Autonomous UAV Capstone

Final Status Presentation

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April 28th, 2022

Mission Needs Statement

To design a low cost, open architecture, and cooperative autonomous quadcopter adaptive for Coast Guard use.

- Supplement ScanEagle's success
- No dedicated launching system, usable on small platforms
- No dedicated pilot
- Cheap enough to be bought in large quantities

Boeing ScanEagle

Project Requirements

- The RoboBoat competition guidelines served as a baseline for UAV’s requirements.
- RoboBoat is an international competition where an autonomous surface vessel (ASV) performs navigating and docking tasks.
- Each ASV is allowed to cooperate with a UAV.

- **Requirements:**
  - Lightweight (<10 lbs)
  - Remain positively buoyant (120 seconds)
  - Deliver small payloads (1.5 in. Diameter)
  - Low cost (<$1000)
  - Capable of stable flight
  - Utilize multiple modes of navigation
  - Capable of flying autonomous search patterns
  - Capable of autonomous landing/takeoff from vessel

Year in Review

1. Enabling Flight:
    i. Identifying Major Systems
    ii. Physical Platform
    iii. Calculations, Tuning
2. Workflow Separation
3. System Integration

Major Developmental Systems

Communications

Computer Vision

Drone Control

Satellite Navigation

Landing Assembly

Payload Delivery

Drone Hardware & Physical Specifications

- Built on S500 Platform (Total Weight = 3.4 lb)
- Flight Controller: PixHawk 2.4.8
- Microprocessor: Raspberry Pi 4
- Communications: Xbee Series 3, RC XMIT/RCV
- Navigation: LIDAR, ZED-F9P, Raspberry Pi Camera
- Power Supply: 11.1 V LiPo Battery

- **Total Weight: 3.4 lbs**
- **Total Reproduction Cost: ~$900**
- **Battery Life: 6-10.7 Minutes**

Minimum Battery Life

Battery Capacity (Ah)	Amperage Draw		Battery Life (Minutes)
4.2	MT2213 Motor x4	38.4	6.00
	Raspberry Pi	3	
	Xbee	0.017	
	Zed F9P	0.12	
	LIDAR	0.085	
	Pixhawk	0.28	
	PiCam	0.095	
	Total	**41.997**	

Average Battery Life

Battery Capacity (Ah)	Amperage Draw		Battery Life (Minutes)
4.2	MT2213 Motor x4	20	10.68
	Raspberry Pi	3	
	Xbee	0.017	
	Zed F9P	0.12	
	LIDAR	0.085	
	Pixhawk	0.28	
	PiCam	0.095	
	Total	**23.597**	

Drone Control

- Connects the 6 major systems

- Pixhawk Flight Controller
  Hardware
- PX4 Autopilot
  Software

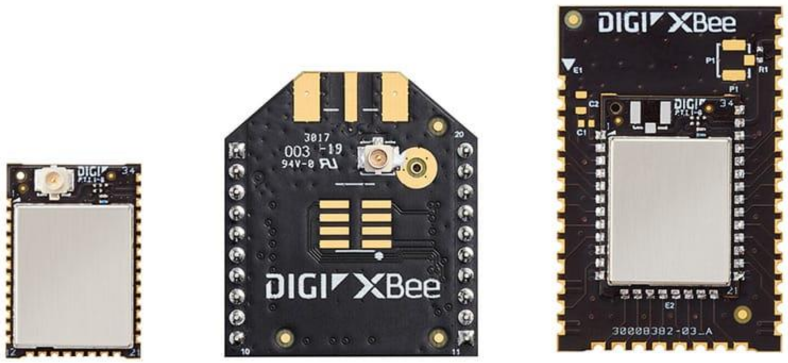
Flight Modes

Testing

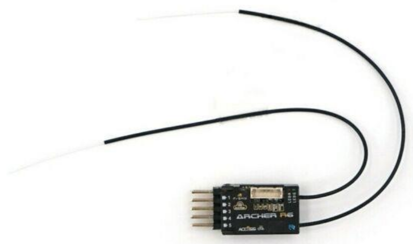
Pixhawk 2.4.8

Communications

- Digi DigiMesh®
    - Mesh Networking
        - Communication with arbitrary number of distinct systems
- Digi XBee 3 DigiMesh 2.4 RF Modules
- FrSky Taranis Radio Controller



