

Electrical Engineering Capstone Design Project

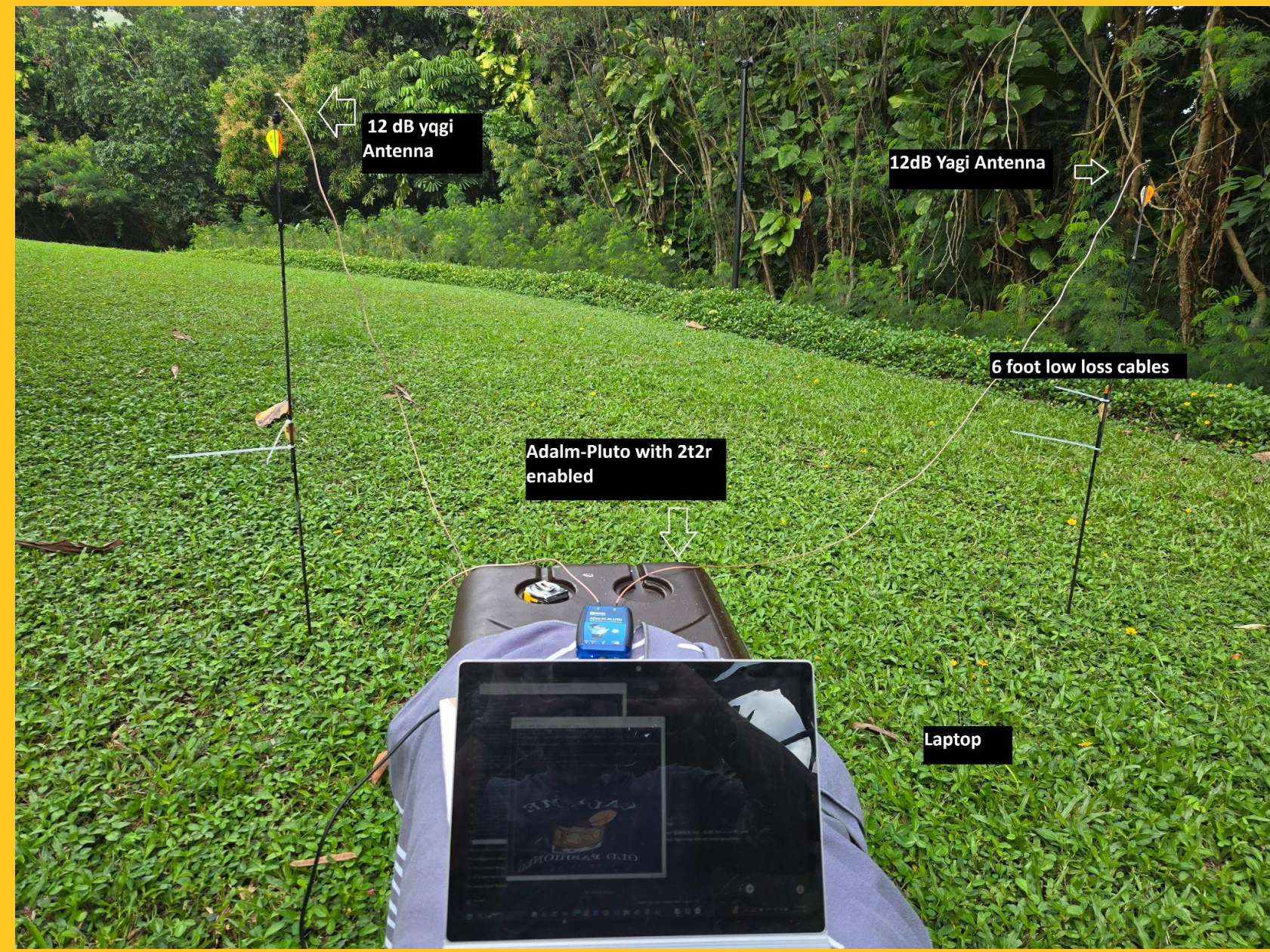
Drone Detection Using Active Radar

Spring 2026



Team 21

Neil Carroll
 Kenneth Matt Jefcoats
 Dustin Weatherly
 Riley Cabanero
 Mentor: Dr. David Allee

