LAAIRS Precision Landing

GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF AEROSPACE AND MECHANICAL ENGINEERING
The UNIVERSITY *of* OKLAHOMA

The Team



Project Members:
(*Left to Right*)
Jesse Hodgson
Hudson Brooks
Brady Owens
Sarah Kemppainen

Project Sponsor:
Tony Segales
Faculty Advisor:
Dr. Srikanth Bashetty

What is LAAIRS?

The Laboratory for Advanced Atmospheric Investigation using Robotic Sondes

A program in the National Weather Center to use drones as atmospheric samplers.

The Problem
- Weather Balloons only sample the atmosphere twice a day
- The atmospheric boundary layer (ABL) is highly dynamic
- A severe lack of data in the ABL makes weather models inaccurate

The Objective
- Solve the data gap by creating an autonomous vertical atmospheric profiler

The Solution – **CopterSonde**
- A high-performance drone capable of collecting hundreds of atmospheric samples a day.
- The end goal is a fleet of drones across the country providing data to improve weather models.



LAAIRS Mission Objectives
1. ***Integrate precision landing***
2. Integrate automated charging
3. Advance CopterSonde autonomy

Objectives

- Turn UWB sensors into a localized 3D positioning system (LPS)
- Create a GUI to display drone position
- Create a straightforward and user-friendly interface
- Filter data to obtain more accurate results
- Send commands to the drone to land
- Perform consistent precision landings using the LPS within 2.25 m²

Constraints

- Must use Makersfab ESP 32 UWB boards
- Must autonomously land in harsh weather and winds up to 75mph
- Requires high precision to land on a 1.5x1.5 meter landing pad
- Consume minimal amounts of power, weight, and space on the drone
- Minimize per-unit cost to make mass adoption easier

Materials

- Makersfab ESP32 UWB Boards x5
- Tripods: 3 short, 1 tall
- 20ft Micro-USB cables x4
- 4 Port USB-A Hub
- 3D printed Anchor Housing x4



Estimated Final Cost: $430

Engineering Standards

I. FCC Title 47 CFR Part 15 Subpart F
II. FAA Part 107, Part 135

Project Overview

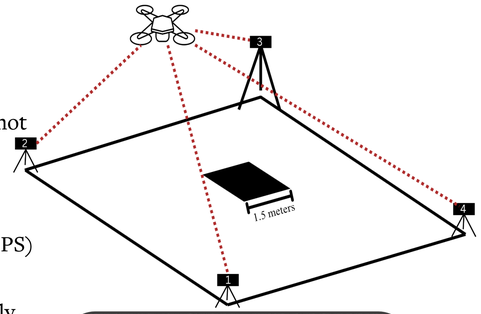
The **CopterSonde** weather drone is a fully autonomous vertical atmospheric profiler that functions similarly to a weather balloon.

The Problem: The current GPS landing system is not precise enough to land on the charging pad consistently.

The Solution: Use Radio-Based **Ultra-Wideband** technology to create a local positioning system (LPS) to guide the drone home.

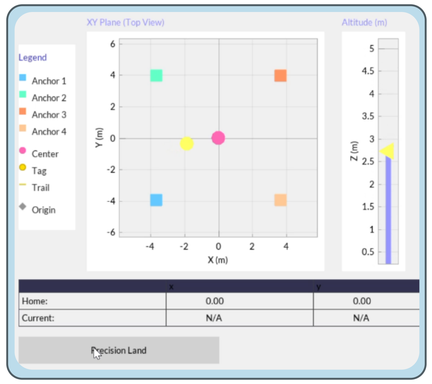
Success Criteria: CopterSonde lands autonomously and reliably in a 1.5 by 1.5 sq. meter area.

Impact: Brings CopterSonde closer to being a fully autonomous system. Deployment of CopterSonde will significantly increase atmospheric data, improving weather models and making way for a more predictable future.





