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Eye in the Sky: An Automated UAV System for Wildlife Tracking

Gabriel Vega

Michael Shafer, PhD

Carol Chambers, PhD

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Cleveland, OH

Outline– UAV-RT

- Current Issues with Wildlife Tracking
  – Addressing inefficiencies and risk
- Field UAV Design
  – Packable (protected when stored)
  – Simple fabrication and field repairable
- Radio Telemetry Development
  – UAV radio relay (400 ft pole for antenna)
  – Environment mapping, DOA, and estimated tag localization
- Technology Dissemination
  – Website development
    - System design (plans, tutorials)
    - Open source software and firmware
- Future Work
  – Automated localization/path planning implementation
  – Synthesis of data analysis (easy field use)

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Current Issues

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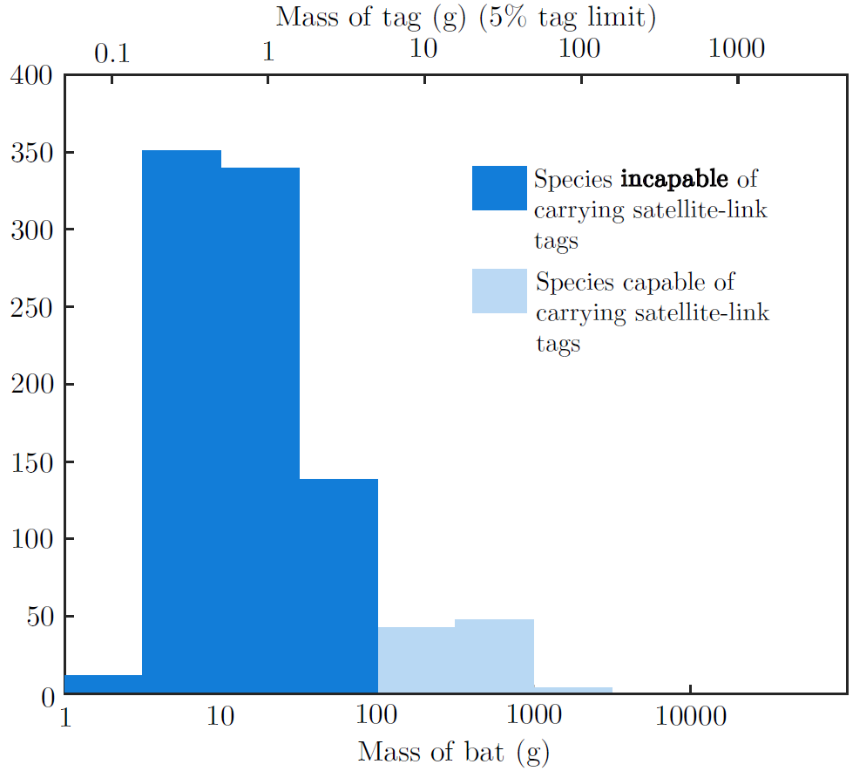
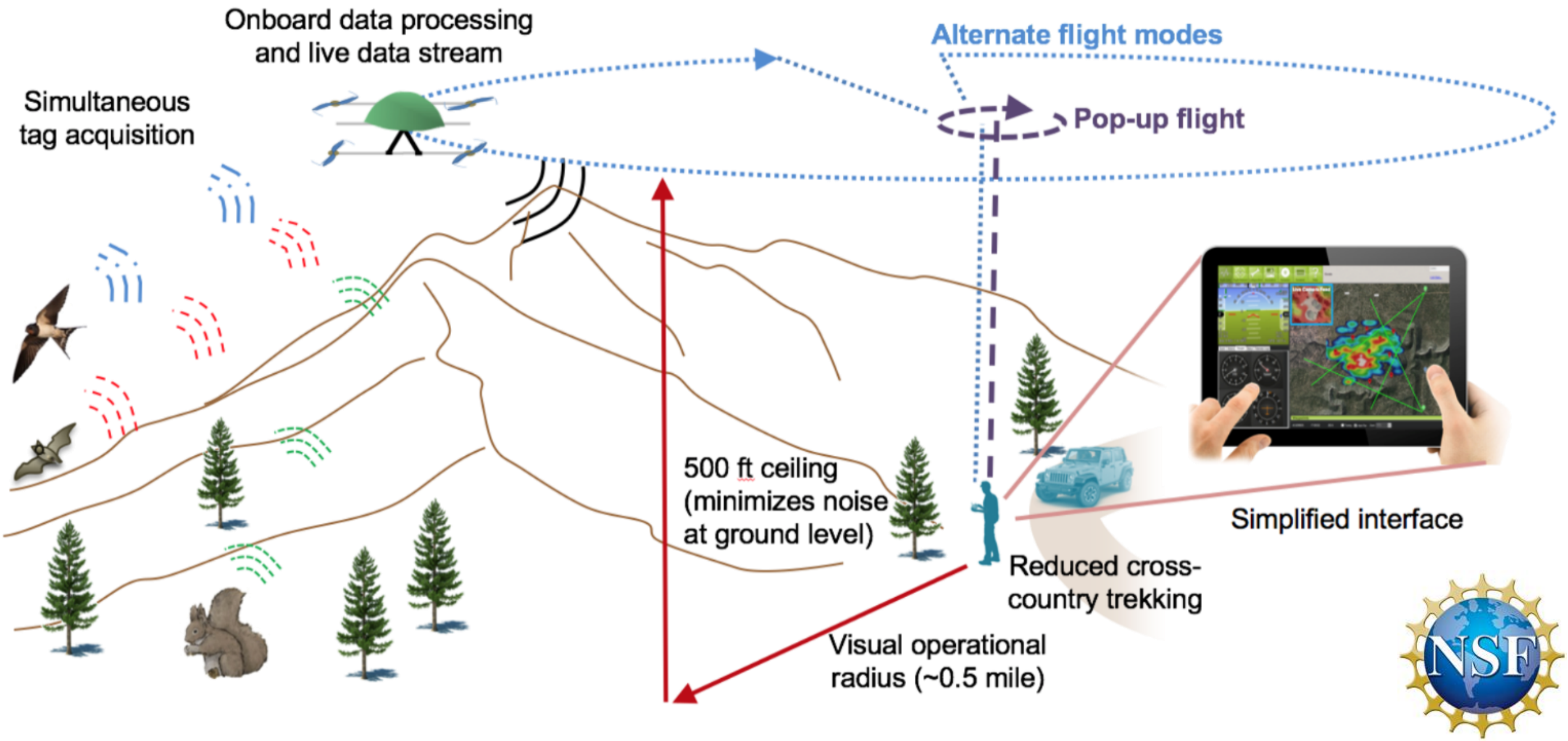
- Current search methods are inefficient
  - Limited access to rough terrain
  - Dangerous and costly manned aircraft searches
  - Timely cross-country hiking
- GPS tags present additional cost and weight



UAV-Radio Telemetry Research Program

- Collaboration: biologists, electrical & mechanical engineers
- Final system will integrate autonomous flight capability with onboard data processing
- Improved mobility and vantage point



