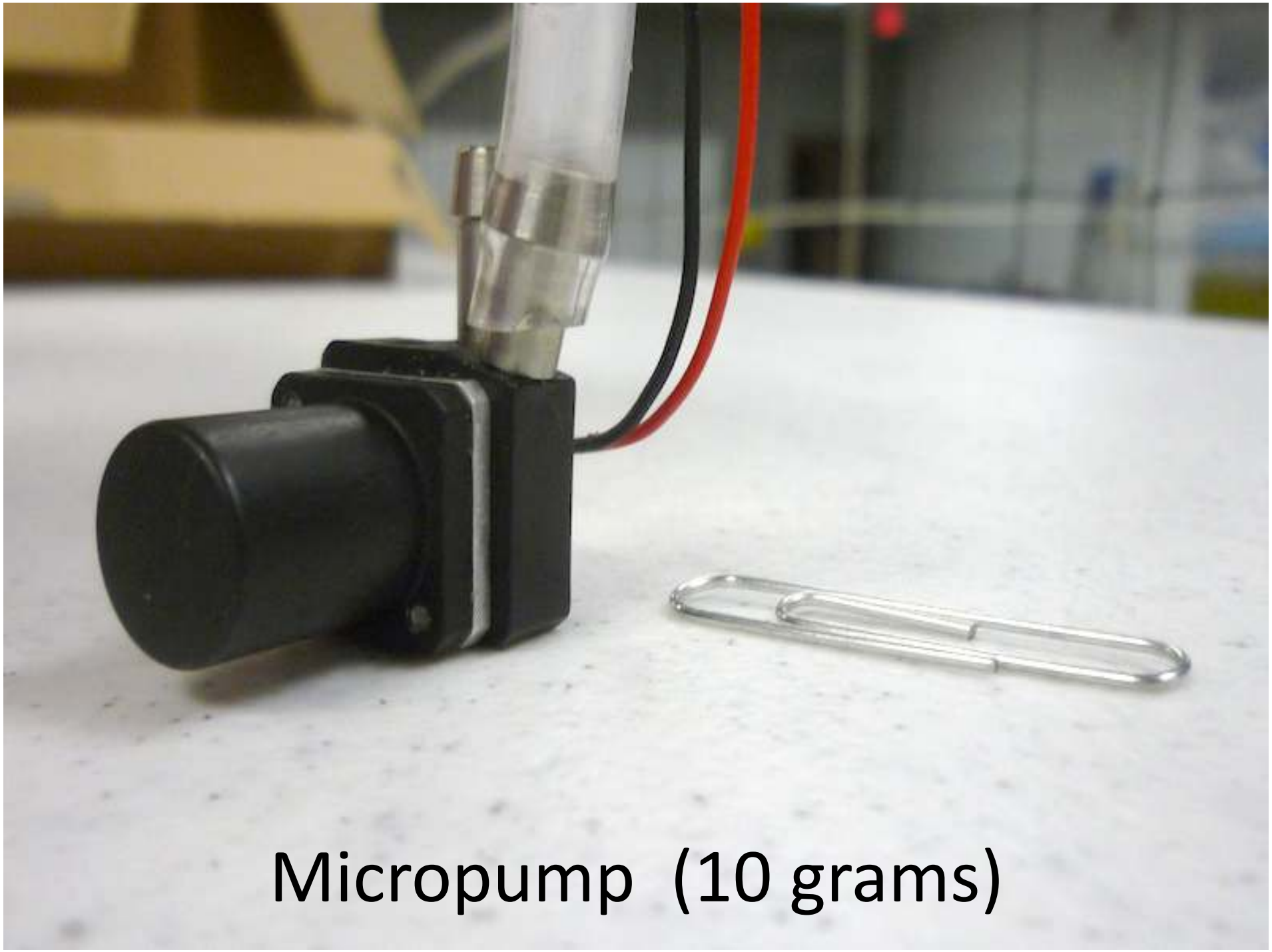
Why Water Sampling?