Positioning



Tested Systems:
- Multiple Trilateration algorithms
- Tuning Exponential Moving Average filter responsiveness
- Tuning Kalman Filter prediction
- Optimal Anchor configuration and layout
- UWB susceptibility to interference and loss of connection
- Anchor serial connection and optimization

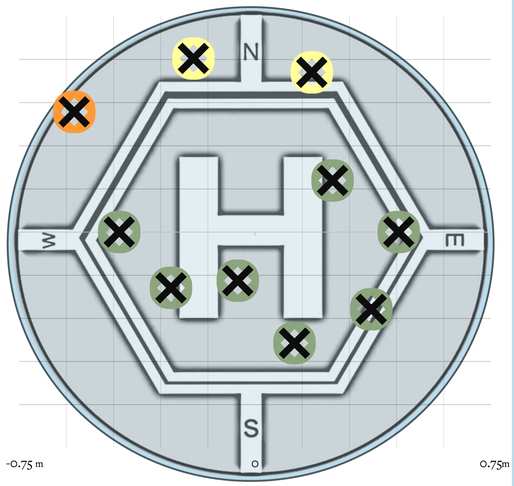
Testing Procedure:
- Set up anchors in the grid
- Tag (yellow) was moved around the grid freely
- Tag was placed at known locations and compared on the GUI to where the drone "thinks" it is
- Data was collected and analyzed, informing future improvements

Landing

Landing System
- GPS brings the drone within UWB range
- Flight computer converts the LPS 3D position into degrees of latitude and longitude
- Commands the drone to move from its current position to the updated latitude and longitude
- Updated move commands are sent while the drone lands

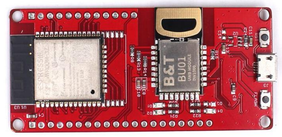
Landing Performance
- Consistently achieving landings an average of 0.45 meters from the center of the launch pad
- The figure on the right shows the landing location of 10 consecutive successful landings
- Landings occurred in high wind conditions
- Significantly outperforms GPS landings

Landing Data



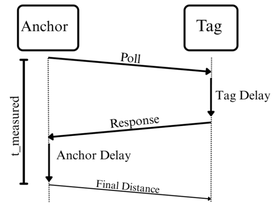
Ultra-Wideband Sensor

Makersfab ESP 32 Ultra-Wideband Sensor
- Finds distance from a stationary anchor to a mobile tag
- Uses the signal **time of flight** to calculate the distance
- Ultra-Wideband: Radio waves >500 MHz
- Low Data Rate: 150 kilobits/s

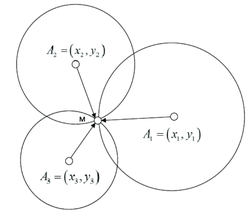


Testing findings
- Theoretical high precision and accuracy (<5 cm error)
- Obstacles can cause 50+ cm of error
- Limited range: ~40 meters

Anchor Calibration
- Every ESP 32 board has its own unique internal delay
- Enclosed housings cause a consistent delay
- Calibration removes delays from the distance calculation

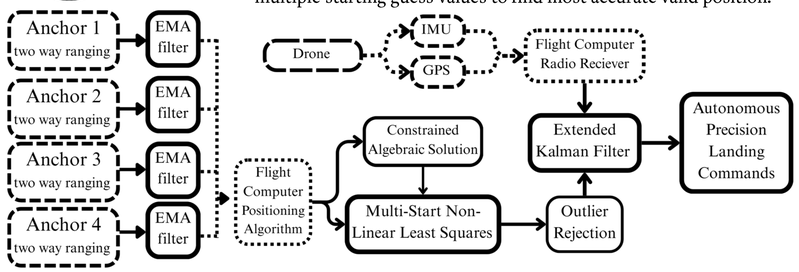


Positioning & Filtering



The local positioning system works similarly to GPS, using only the distance from 4 ground-based anchors to a tag on the drone.

3D trilateration is an overdetermined system, meaning any error in the sensors will lead to no possible algebraic solution.
Tested Algorithms:
Algebraic, Linear Least Squares, Weighted Least Squares
Final Algorithm:
Multi-start Non-Linear least squares: An iterative method with multiple starting guess values to find most accurate valid position.



Filtering algorithms to remove measurement error of the UWB range readings
- Exponential Moving Average (EMA) Filter: averages sections of raw data and weighs the most recent data heaviest to filter random noise
- Kalman Filter: a predictive algorithm that utilizes physics to determine where the drone can physically be
- Outlier Rejection: Removes any obviously erroneous positions from progressing

Design Process

Phase I
- Research
- UWB Calibration
- Data Filtering
- Anchor Housing
- UWB Testing

Phase II
- Trilateration
- Anchor Configuration
- Positioning System GUI
- Ground Testing

Phase III
- Multi-Start Trilateration
- Landing Commands
- Flight Testing