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Packable Design

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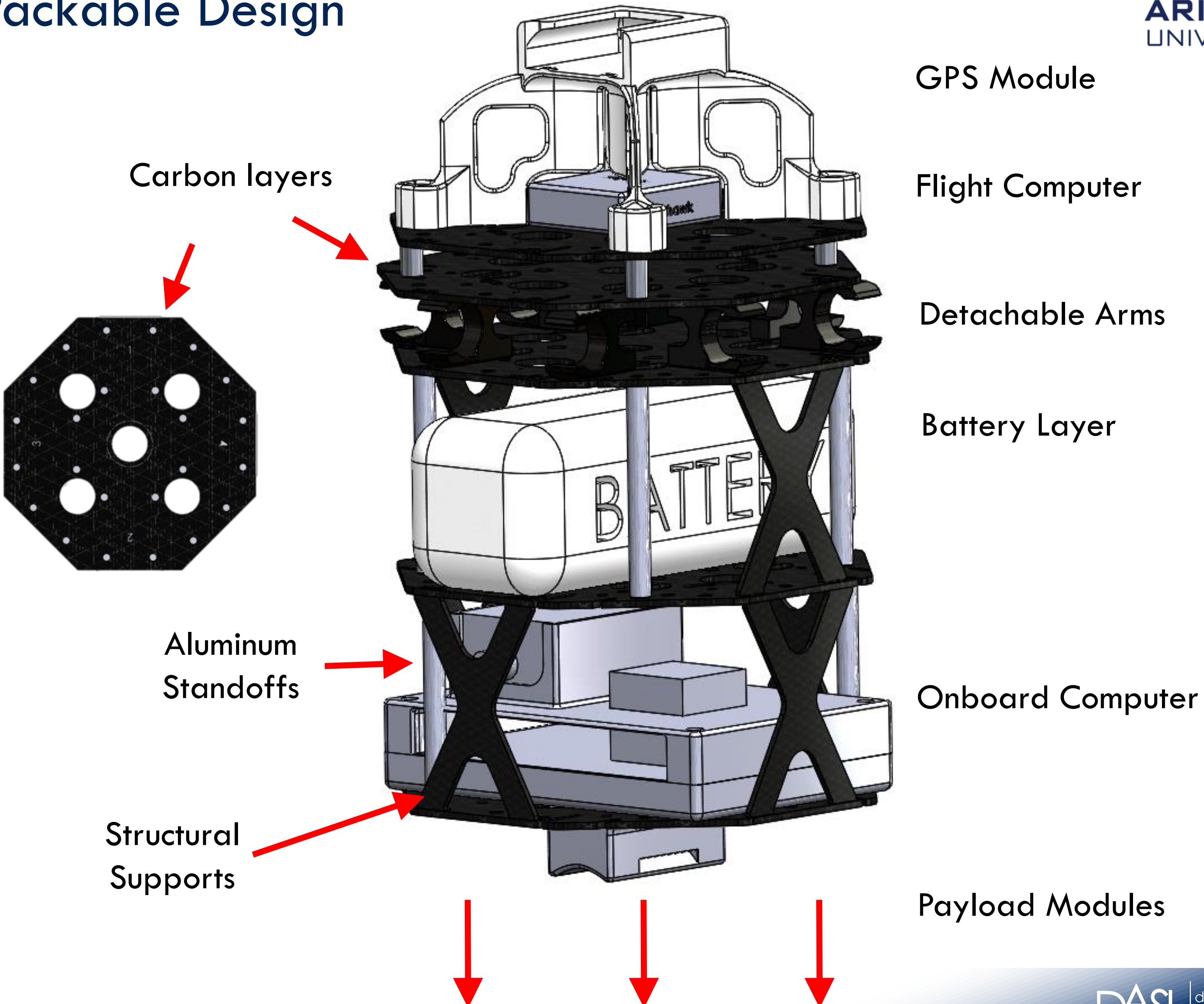
Packable Design



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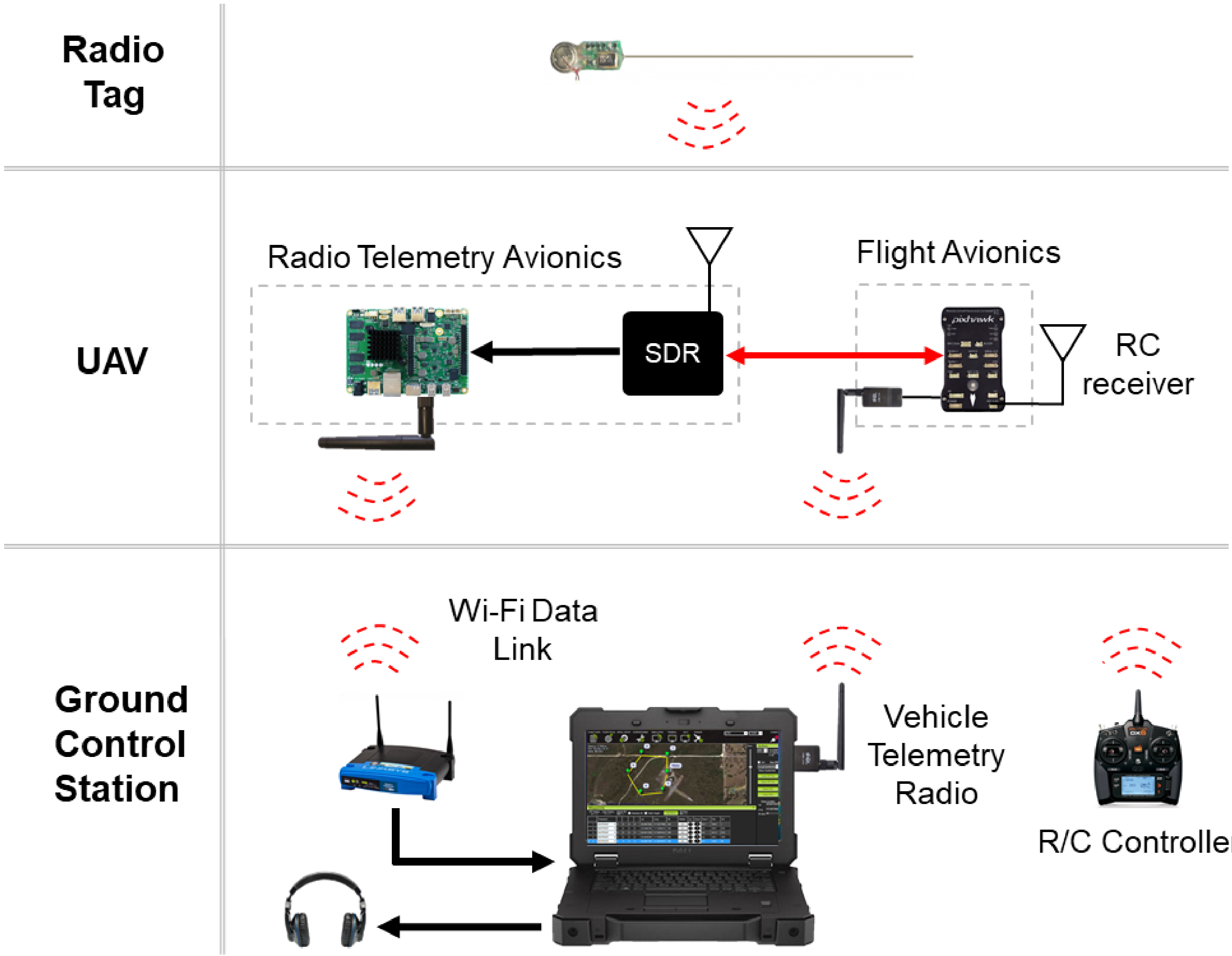
System Overview