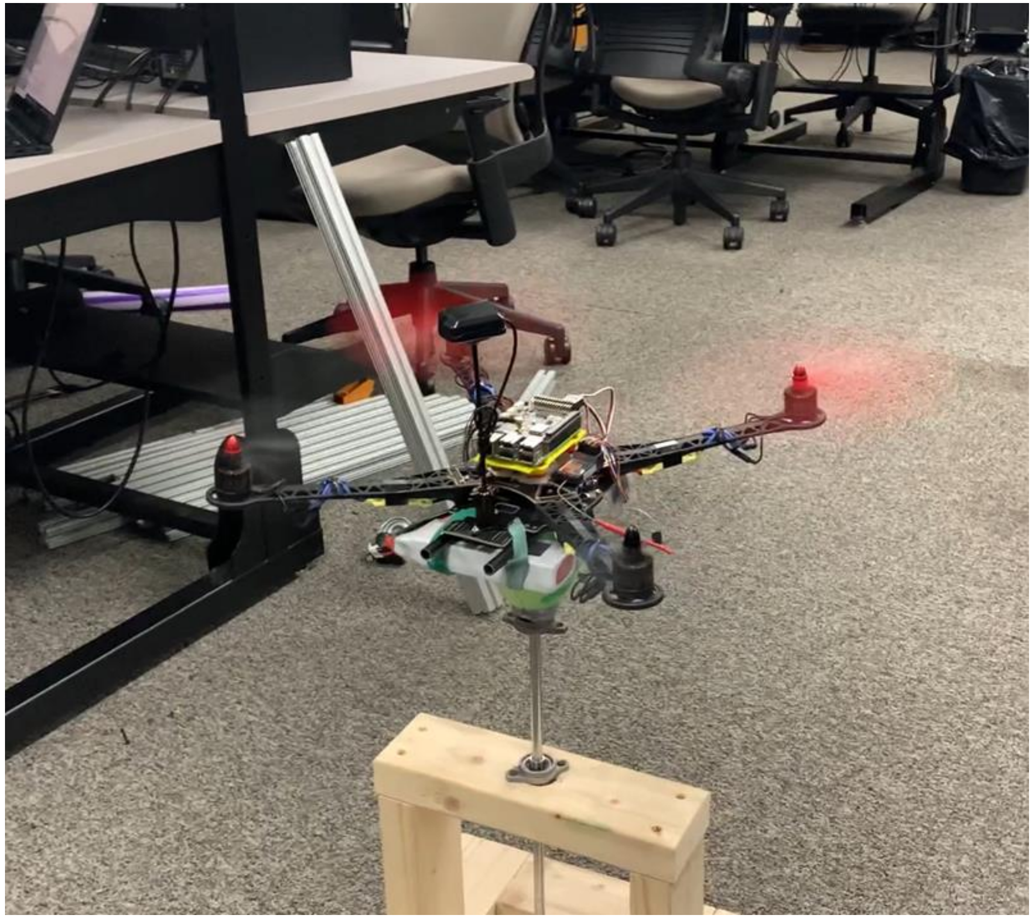
XBee 3 DigiMesh Modules



FrSky 2.4 GHz ‘Whip’ Receiver

Demonstration of Manual Flight

Stability During Disturbance Inputs



Tuning Flight Controller Gains on Test Bed

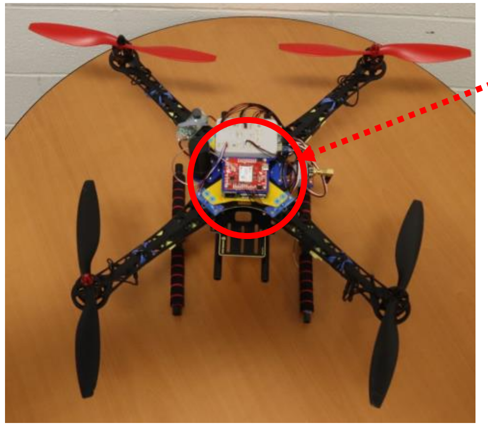
Year in Review

1. Enabling Flight:
2. **Workflow Separation**
   i. **Satellite Navigation with Real-Time Kinematics (RTK)**
   ii. **Computer Vision**
   iii. **Simulation Environment**
3. System Integration

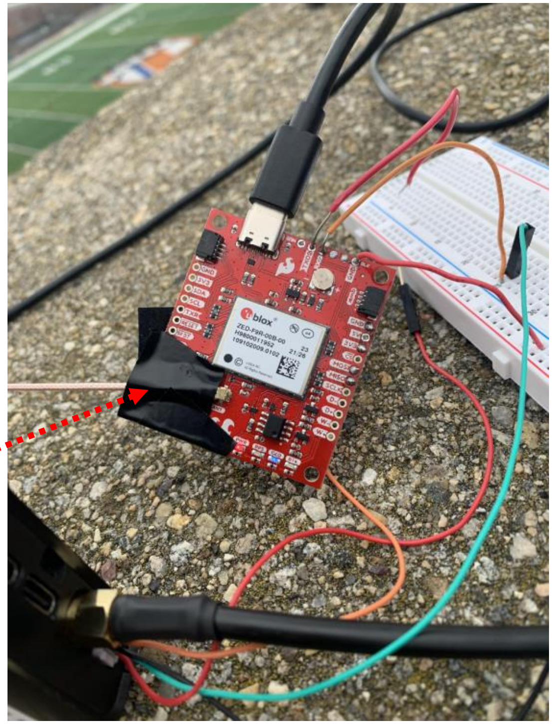
Satellite Navigation with RTK

Real-Time Kinematic Positioning

- 2 Receivers
  - Base Station
  - Rover Receiver
- Improves accuracy
  - Control finely tuned movements
  - Accuracy for landing pad



