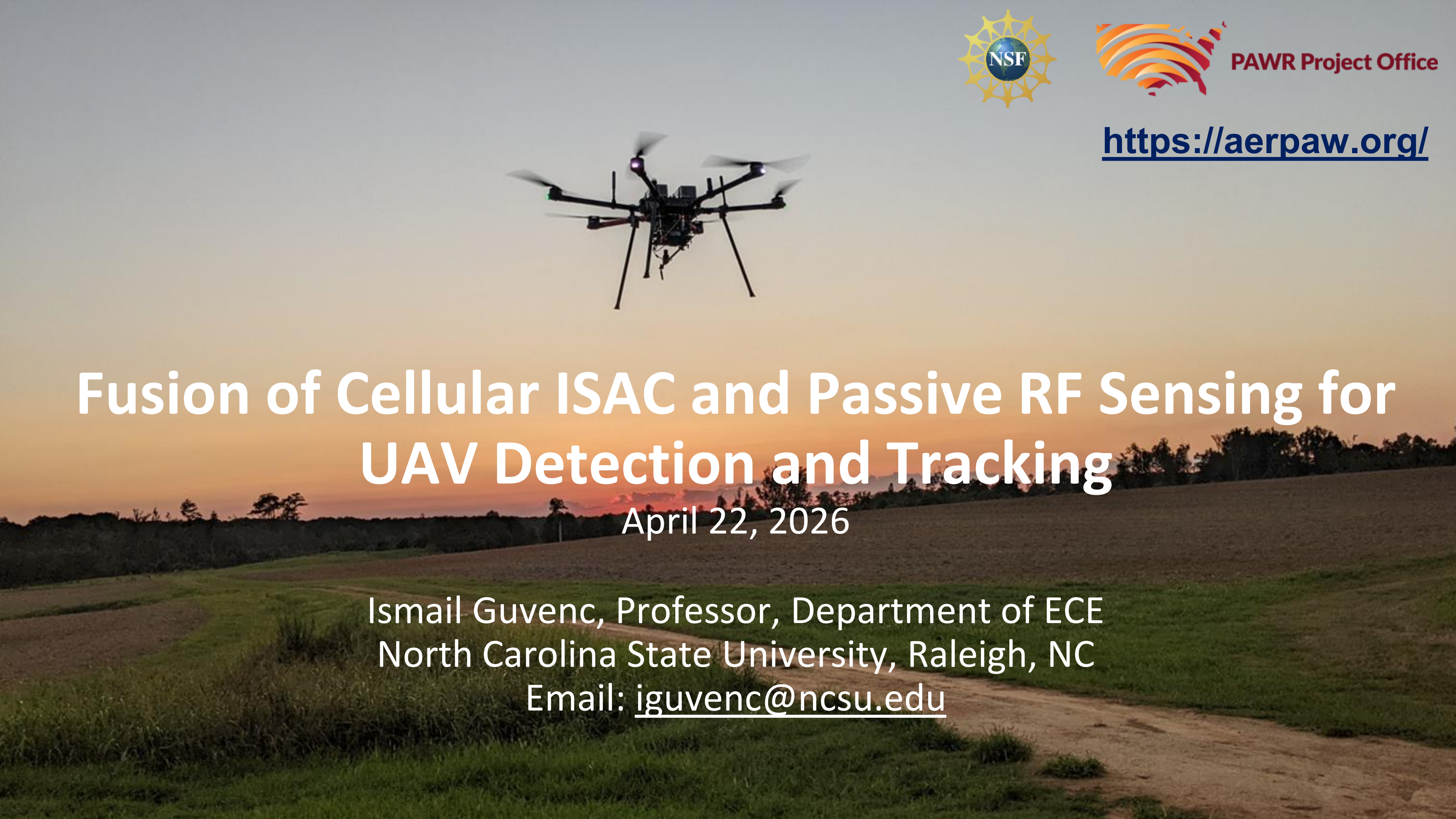


PAWR Project Office

https://aerpaw.org/

Fusion of Cellular ISAC and Passive RF Sensing for UAV Detection and Tracking

April 22, 2026

Ismail Guvenc, Professor, Department of ECE
North Carolina State University, Raleigh, NC
Email: iguvenc@ncsu.edu