How is it Done Now?
Grab Sampling

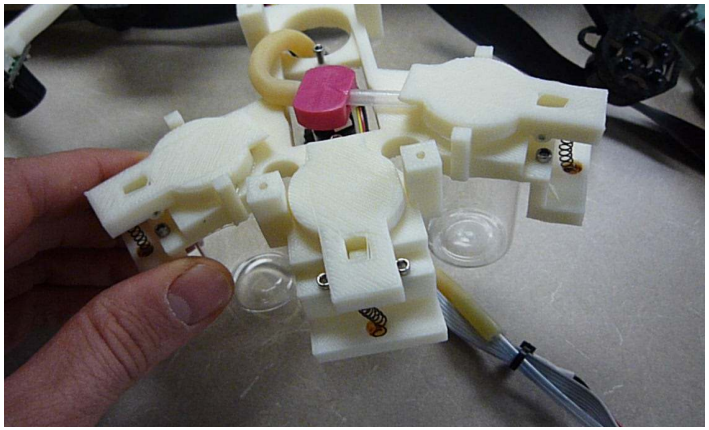
How Do We Sample Water?

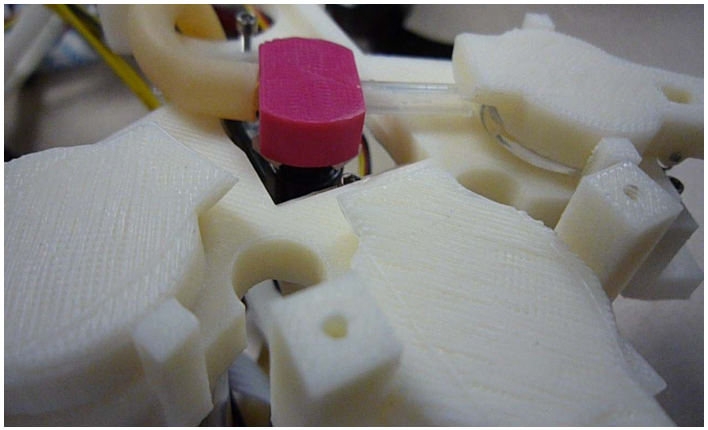


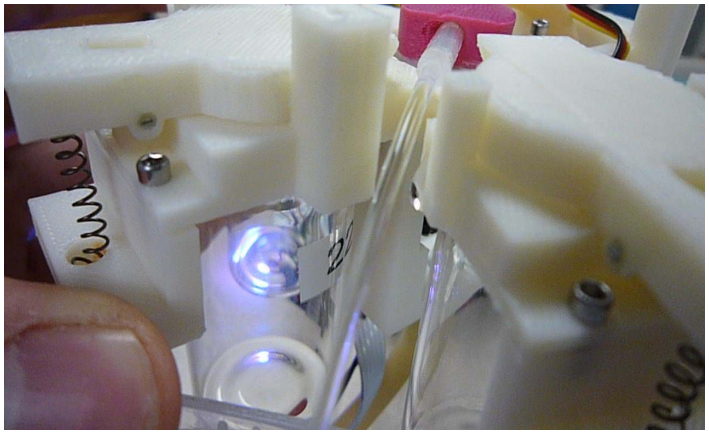
- UAV – AscTec Firefly
- Electromechanical
  - Pump
  - Conductivity Sensors
  - Breakaway Mechanism
  - 'Chassis' & 'Needle'
  - Embedded System
- Software
  - Altitude Control
  - Safety System
  - Autonomy

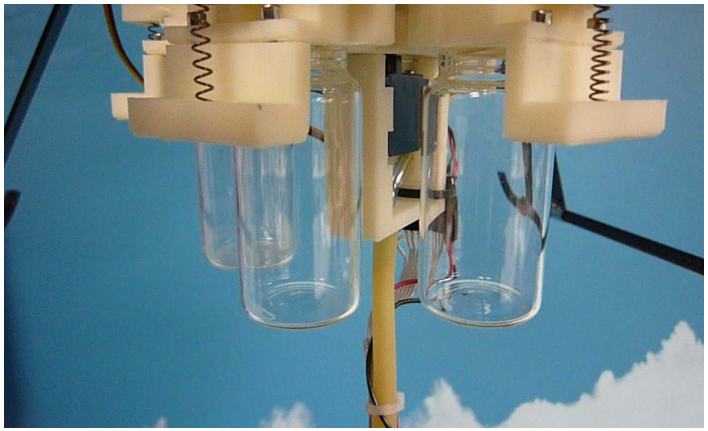

Micropump (10 grams)