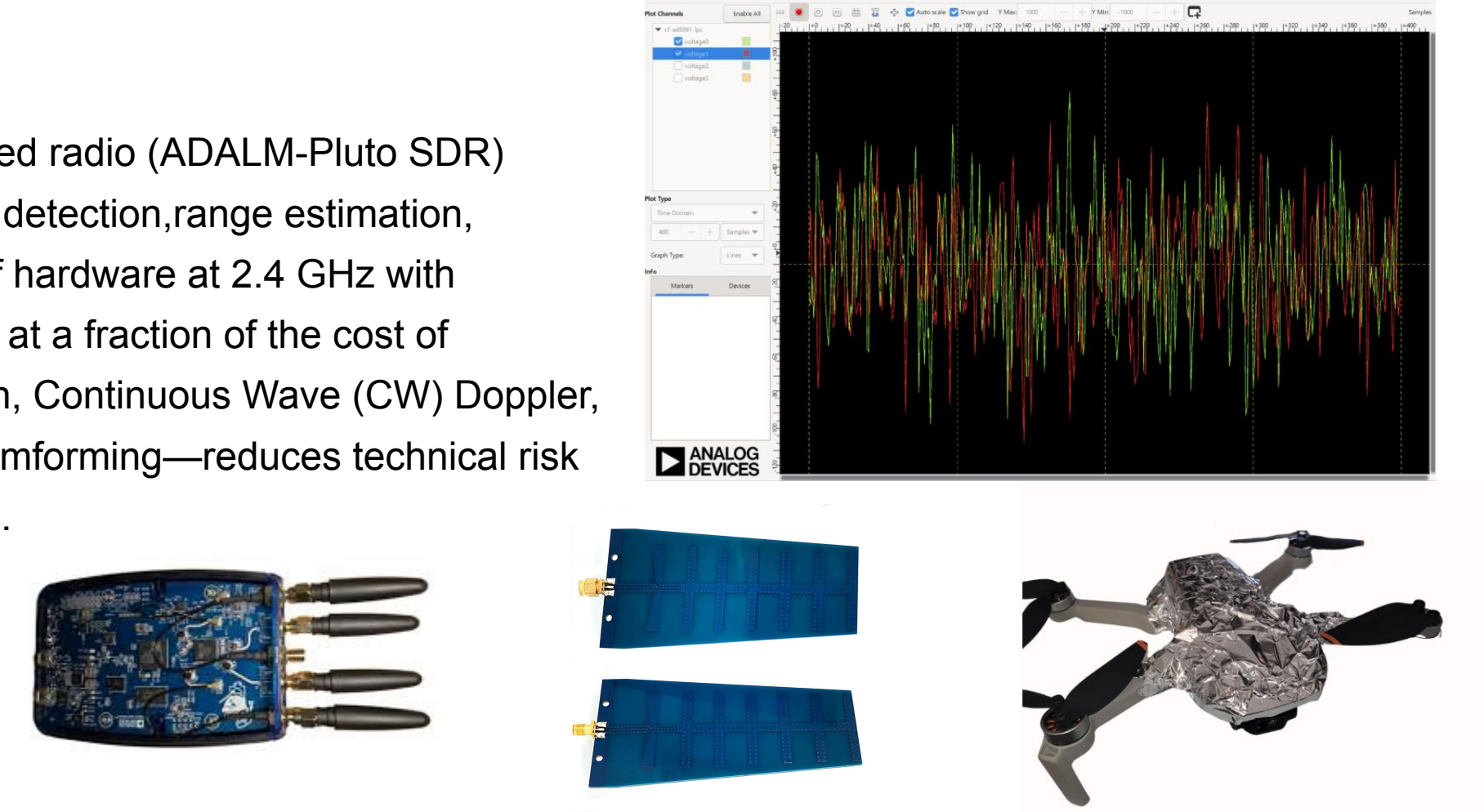


PROJECT GOAL

The rapid growth of small unmanned aerial vehicles (drones) around critical infrastructure, airports, industrial sites, and public venues has created a strong need for low-cost, compact radar systems.

This project demonstrates that a general-purpose software-defined radio (ADALM-Pluto SDR) can be configured as a functional active radar capable of motion detection, range estimation, and directional (angle-of-arrival) sensing. Using only off-the-shelf hardware at 2.4 GHz with 12 dBi Yagi antennas, the system replicates core radar functions at a fraction of the cost of commercial solutions. The phased approach—baseline validation, Continuous Wave (CW) Doppler, Stepped Frequency Continuous Wave (SFCW) ranging, and beamforming—reduces technical risk while proving low-cost SDR radar is achievable and reproducible.