Outline

- **NSF AERPAW Platform Overview**
- Research Examples from AERPAW
- Fusion of Radar and Passive RF Sensing
- 5G ISAC based UAV Detection and Tracking

NSF Platforms for Advanced Wireless Research (PAWR)

Funded Apr. 2018

POWDER

Salt Lake City, UT

Software defined networks and massive MIMO

AVAILABLE TODAY !!

Funded Apr. 2018

COSMOS

West Harlem, NY

Millimeter wave and backhaul research

AVAILABLE TODAY !!

Funded Sept. 2019

AERPAW

Raleigh, NC

Unmanned aerial vehicles and mobility

AVAILABLE TODAY !!

Funded June 2021

ARA

Ames,IA

Rural broadband wireless

AVAILABLE TODAY !!

NC STATE UNIVERSITY
wireless research center
MISSISSIPPI STATE UNIVERSITY
renci
PURDUE UNIVERSITY
UNIVERSITY OF SOUTH CAROLINA
ERICSSON
KEYSIGHT TECHNOLOGIES
nI
at&t
G U S
UNMANNED EXPERTS
COMMSCOPE
Meta
anymile
cisco

Ismail Guvenc
PI, NC State (SDRs, 4G/5G standards, PHY/MAC)

Rudra Dutta
NC State (SDN, architecture, CentMesh)

Mihail Sichitiu
NC State (drones, architecture, CentMesh)

Brian Floyd
NC State (mmW circuits, arrays)

Tom Zajkowski
NC State (UAS operations, FAA permitting)

Magreth Mushi,
NC State, Network Arch.
& Platform Operations

Ozgur Ozdemir, NC
State SDRs, Keysight,
Operations

Moahmed Rabeek
Sarbudeen, NC State, RF
Front Ends and O-RAN

Vuk Marojevic
MSU (security, SDRs, waveforms, CORNET)

Gerard Hayes
NC State, WRC (wireless and testing)

Yufeng Xin
RENCI, UNC-CH (data models, software architecture control framework)

David W. Matolak
USC (aerial propagation, waveforms)

David Love
Purdue (MIMO, SDRs, agriculture)

Lavanya Sridharan,
NC State, Project
Coordinator

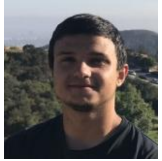
Mike Barts, WRC-NC
RF, Towers, Antennas,
Front Ends