Chassis, Servo, Flushing, Vials

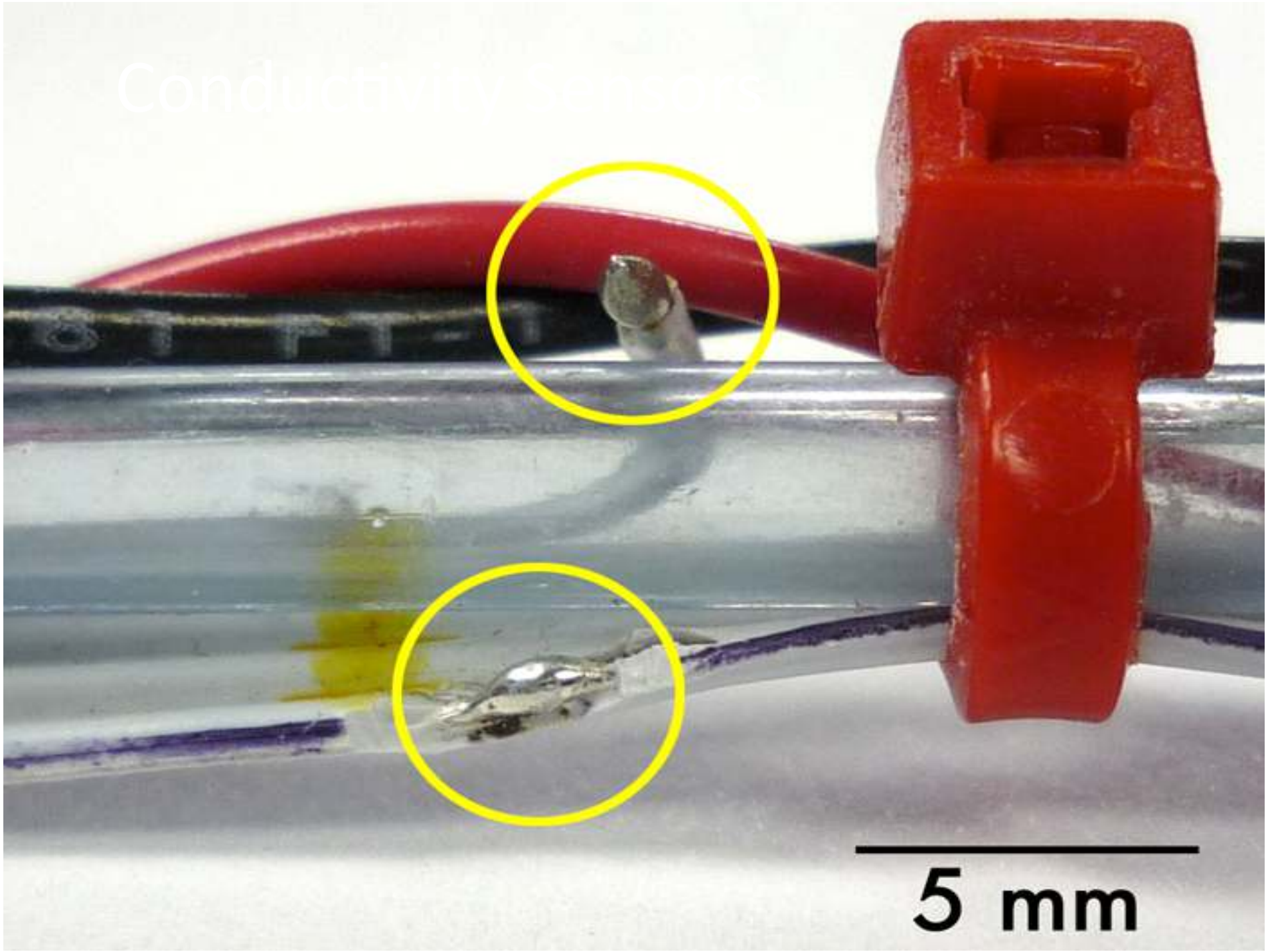








Ultrasonic Sensors


Conductivity sensors
5 mm

Altitude

Pressure

1.85 m

0 m

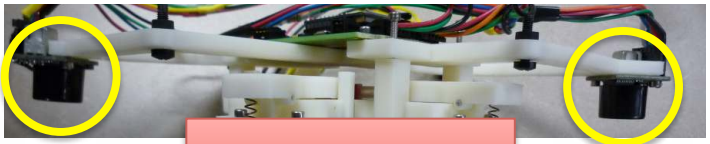
Pressure

Ultrasonic

Conductivity

Kalman Filter

Low Altitude Estimation



Ultrasonic

1.85 m

Max Filter

+1 point

Low Variance

During previous 1 second

+2 points

Proximity to Current

Test

Choose or Average