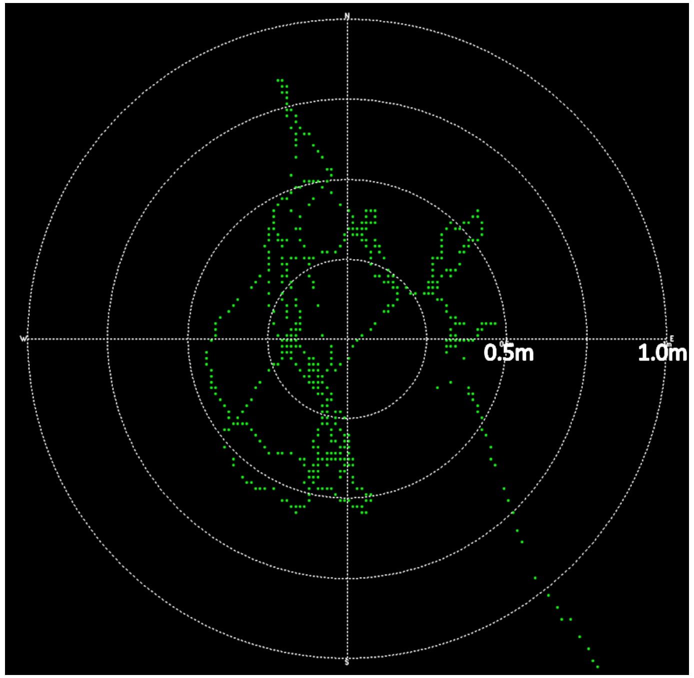
Receiver Placement



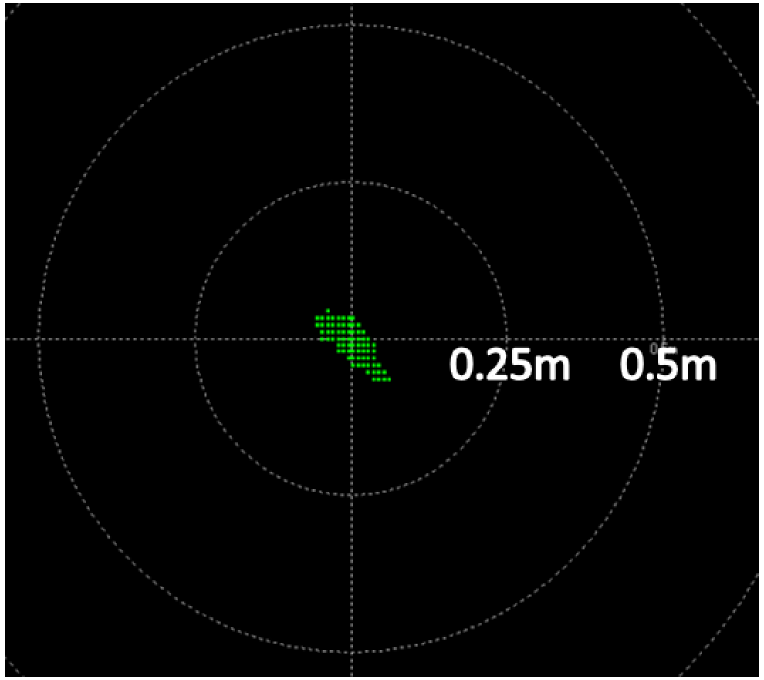
ZED-F9P Rover Receiver

Base Station

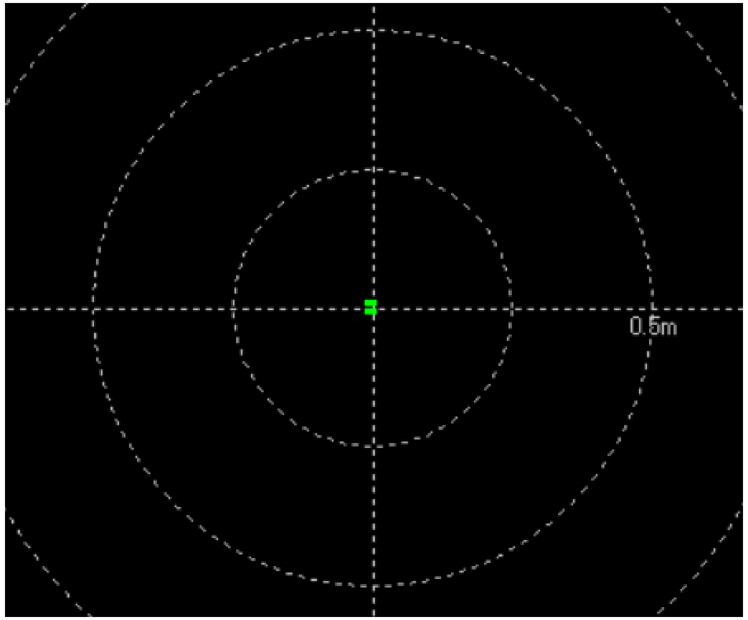
RTK Testing Development



GNSS: Average +/- 60 cm



RTK (QGroundControl): +/- 6 cm



UBX - NAV (Navigation) - HPPOSECEF (High Precision Position ECEF)