Asokan Ram, WRC-NC
4G/5G Ericsson Deployment

Alphan Sahin, USC
mmWave Experiment
Development

Joshua Moore,
MSU, SDR Development

Chase Ueltschey, MSU
SDR Development



Anil Gurses, NC
State AERPAW Digital
Twin

Christopher
Roberts, NC State,
Web Portal and
Control Framework

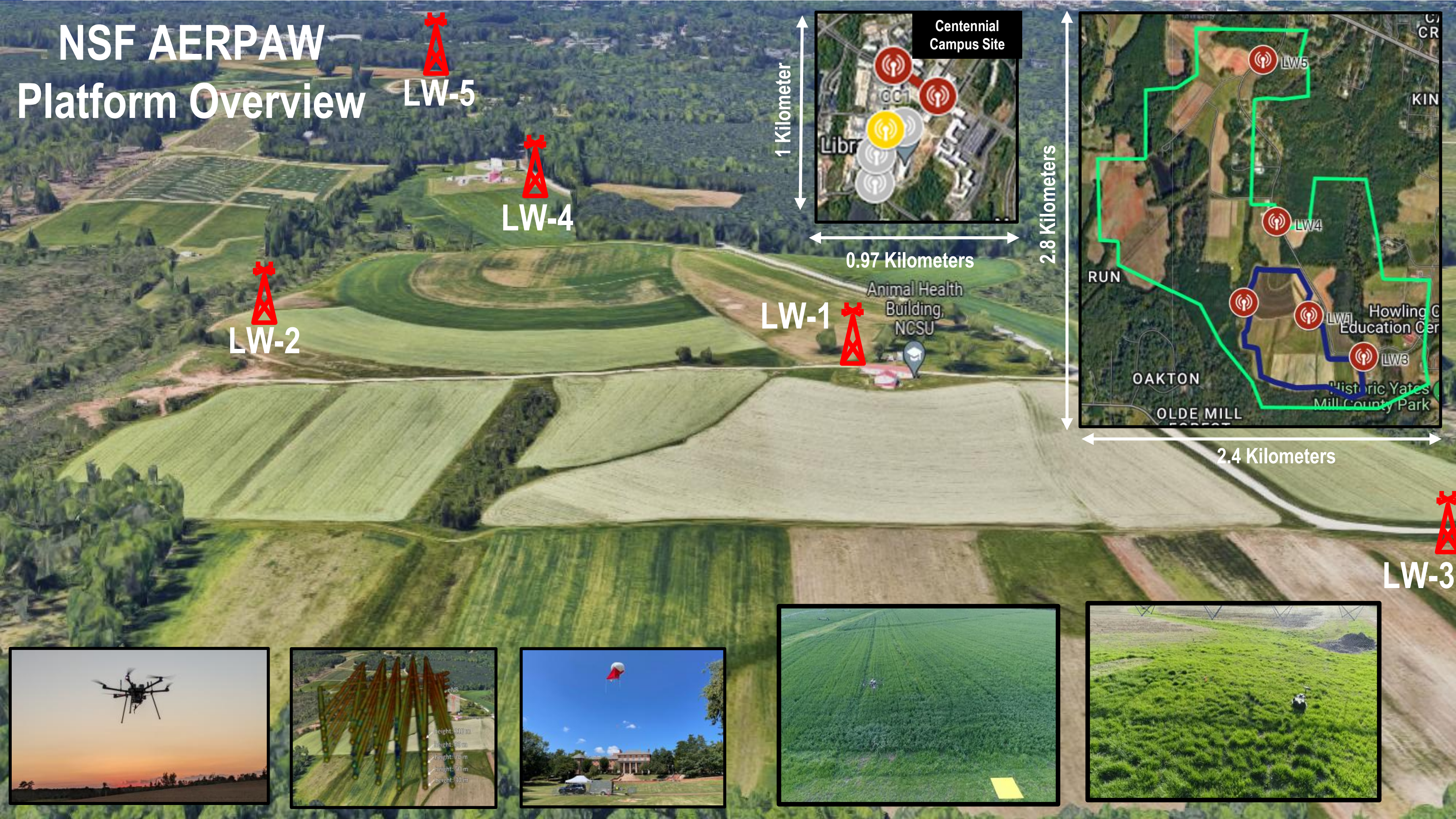
Sunc Joon Maeng,
NC State, Dynamic
Radio Zones