Kalman Height Estimate

pressure

Altitude

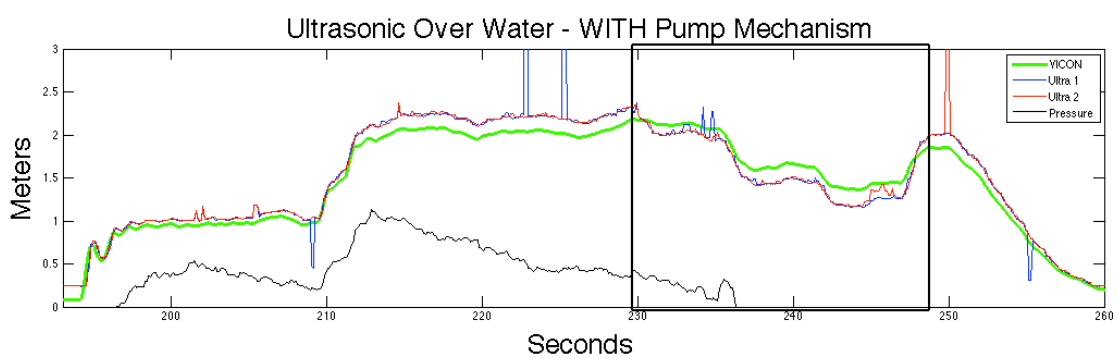
Water Conductivity

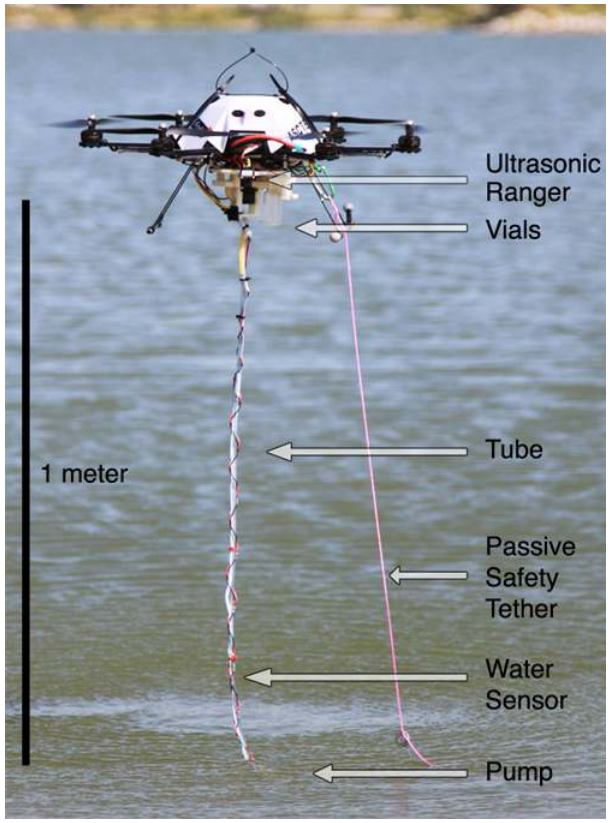
youtu.be/7mPbyXZpBws

Autonomous Water Sampling

Aerial Water Sampling

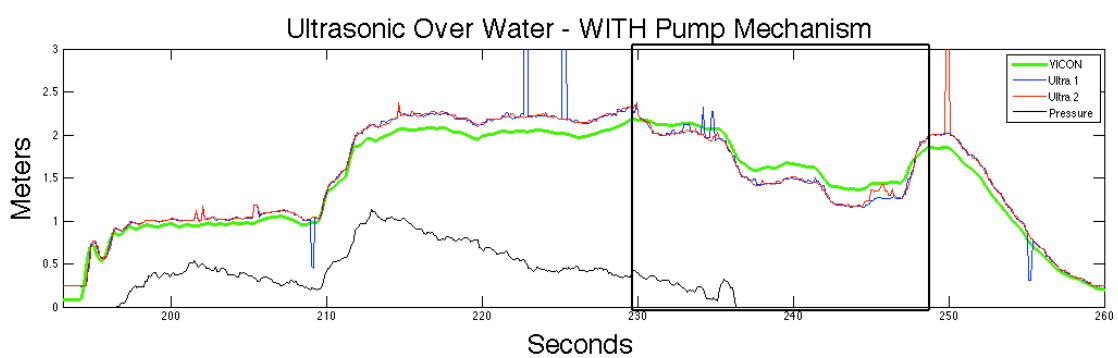
- Findings
  - Successfully captured 100s of samples indoors
  - 100+ outdoors
  - Stable in 10-15mph winds
  - Samples compare to grab samples