GNU Radio Flowgraph

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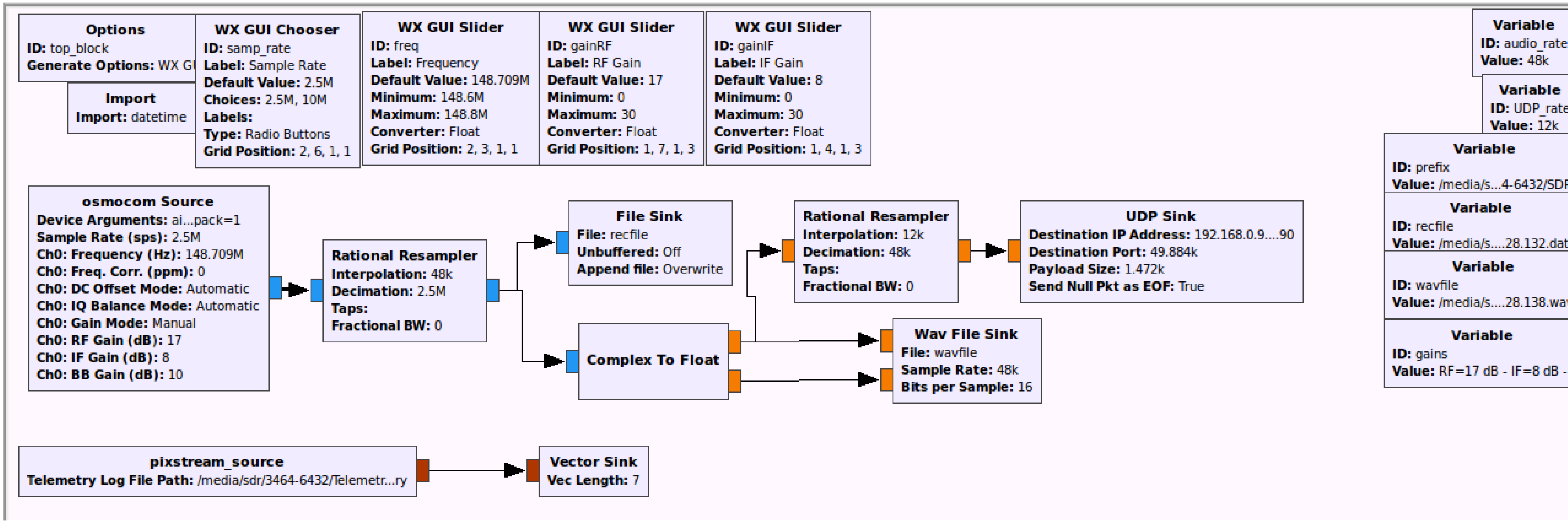


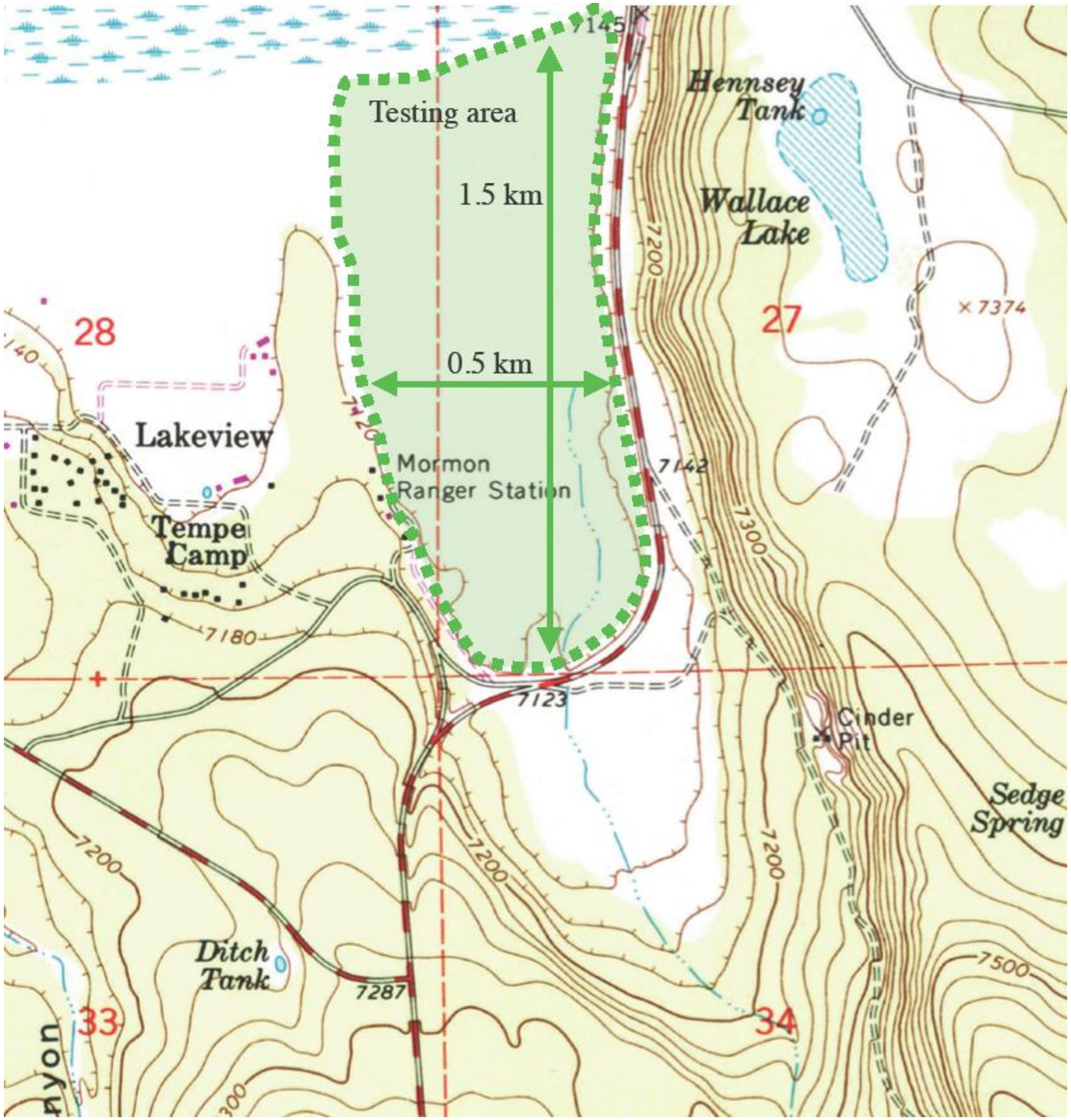
- GNU radio software used with Airspy (SDR front end)
- Software used to input and store incoming signal from beacon