Time of week	417853.000	[s]
ECEF - X	1473304.6442	[m]
ECEF - Y	-4561312.0588	[m]
ECEF - Z	4193547.4200	[m]
ECEF Invalid	☐	

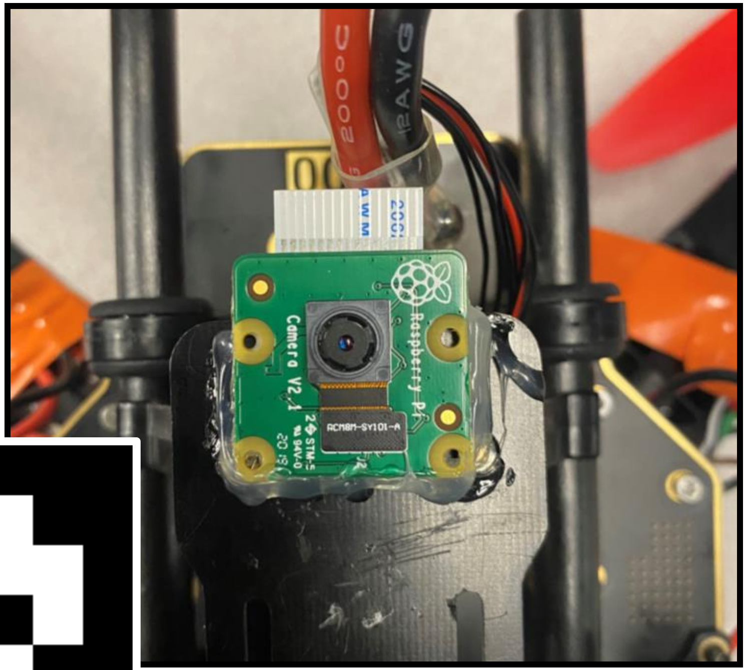
Accuracy Estimate

Position 3D	0.0173	[m]

RTK: +/- 17 mm

Computer Vision

- What is Computer Vision
- Enables image detection
- Hardware
  - Raspberry Pi4 + PiCam
    - 480p @ 15-20 FPS
- Software
  - OpenCV & PyCharm EDU
- ArUco Markers



Dual ArUco Marker Solution

- 2' x 2' Velcro ArUco Marker
  - Smaller 4" x 4" marker in center
- Successful detection in real-world and simulated tests
- Large marker detectable up to at least 50'
- Small marker detectable at up to ~13'