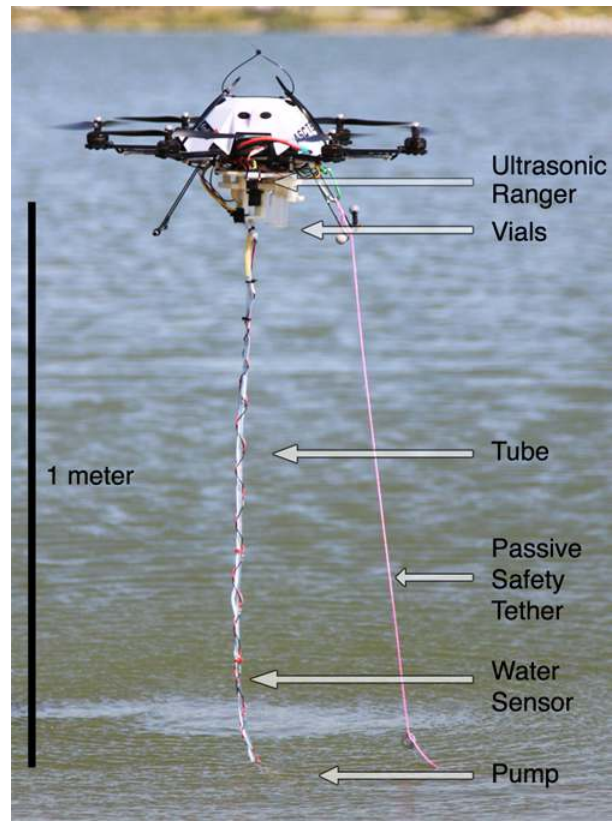




Aerial Water Sampling

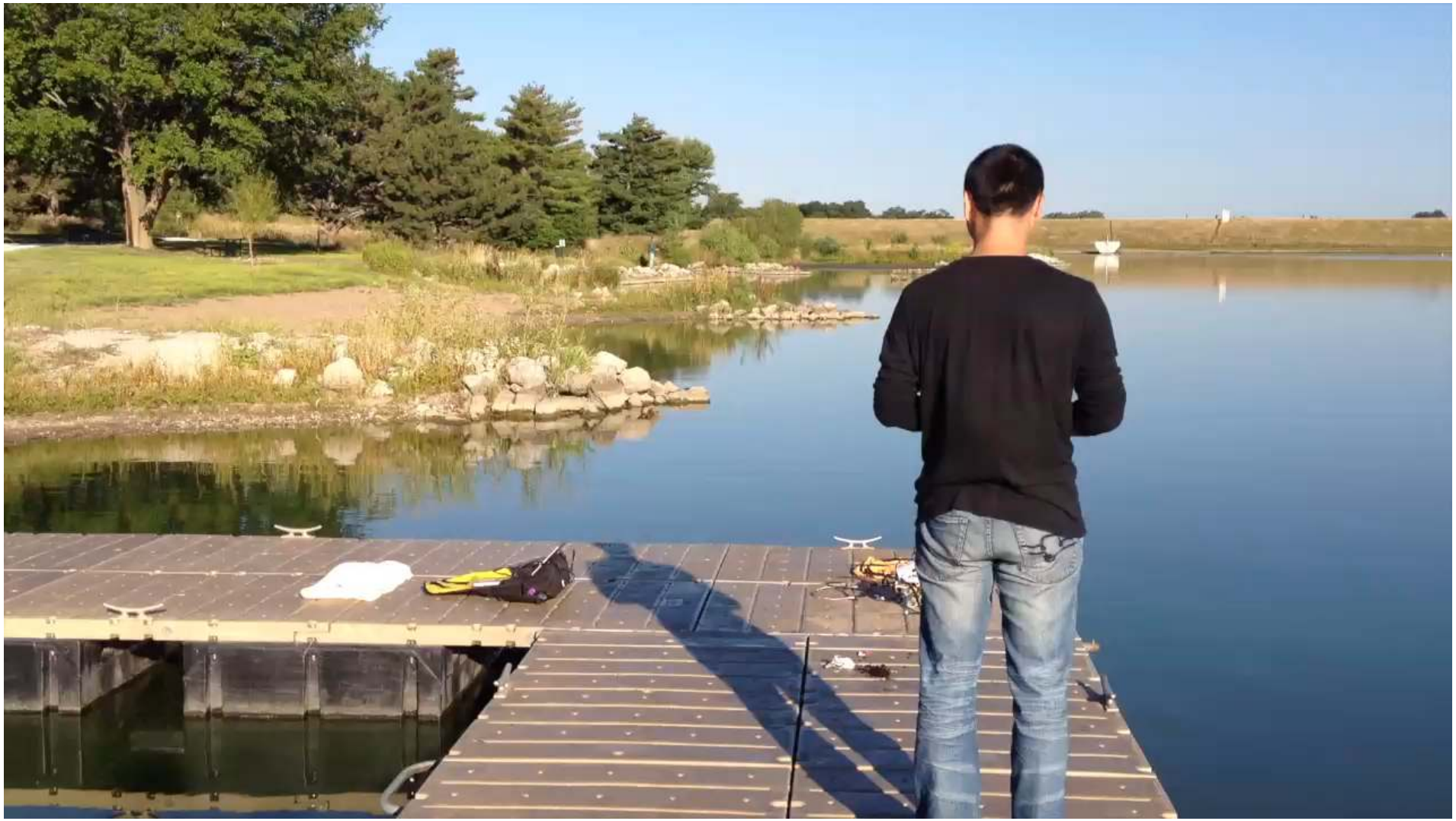
- Uses
  - Faster sampling of hard to access locations
  - Add conductivity, Temp, DO, etc.
  - Chemical spills
  - Collect DNA samples from water
  - Others?