Mehedi Farhad, NC
State, Unmanned Air
and Ground Vehicles

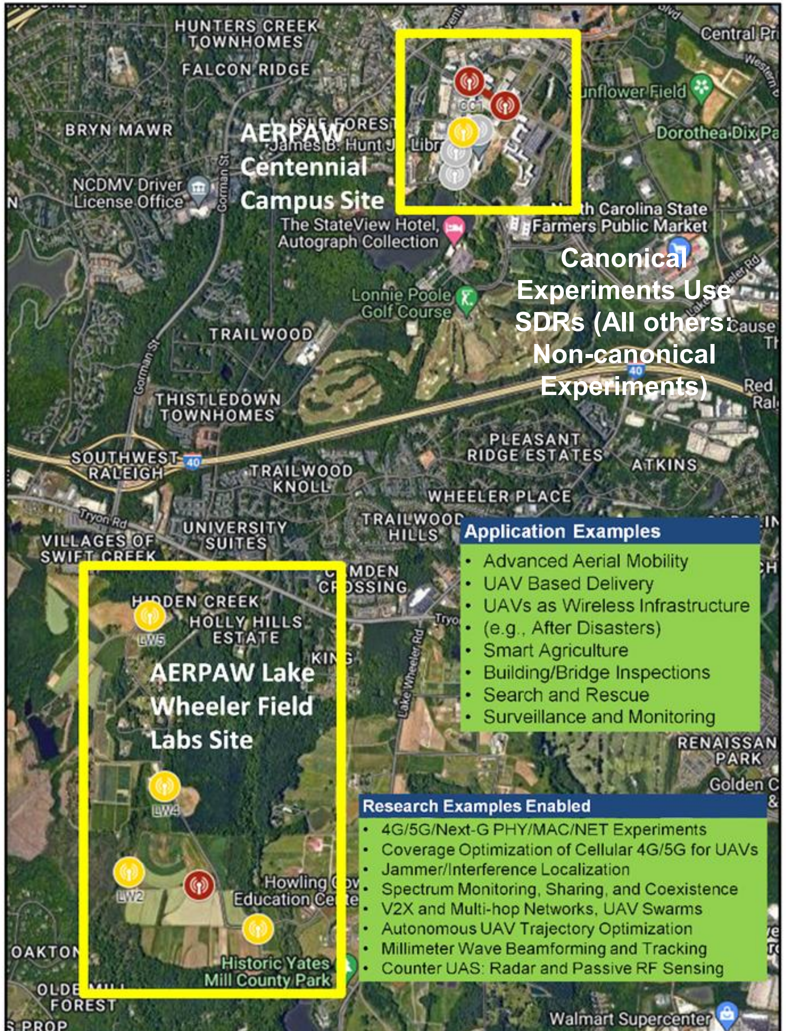
Ed Rogers, NC State
Construction Permits

NC STATE UNIVERSITY Electrical and Computer Engineering
NC STATE UNIVERSITY Computer Science
ITRE Institute for Transportation Research and Education NC STATE UNIVERSITY
NC STATE UNIVERSITY College of Agriculture and Life Sciences
NC STATE UNIVERSITY OFFICE OF INFORMATION TECHNOLOGY

NSF AERPAW Platform Overview



Deployment Map for AERPAW Fixed Nodes



Canonical Experiments Use SDRs (All others: Non-canonical Experiments)

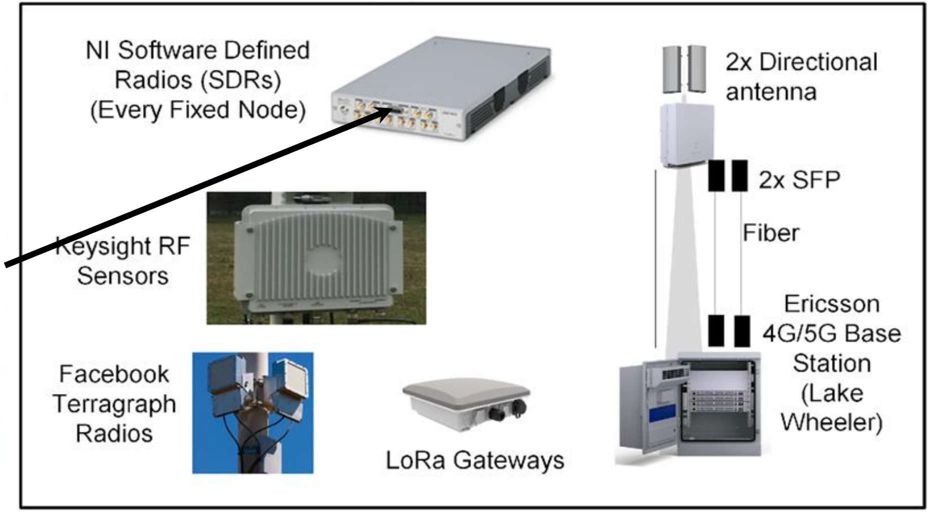
Application Examples

- Advanced Aerial Mobility
- UAV Based Delivery
- UAVs as Wireless Infrastructure
- (e.g., After Disasters)
- Smart Agriculture
- Building/Bridge Inspections
- Search and Rescue
- Surveillance and Monitoring