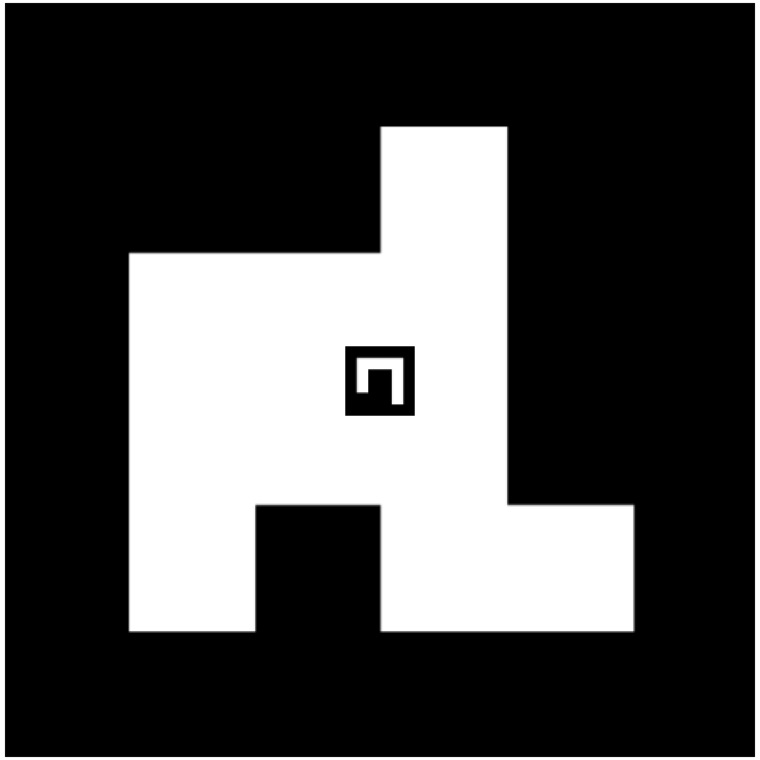
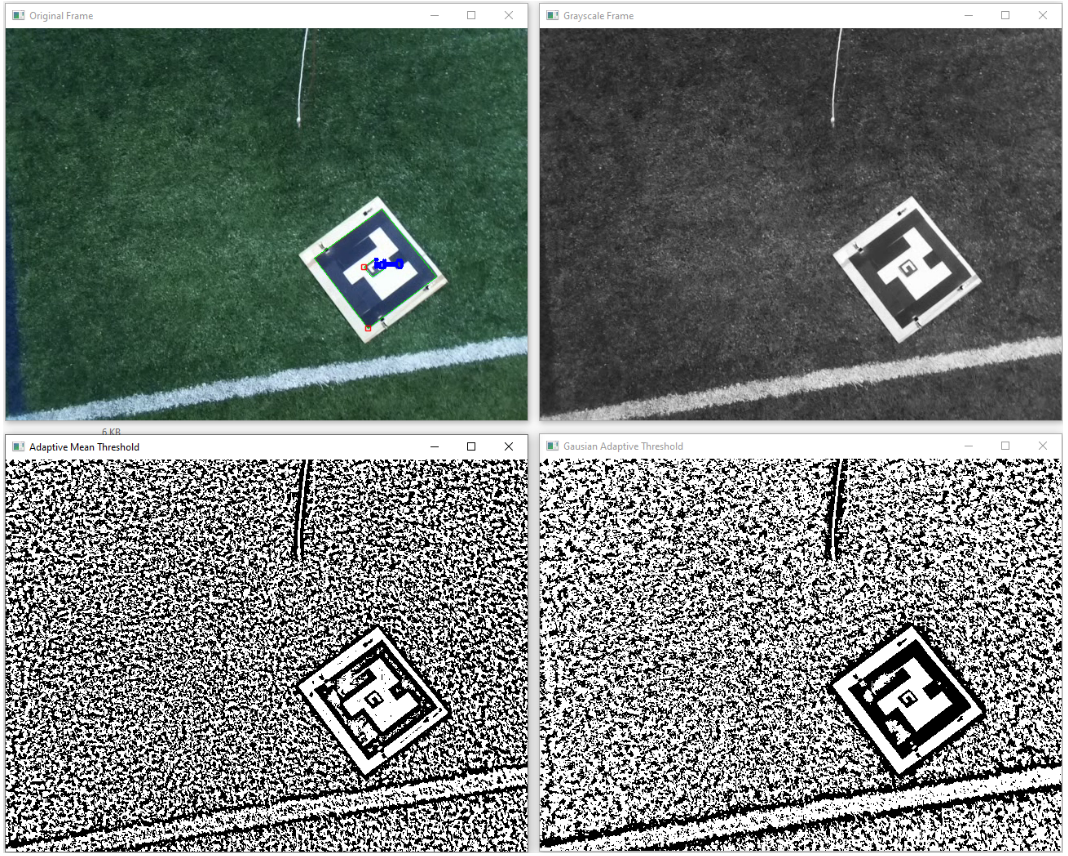


Image Refinement

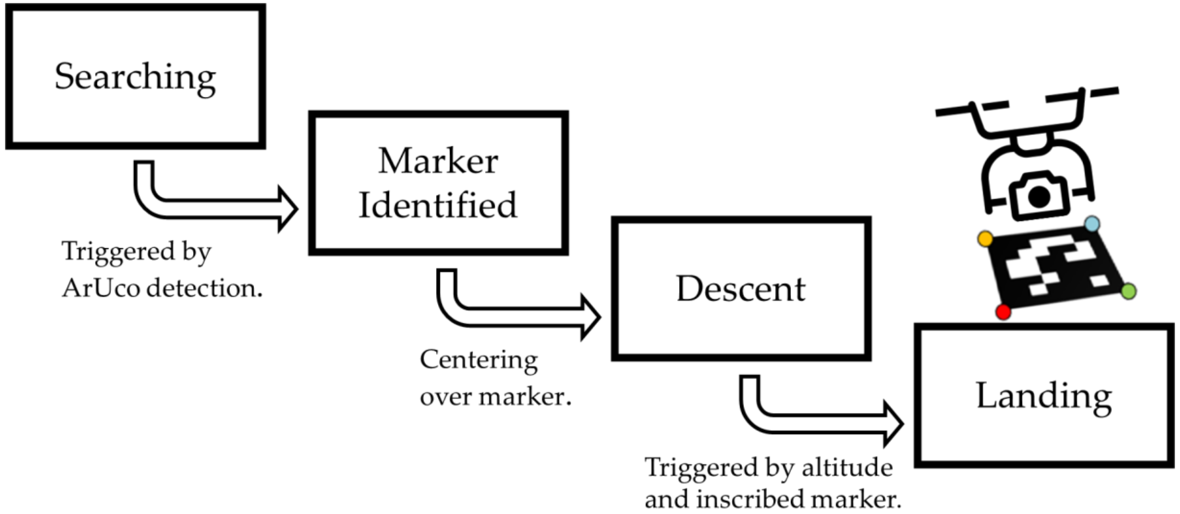
- Raw video feed
- Grayscale
- Adaptive Mean Threshold
- Gaussian Adaptive Threshold