Image credit: https://airspy.com/airspy-r2/

Current Test Design

Ground Station

Lake Mormon Testing Site



Flight video – Search Method

DOA Estimation

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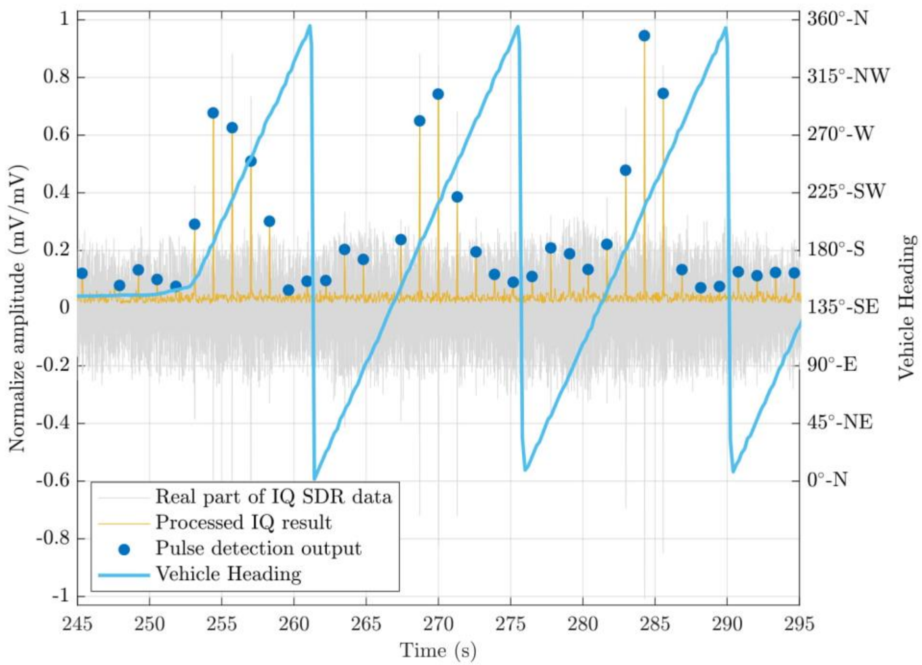
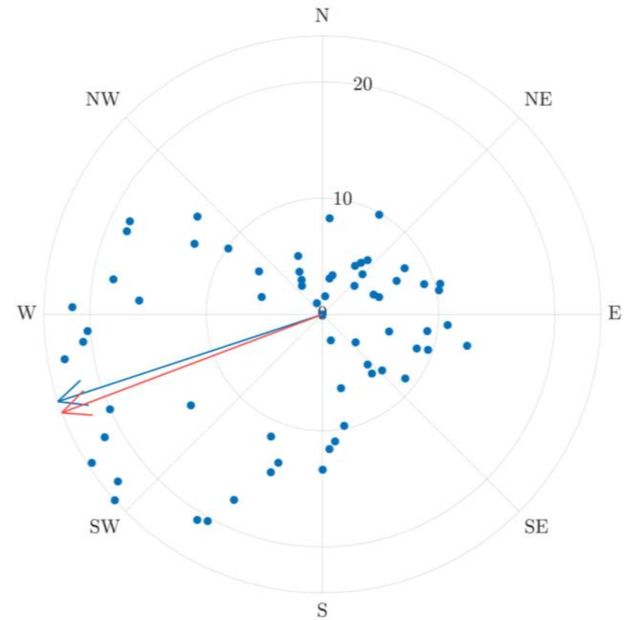
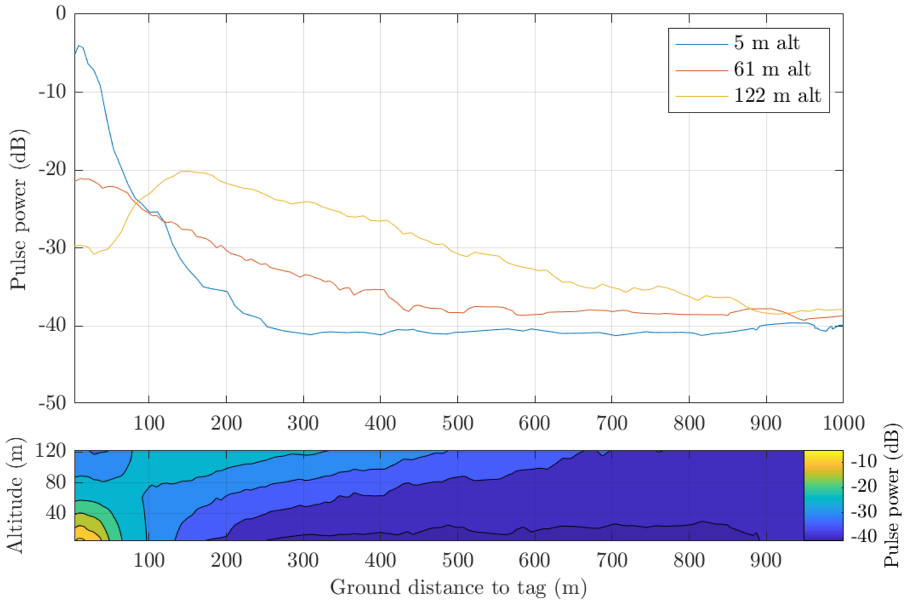




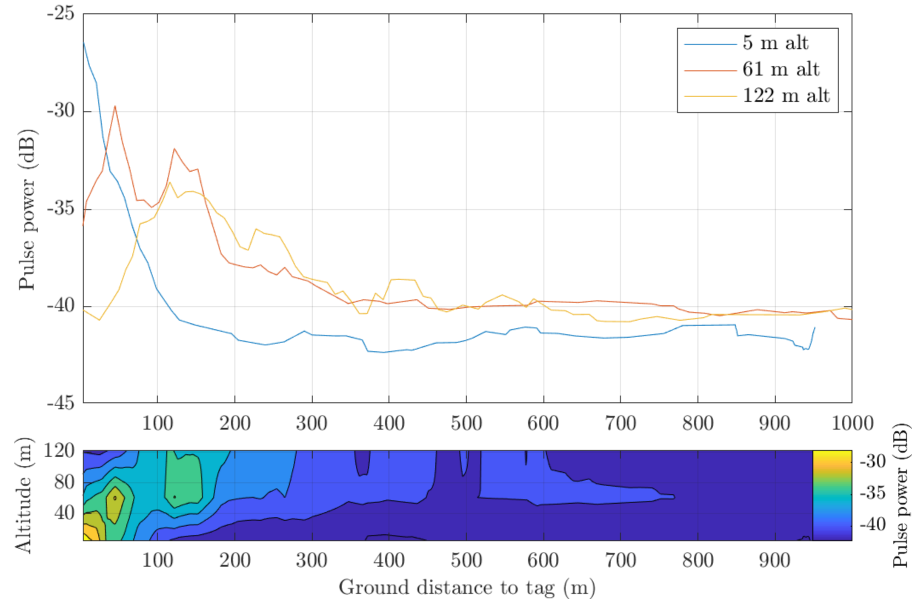
Data processing stages:

1. Raw Data (grey)
2. Data Filtered
3. Maximus determined (yellow)
4. Pulses Detected (blue dot)
5. Matched to Vehicle Heading (blue)
6. Bearing Estimation (blue arrow)

Range Test (Characterizing System)



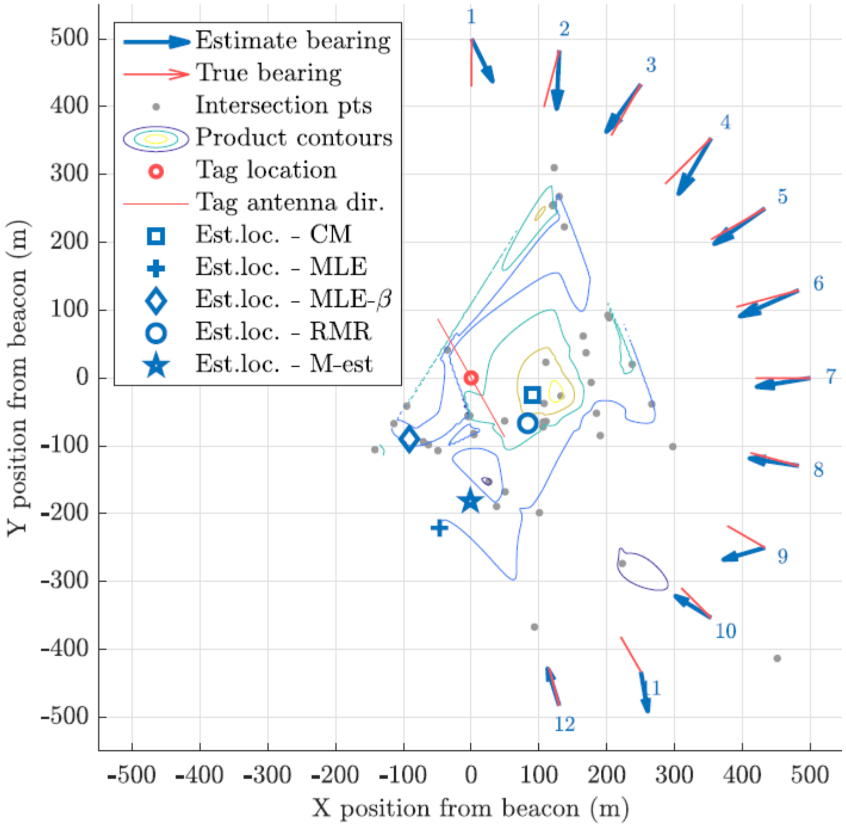
Horizontal Beacon

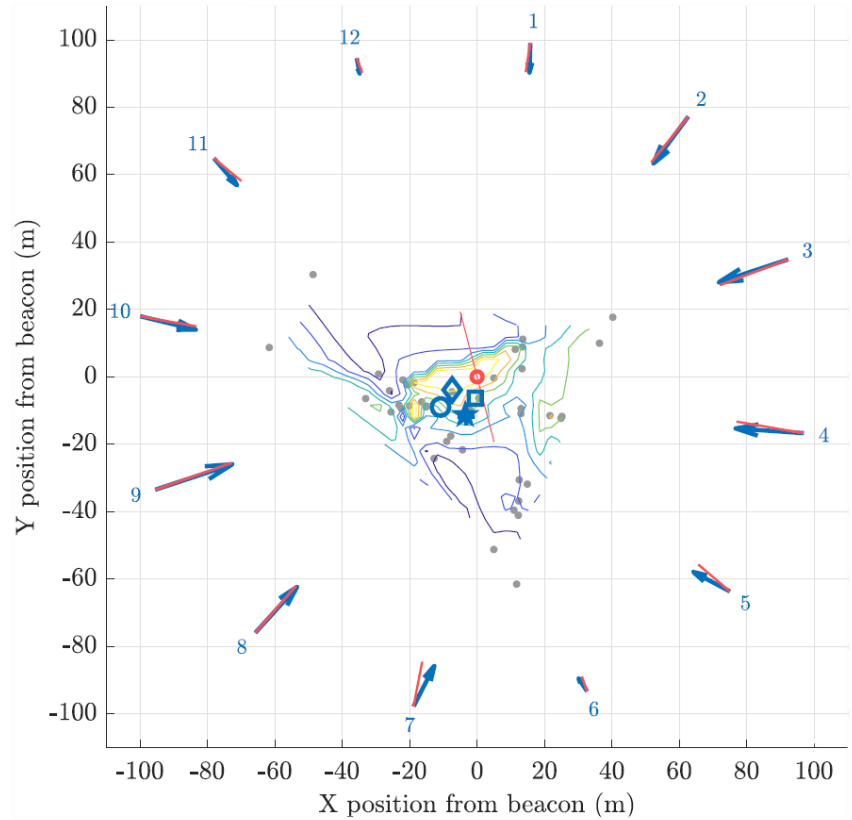


Vertical Beacon

- Received signal stronger with horizontal tag orientation
- System detects pulses without issue up to 1km
  - Detection algorithm still being optimized
  - Able to hear and see pules intermittently at 1.5 km ≈ 0.93 miles
- Detected pulse strength depends on alt, distance, and beacon antenna orientation.