- Key Advantages**
- Extremely low cost (~\$325 hardware)
 - Fully software reconfigurable (Python + libio)
 - Portable foundation for future drone-specific features



TESTING RESULTS & WORK COMPLETED

Baseline Validation (Completed)

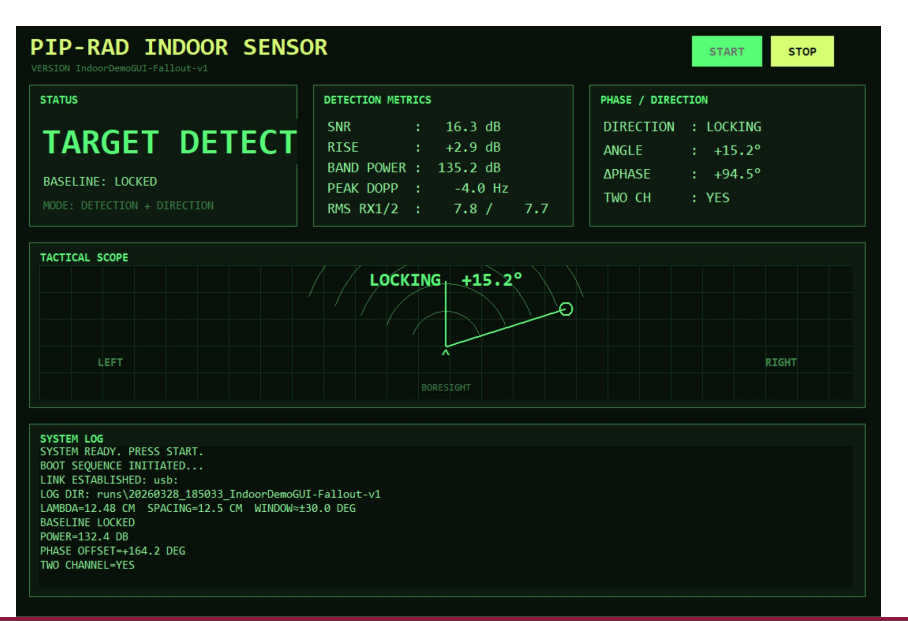
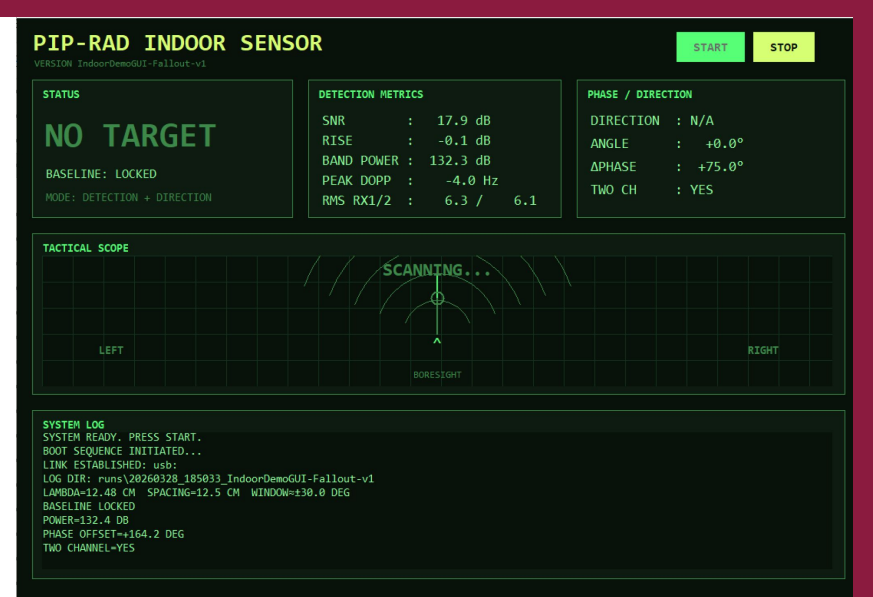
- Transmitter verified with Viavi CX300 service monitor
- Antenna isolation testing: ~20 dB at 1 ft → >26 dB at 8 ft with cross-polarization
- Noise floor and internal coupling fully characterized indoors and outdoors

Continuous Wave Doppler Radar (Fully Functional)

- Reliable motion detection using metal targets indoors and outdoors
- Python pipeline: libio → Butterworth filtering → FFT → peak detection above noise floor
- Successfully distinguishes real reflections from leakage

Ranging Progress

- FMCW: flat range profile (limited bandwidth + sync issues) → abandoned
- SFCW: implemented; indoor testing inconsistent due to multipath