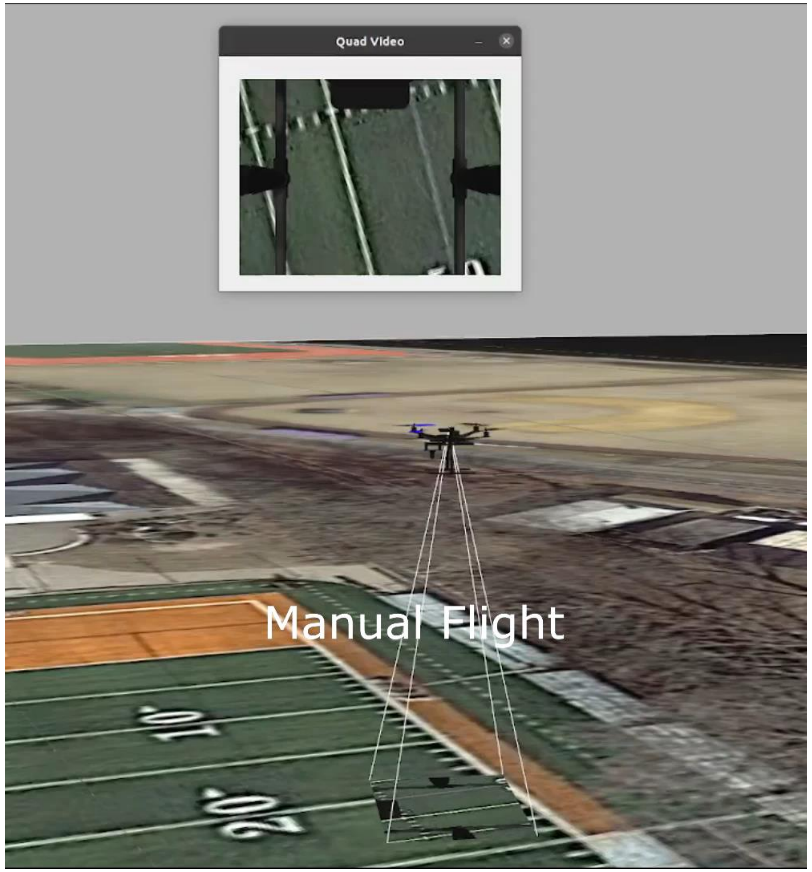


Simulation Environment

Software-in-the-Loop:

- Virtual world, virtual drone
  - Same inertial characteristics
- Low risk, rapid testing
  - Poor tuning transferability





Autonomous Landing in Simulation

Year in Review

1. Enabling Flight:
2. Workflow Separation
3. System Integration/Results
   i. Flotation and Payload Delivery
   ii. Landing Platform Development
   iii. Autonomous Waypoint Flight
   iv. Computer Vision Enabled Landing

Drone Flotation

Initial Solution:

- Foam under propellers
- 6.61 lb. of buoyant force
- Significantly impacted stability of drone during flight

Initial Flotation Solution

Proposed Solution

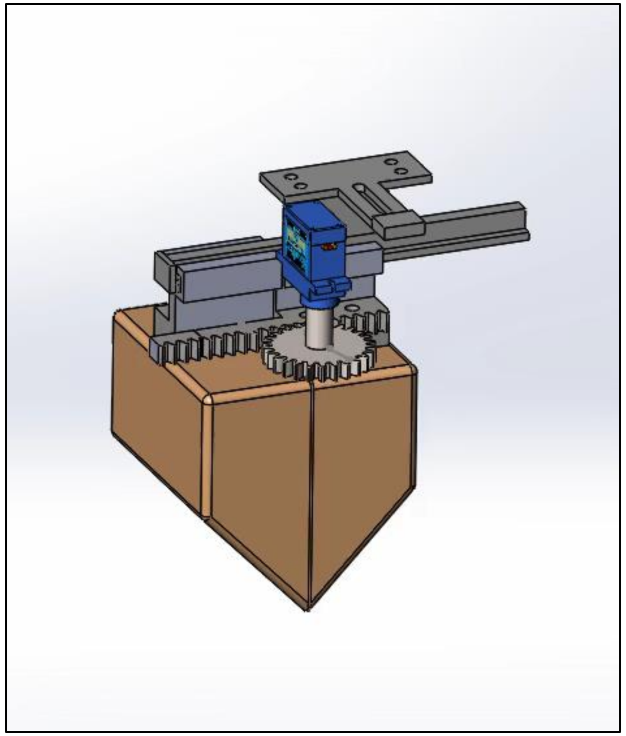
- Hydrostatic activation
- 10 lb. of buoyant force
- Drone would not float upright
- Untested

Proposed Solution: DR9 Drone Retriever

Payload Delivery

Scoop Mechanism:

- Servo Actuated
- Opens to 1.8 in.