youtu.be/rd04BMkHKcQ

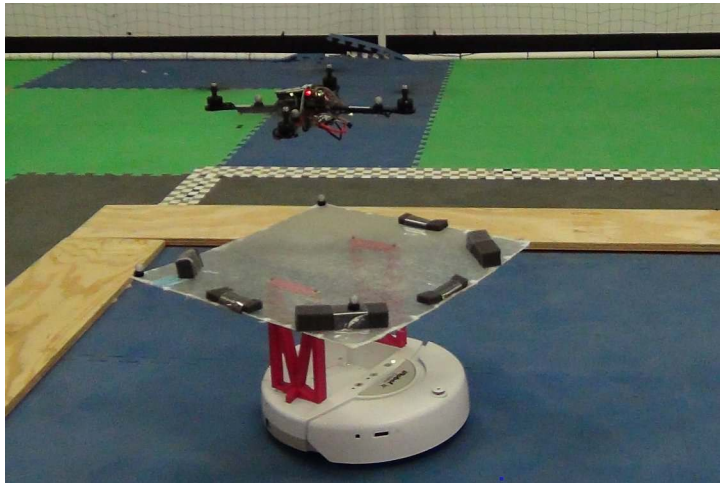
Failures: Part of Field Robotics



Improving Safety, Autonomy, and Reliability

- Goals
  - Operate reliably under unpredictable conditions
  - Avoid operations that may lead to loss of control