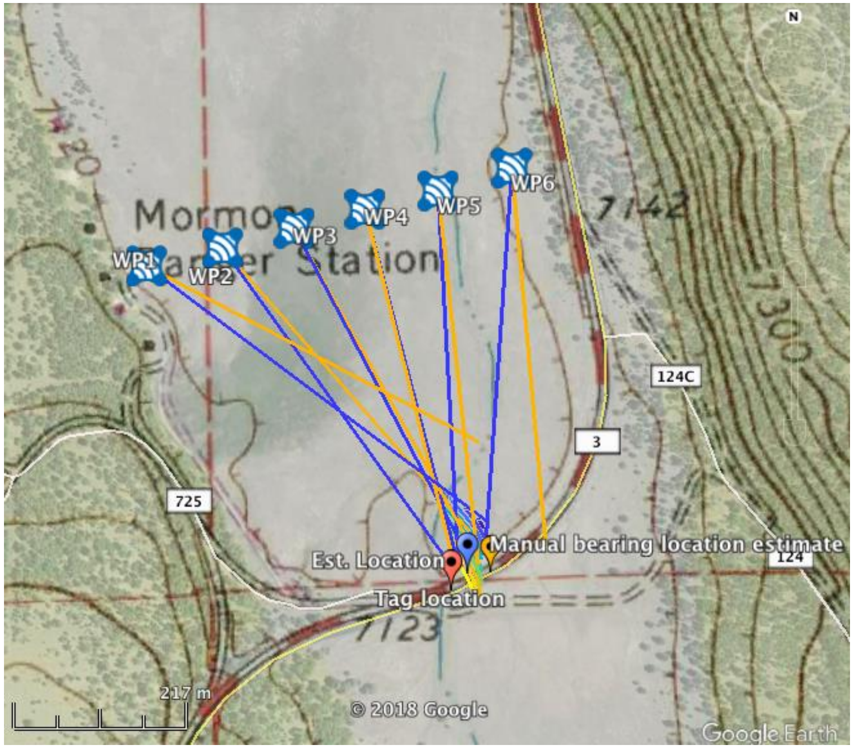
Localization Results

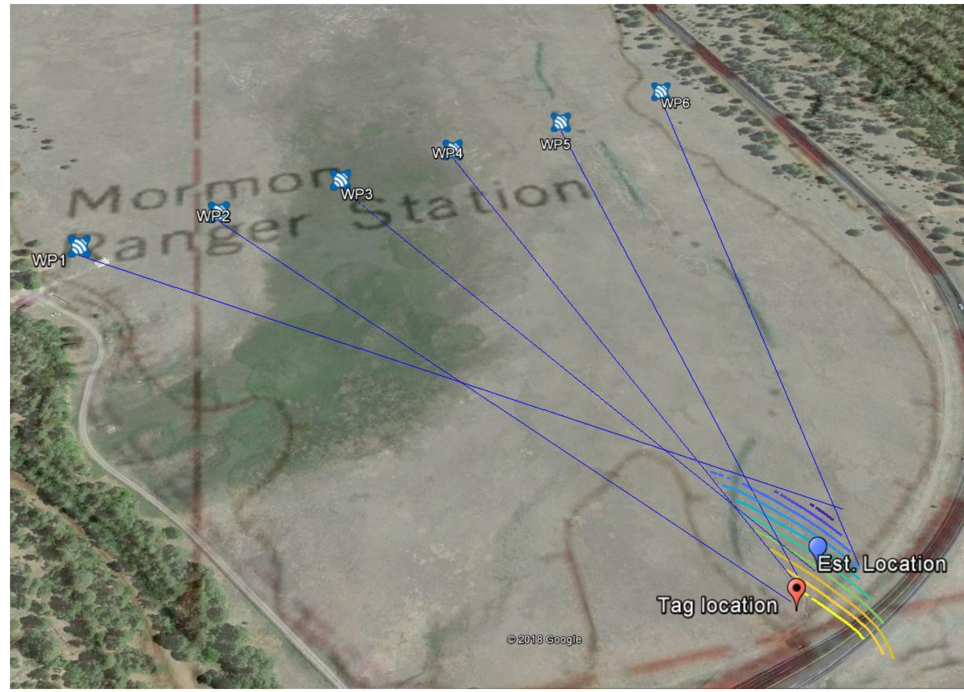




Flight info				Bearing Error		Localization Error					
Tiral Descrip.	Dist. (m)	Alt. (m)	Waypoints	Median	Std. Dev.	CM (m)	MLE (m)	MLM-Ɓ (m)	RMR (m)	M-est (m)	Avg. (m)
UAV: 1/2-Circ	500	75	12	9.3°	43.8°	94 19%	226 45%	128 26%	107 21%	181 36%	147 29%
UAV: Circ	100	15	12	6.7°	5.2°	6 6%	12 12%	8 8%	14 14%	12 12%	11 11%

Human vs Drone Results





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UAV: Line	500	122	6	2.3°	2.9°	34 6%	32 6%	22 4%	19 4%	31 6%	28 5%
UAV: Line	500	61	6	2.4°	2.9°	32 6%	35 7%	25 5%	11 2%	35 7%	28 5%
Humman: Line	500	2	6	5.1°	6.3°	N/A	71 13%	52 10%	80 15%	74 14%	69 13%

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Website Overview

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- Website developed to provide overview of system and detailed design and software dissemination
- Provides summary of project goals and is being optimized to create an open source environment so users can create and modify their own system

https://www2.nau.edu/uavrt-p/

Website Overview

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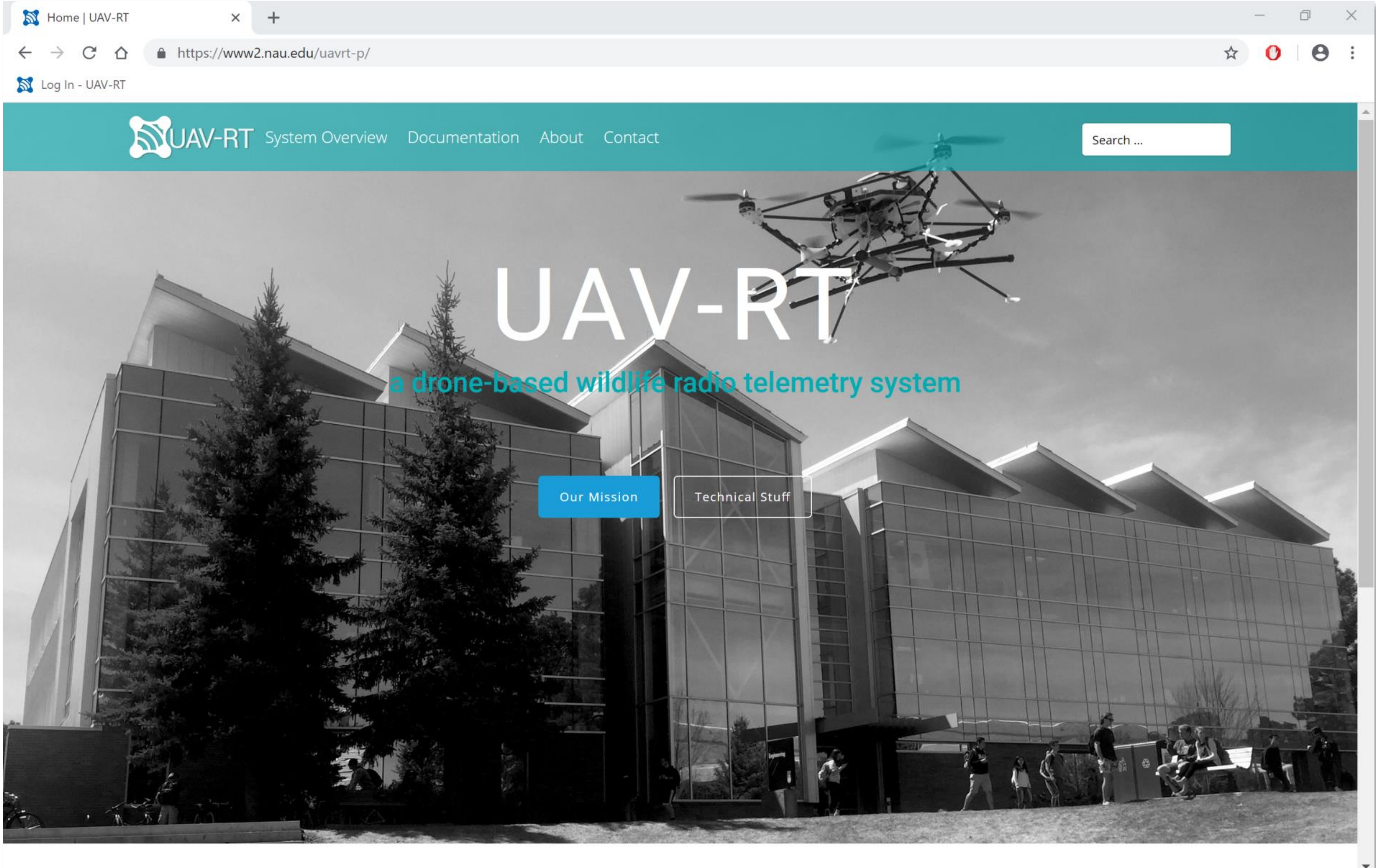