SolidWorks Rendering of Delivery System

Live Test of Delivery

Landing Platform Development

<u>Autonomous Surface Vessel Landing Platform:</u>

- 2.5 x 2.5 ft. Plywood
- Velcro ArUco Marker
- Creates enough friction to secure drone *and* allow takeoff

Take-off From Velcro Connection

Stable Take-off After Missed Landing

Autonomous Waypoint Flight

Combining Stable Flight with Navigation:

- Standard GPS
- Predefined creeping line search

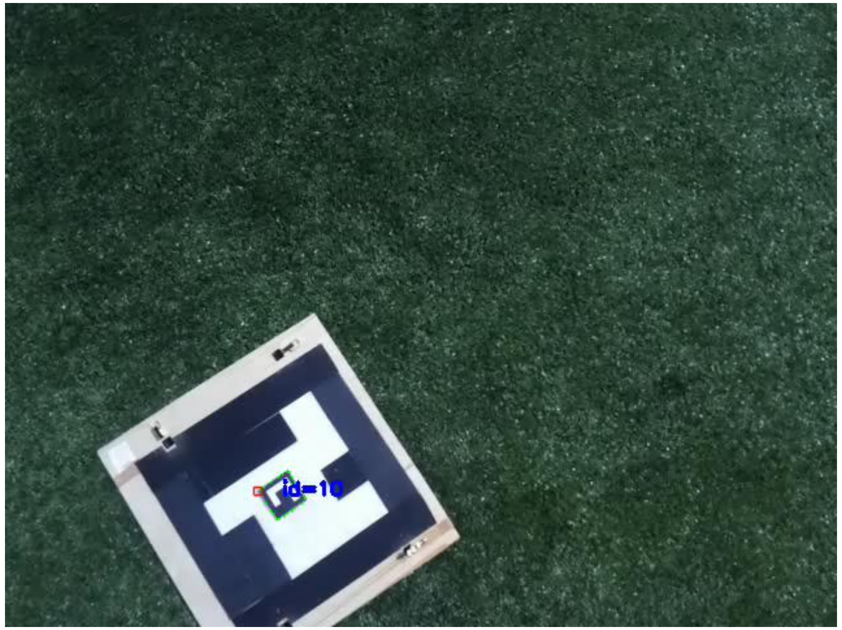
Autonomous Creeping Line Search

Computer Vision Enabled Landing

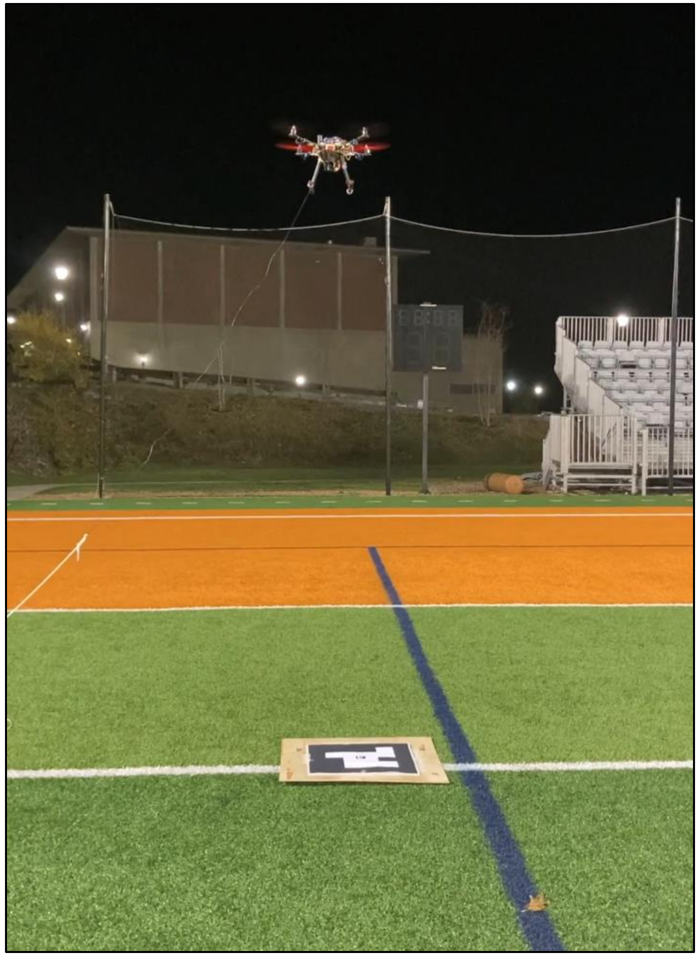
Real World Testing:

- Combine all workflows
- High risk, time-consuming

High-Reward Information

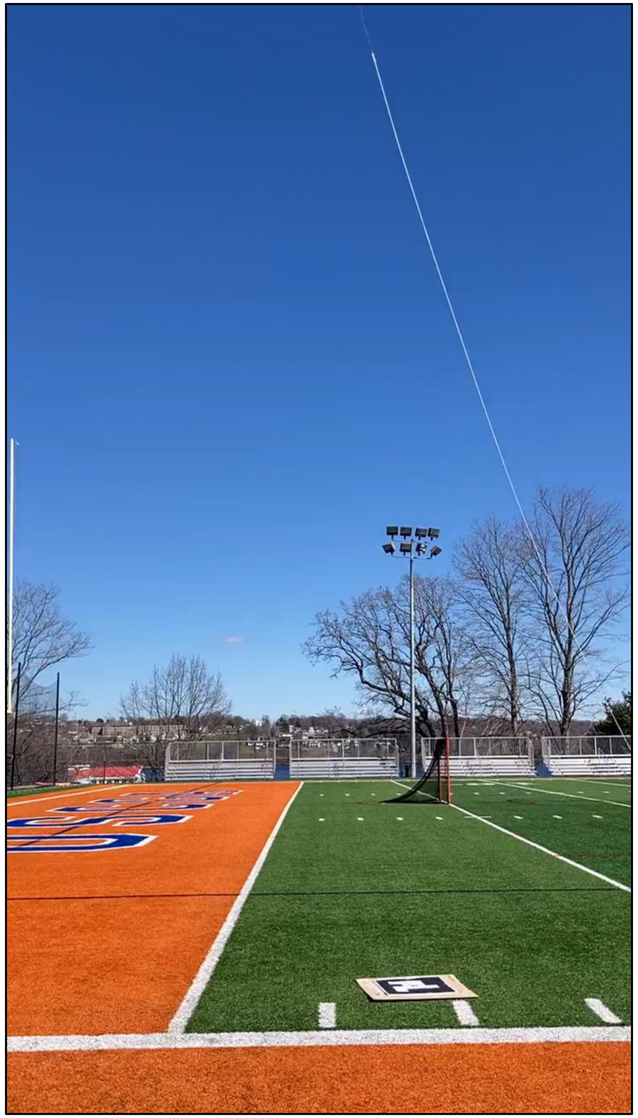


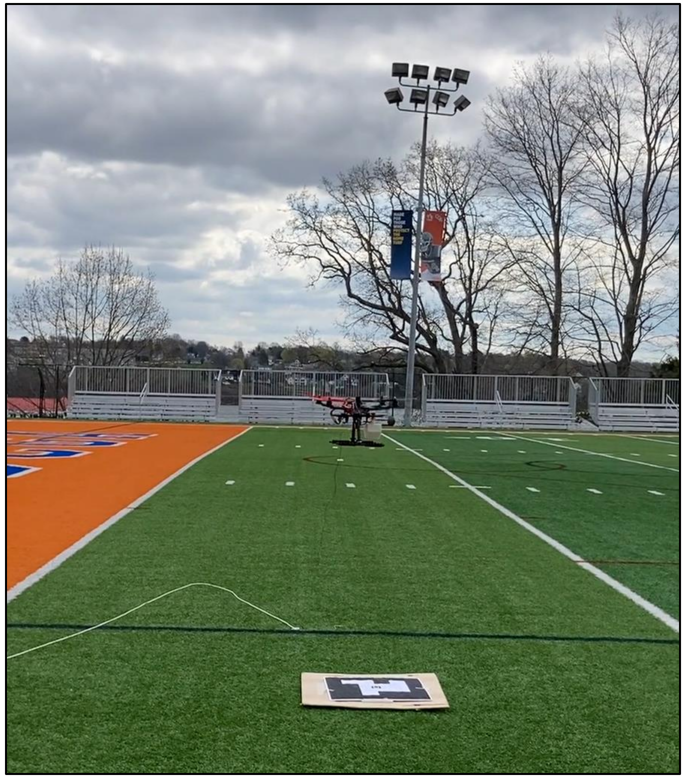
Video from the onboard camera.



Autonomous Landing (26 Mar. 2022)

Questions?





Budget

Major Costs:

- S500 Frame: $59
- Motors: $100
- Raspberry Pi 3B+: $75
- Pixhawk 2.4.8: $75
- RTK: $350

Drone Reproduction Cost: $900

Future Costs:

- Drone Retriever DR9: $85

Platform Requirements

Requirement	Solution
Weigh less than 10 pounds (T), ideally 5 pounds (O).	Small Platform: 3.4 pounds.
Be capable of precision navigation, ideally 10cm (O).	Equipped with GPS-RTK, Lidar, and a camera.
Capable of transporting small objects.	Servo Actuated close/release scoop mechanism.
Positively buoyancy in water for 120 seconds (T), or indefinitely (O).	Foam outriggers underneath propellers. 5.1 lbs of buoyant force.
Safety guidelines: remote kill switch, not exceed 60 V DC.	Remote kill switch configured on RC transmitter. Utilizes an 11.1 V LiPo battery.
Total cost to reproduce less than $1,000 (O).	Current sum of components is approximately $900.