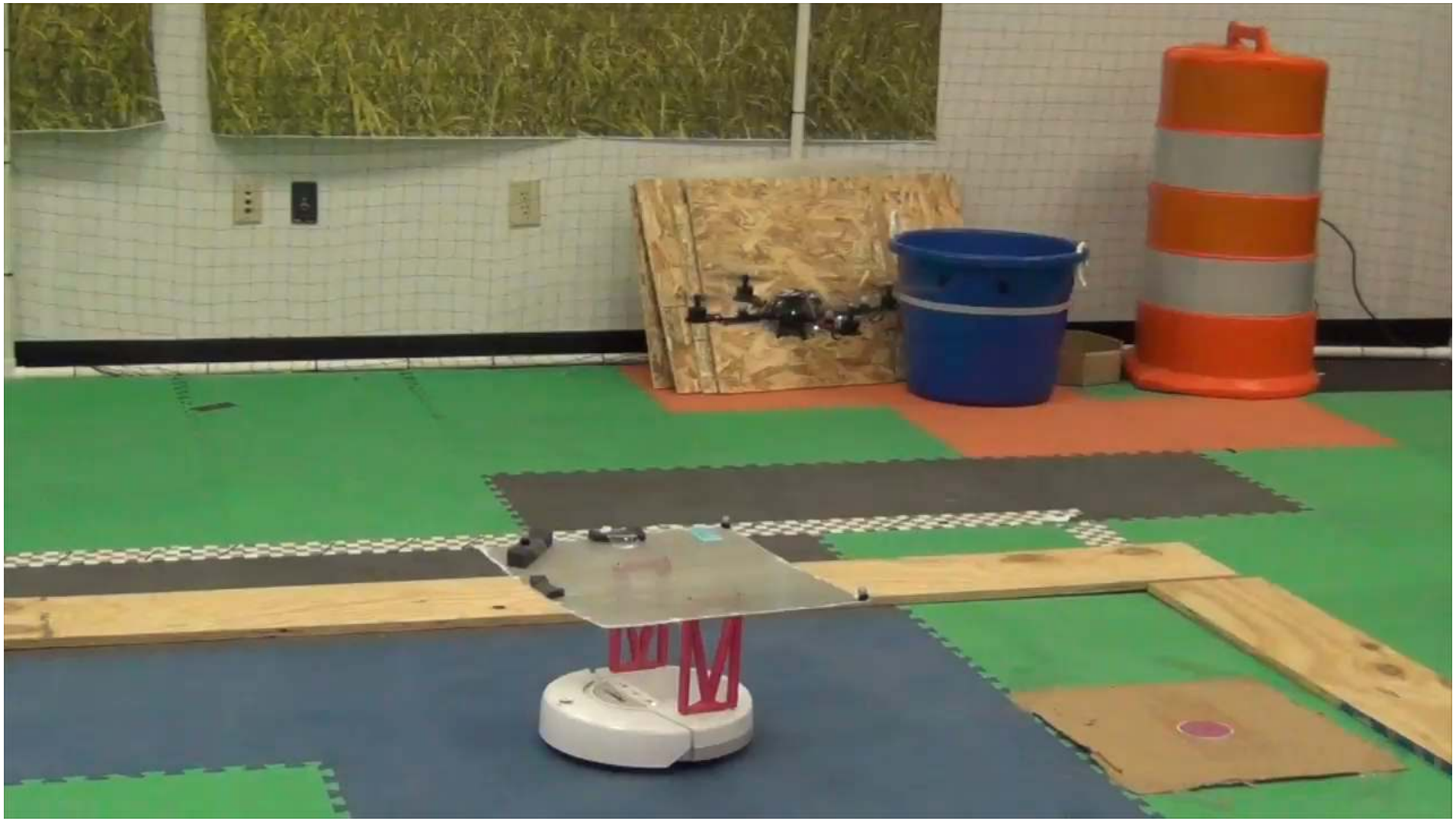
- Research Challenges
  - Characterize known successful system operations
  - Synthesize those operations into a monitor that bounds UAV behavior



Student: Hengle Jiang Collaborator: S. Elbaum

youtu.be/VIAg8dM8TLk

Improving Safety, Autonomy, and Reliability

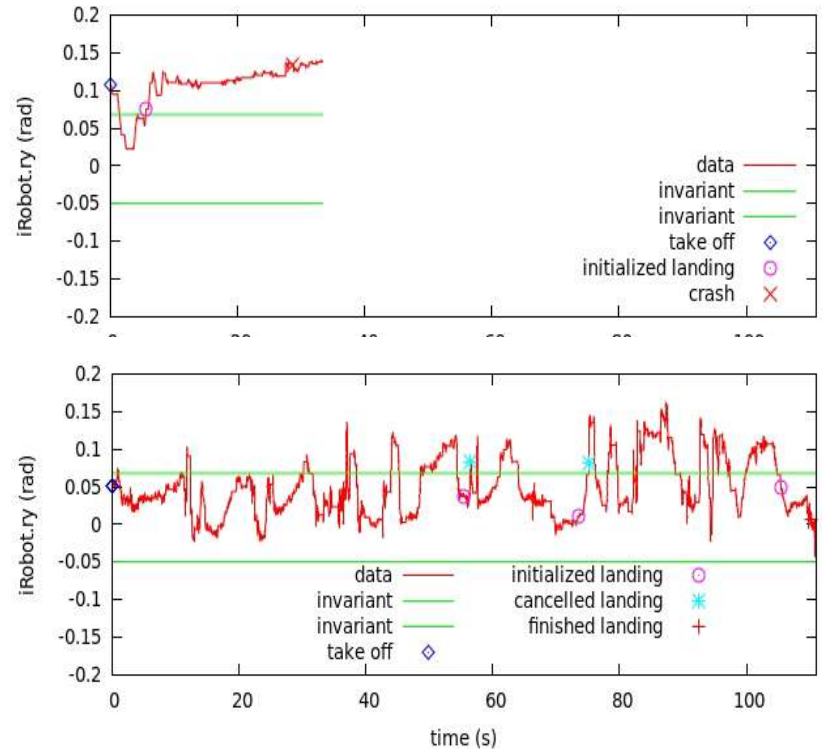


Improving Safety, Autonomy, and Reliability

- Findings
  - Success rate for unplanned scenarios from
  - 20% to 80%
  - Approach is applicable to any UAV task
  - Need to identify remedial actions
  - Required for close interactions with environment