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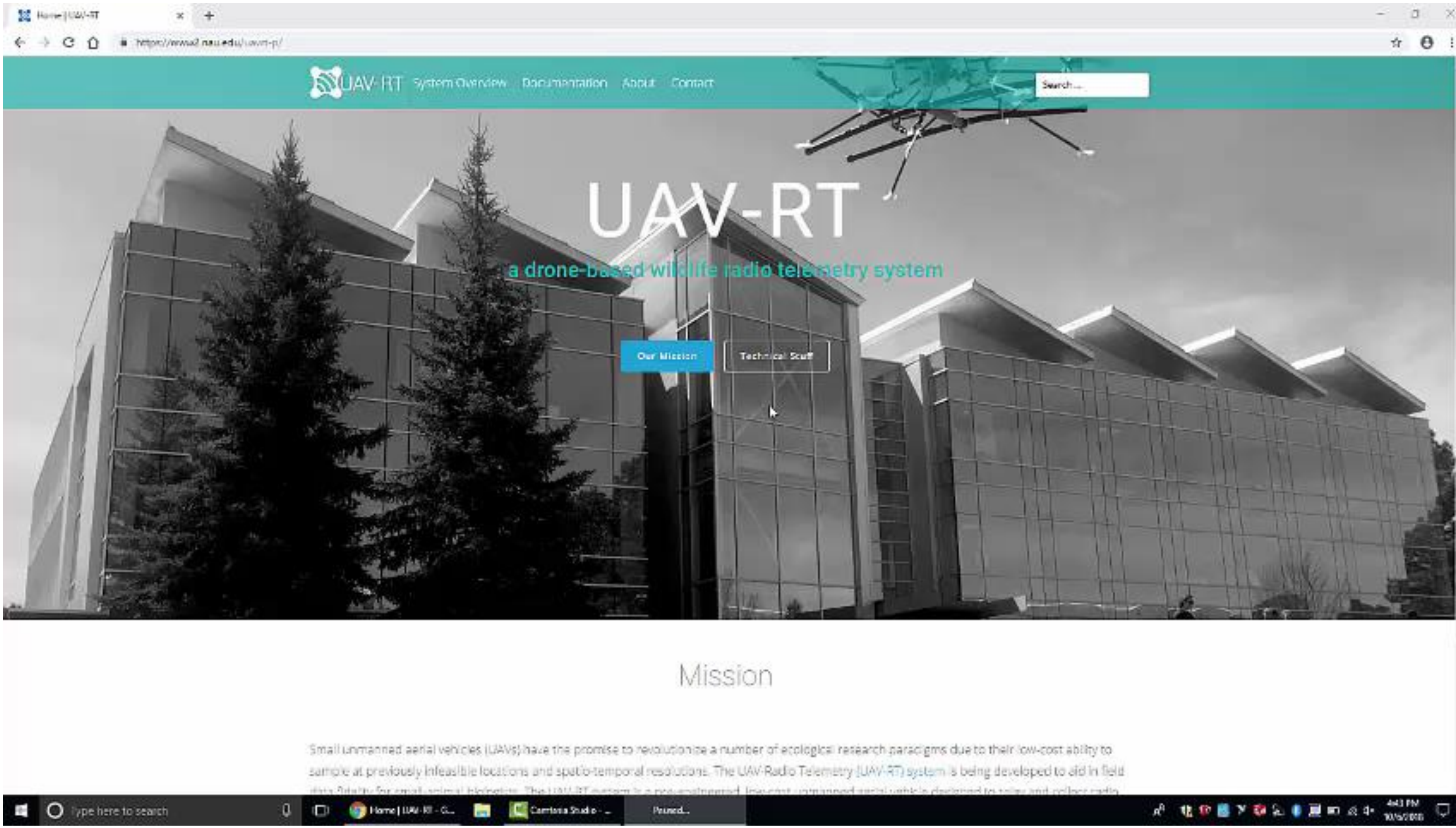

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Applying Automation

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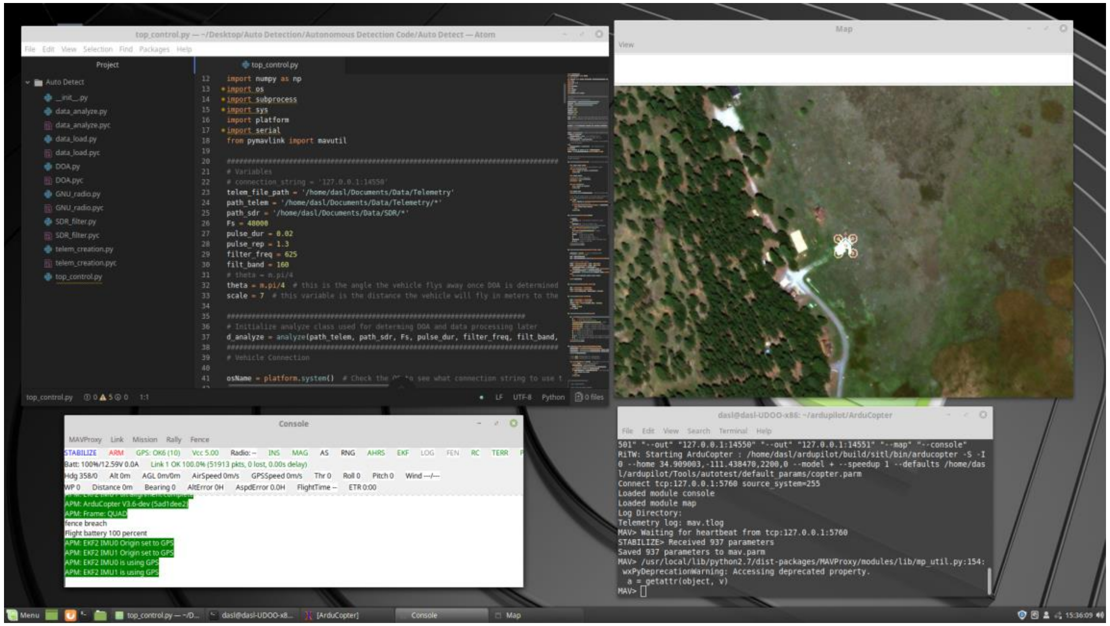
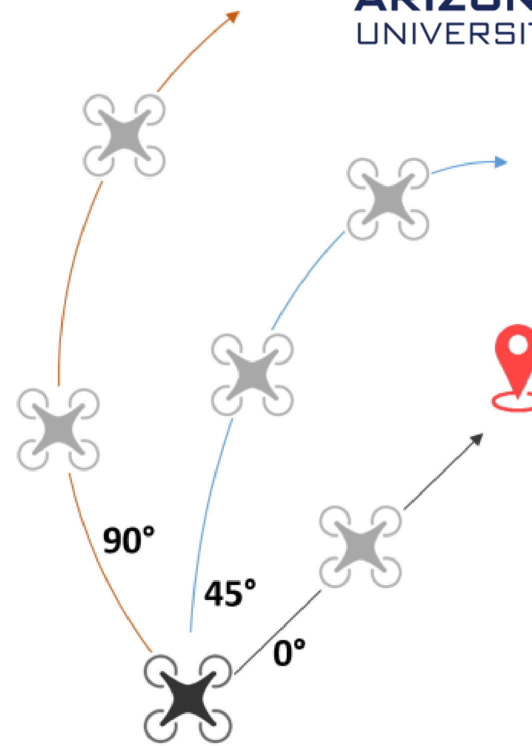