SYSTEM DESIGN

Hardware Platform

- ADALM-Pluto SDR with unlocked 2T2R firmware (AD9361-based)
- 12 dBi directional Yagi antennas @ 2.4 GHz
- Transmit buffer set to 2¹⁴ for full DAC amplitude



Phased Technical Approach

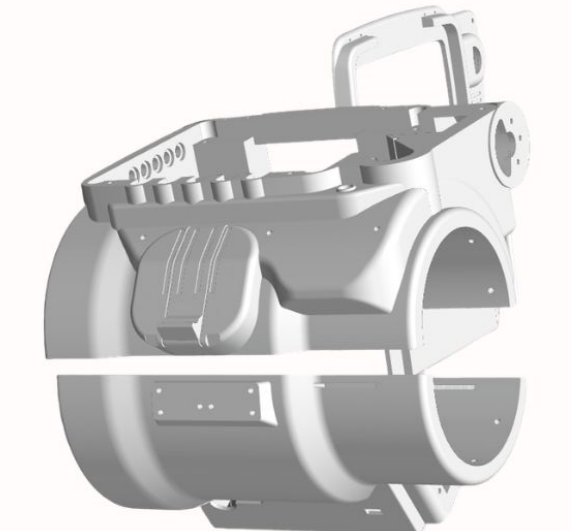
- Continuous Wave (CW) Doppler** – baseline motion detection via FFT and peak detection
- Ranging** – FMCW attempted then abandoned; pivoted to **Stepped Frequency Continuous Wave (SFCW)**
- Direction Finding (stretch goal)** – one-transmit, two-receive beamforming using phase difference

Primary Technical Challenge:

The Pluto is a general-purpose SDR, not a dedicated radar front-end. Rigorous baseline validation of transmitter operation, antenna isolation (>26 dB), noise floor, and synchronization was required before advancing to ranging or beamforming.

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MS OUTPUT DEBUG CONSOLE TERMINAL PORTS
Power 125.4 rise=+8.4 SNR= 16.8 pk= ~8Hz rms= 4.7 mVx= 9.8
Power 124.1 rise=-8.9 SNR= 15.5 pk= -12Hz rms= 4.6 mVx= 9.5
Power 125.3 rise=+8.3 SNR= 19.9 pk= -12Hz rms= 4.6 mVx= 8.1
Power 127.5 rise=+2.5 SNR= 19.7 pk= -8Hz rms= 4.6 mVx= 8.2
Power 124.6 rise=-8.4 SNR= 14.2 pk= -4Hz rms= 4.7 mVx= 11.0
Power 126.2 rise=+1.2 SNR= 28.4 pk= -4Hz rms= 4.6 mVx= 9.5
Power 124.0 rise=-1.8 SNR= 11.8 pk= -4Hz rms= 4.5 mVx= 7.8
Power 123.9 rise=-1.1 SNR= 14.4 pk= -4Hz rms= 4.3 mVx= 18.4
Power 124.3 rise=-0.7 SNR= 14.2 pk= -4Hz rms= 4.3 mVx= 8.0
Power 129.7 rise=+4.7 SNR= 26.5 pk= -8Hz rms= 5.0 mVx= 18.6
Power 131.5 rise=+6.5 SNR= 27.2 pk= -4Hz rms= 3.7 mVx= 12.5
Power 128.4 rise=+3.4 SNR= 26.4 pk= -4Hz rms= 3.7 mVx= 11.7
Power 128.2 rise=+3.2 SNR= 24.9 pk= -8Hz rms= 3.3 mVx= 18.4
Power 132.6 rise=+7.6 SNR= 27.8 pk= -4Hz rms= 3.4 mVx= 15.8
    
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SUMMARY & FUTURE WORK

The team has successfully established a verified low-cost CW Doppler radar baseline using the ADALM-Pluto SDR. Motion detection has been reliably demonstrated both indoors and outdoors.

Remaining Work (Spring 2026)

- Implement dual-channel capture for beamforming (angle-of-arrival)
- Develop real-time detection visualization interface
- Design and 3D-print compact enclosure
- Conduct outdoor validation with actual drone targets
- Final system integration and Capstone Showcase demonstration

Stretch Goal

If beamforming succeeds, the system will provide approximate 2D target location (range + direction).

Conclusion

This project proves that a disciplined, phased SDR-based radar approach can deliver functional drone-detection capability at very low cost. The completed CW baseline, combined with planned beamforming and packaging, creates a solid, reproducible foundation for future low-cost radar sensing applications.