Without Monitor

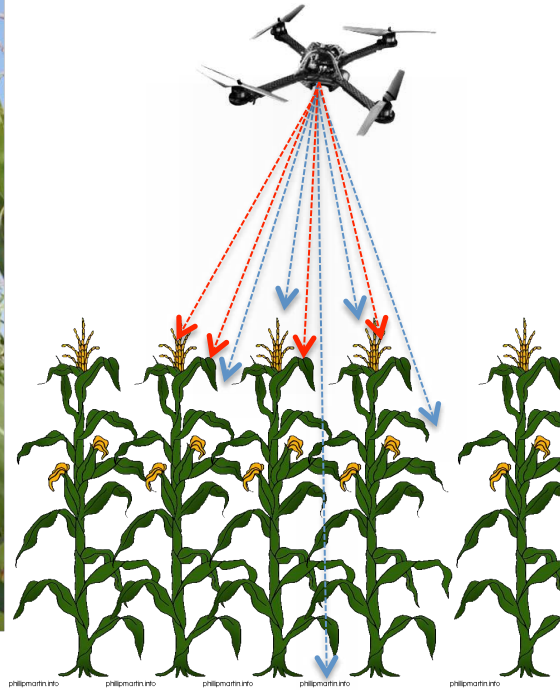
With Monitor



Crop Height Measurement

- Goals
  - Fast and precise crop height measurement
  - Improve understanding of water and nitrogen stressors during phenotyping trials

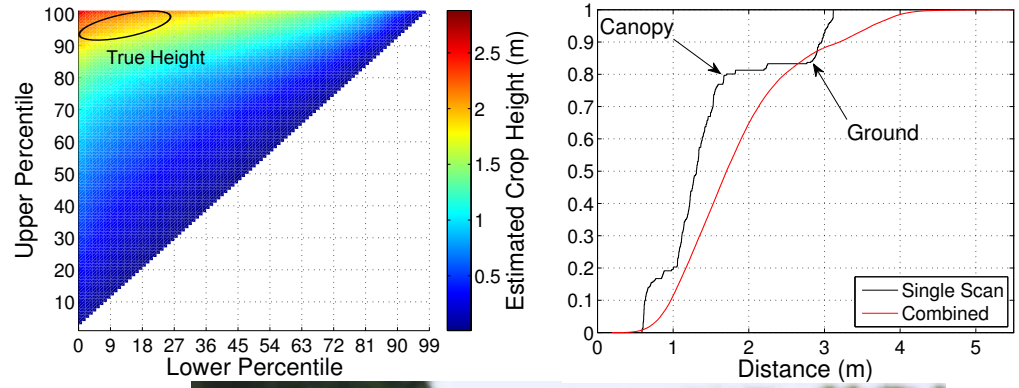
- Research Challenges
  - Fly close (<1m) to crops
  - Follow rows autonomously
  - Obtain precise crop measurements



Student: D. Anthony; Collaborators: S. Elbaum, A. Lorenz and R. Ferguson

Crop Height Measurement

- Findings
  - Filtering of noisy data
  - Can identify ground, top of crops, and intermediate canopy levels
  - Plan height within 3cm of manual measurements
  - Autonomous height control



Summary

- UAVs can be used close to the ground and water
  - Can already fly high and observe
- UAVs have disruptive potential
  - Interactions with environment
  - Collect samples
  - Safety and reliability
  - Autonomy and ease of use

NIMBUS Lab

- Nebraska Intelligent MoBile Unmanned Systems Lab
  - Computer Science and Engineering Department
  - 8 Grad Students, 1 Tech, Undergrads
  - Co-directed with Dr. Sebastian Elbaum

Bringing Aerial Robots Closer to the Ground: Sensing, Sampling, and Safety

nimbus.unl.edu

Carrick Detweiler
Computer Science and Engineering Department
University of Nebraka-Lincoln

This work is supported in part by grants from NSF, USDA, and ORED-UNL.
We would like to thank our collaborators:
C. Allen, M. Brown, R. Ferguson, A. Lorenz, S. Thompson, M. Hamilton, T.J. Fontaine, A. Burgin, and M. Waite.