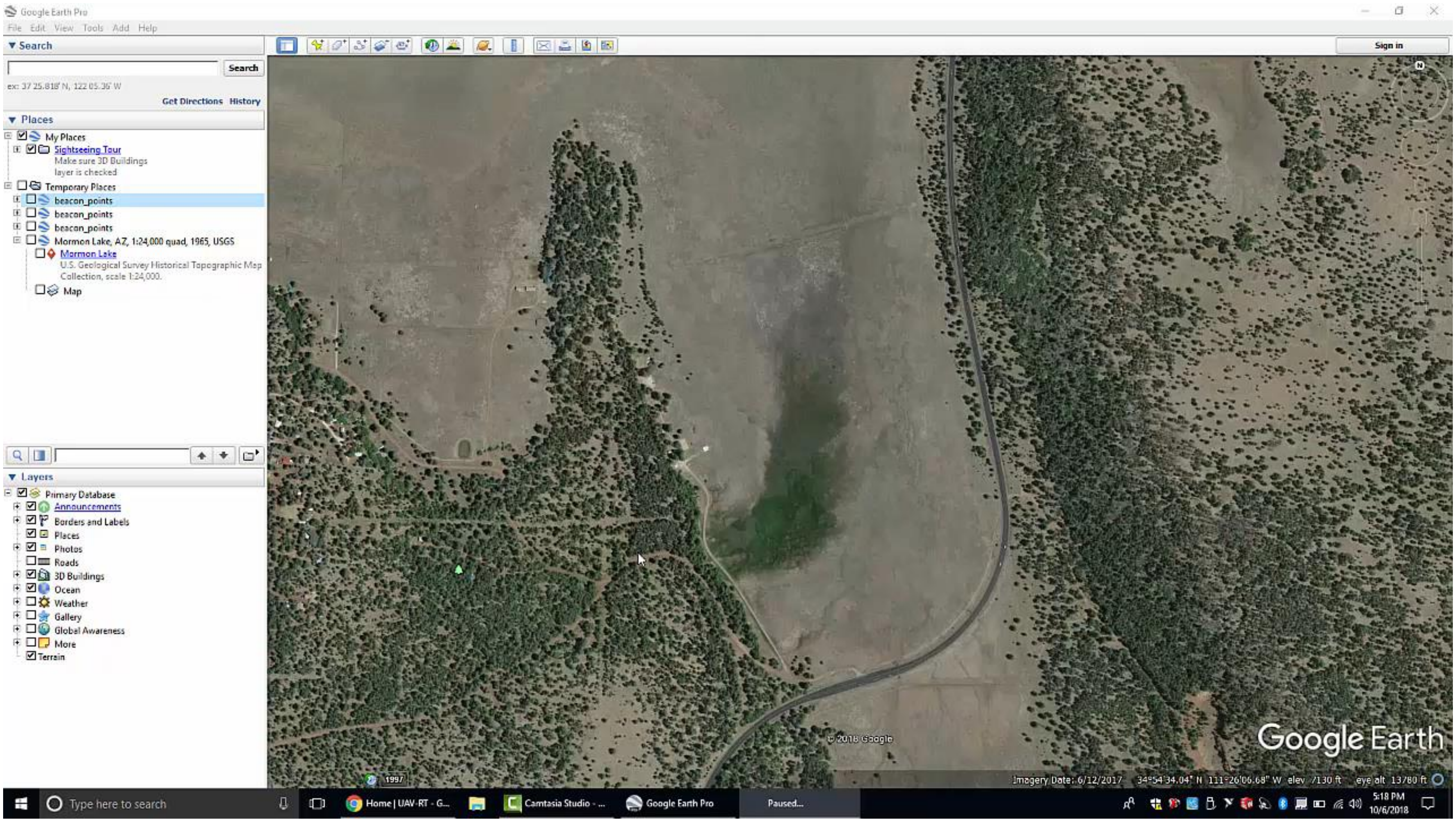


- Currently testing automated localization techniques
- System capable of localizing beacons during flight
  - Vehicle moves in response to initial estimate seeking to improve localization estimate
- Successfully simulated system
  - Currently addressing issues with live drone tests

Field Use Ready

- Synthesizing real-time DOA estimation and post processing visualization
- Designing easy to use software and interfaces that can be used as an additional tool in the field
- Creating a closed loop system

Field Use Ready



Acknowledgments

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- Collaborators:
  - Michael Shafer, PhD
  - Paul Flikkema, PhD
  - Carol Chambers, PhD

- Student Researchers:
  - Gabriel Vega
  - Kellan Rothfus
- Past Researchers:
  - Amir Torabi
  - Matthew Robertson
  - Michael Finley

QUESTIONS?

Center of mass localization

- Based on weighted average of intersection.
- Weights are the product of the mean signal power of the lines generating the intersection point

$$\begin{bmatrix} X_{est} \\ Y_{est} \end{bmatrix} = \frac{1}{\sum_{i=1}^{m} b_i} \sum_{i=1}^{m} b_i \begin{bmatrix} x_i \\ y_i \end{bmatrix}$$

PCA for DOA estimates

$$\vec{P}_{a,i} = \begin{bmatrix} P_i \\ 0 \\ 0 \end{bmatrix}$$

$$\boldsymbol{R}_i = \boldsymbol{R_z}(\phi_v)\boldsymbol{R_y}(\theta_v)\boldsymbol{R_x}(\psi_v)\boldsymbol{R_z}(\phi_a)\boldsymbol{R_y}(\theta_a)\boldsymbol{R_x}(\psi_a)$$

$$\vec{P}_{e,i} = \boldsymbol{R}_i\vec{P}_{a,i}$$

$$\boldsymbol{P_e^*} = \begin{bmatrix} \vec{P}_{e,1}^T \\ \vec{P}_{e,2}^T \\ \vdots \\ \vec{P}_{e,n}^T \end{bmatrix}$$

$$\boldsymbol{P_e} = \left(\boldsymbol{I} - \frac{1}{n}\boldsymbol{J}\right)\boldsymbol{P_e^*}$$

$$\vec{P}_{avg} = \frac{1}{n}\boldsymbol{P}_e^T\vec{j};$$

$$\boldsymbol{P_e} = \boldsymbol{U\Sigma W^T}$$

$$\vec{w}_p = \frac{\vec{P}_{avg} \cdot \vec{w}_1}{\|\vec{P}_{avg}\| \, \|\vec{w}_1\|}\vec{w}_1$$

Bearing error study