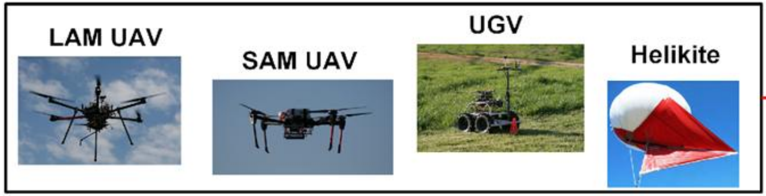
Research Examples Enabled

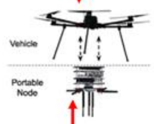
- 4G/5G/Next-G PHY/MAC/NET Experiments
- Coverage Optimization of Cellular 4G/5G for UAVs
- Jammer/Interference Localization
- Spectrum Monitoring, Sharing, and Coexistence
- V2X and Multi-hop Networks, UAV Swarms
- Autonomous UAV Trajectory Optimization
- Millimeter Wave Beamforming and Tracking
- Counter UAS: Radar and Passive RF Sensing

AERPAW Fixed Node Equipment



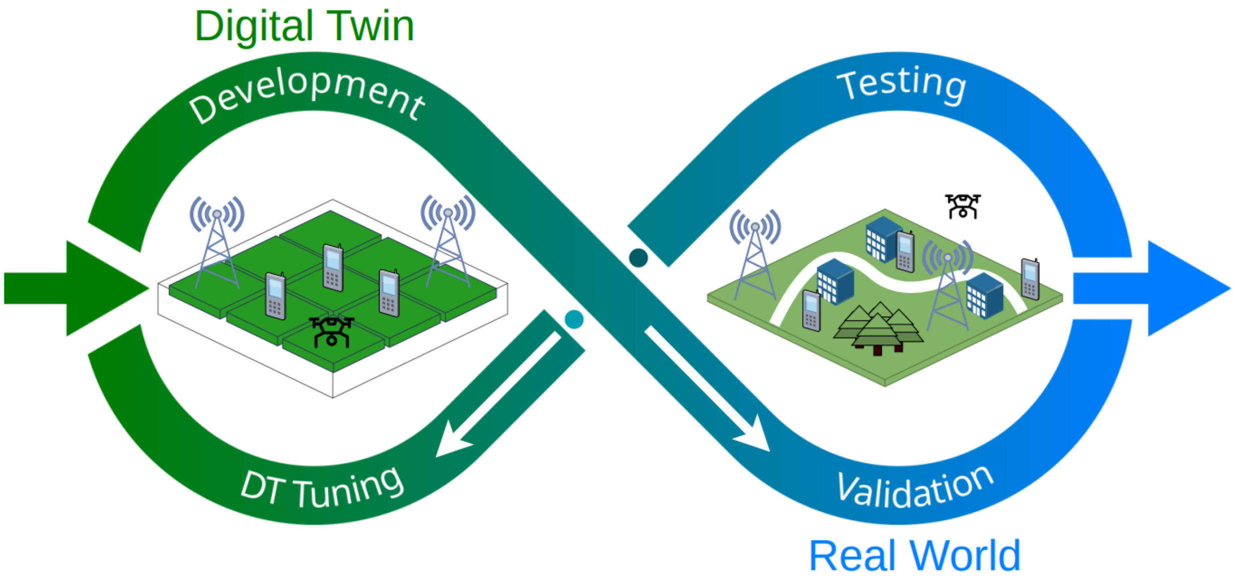
AERPAW Vehicles





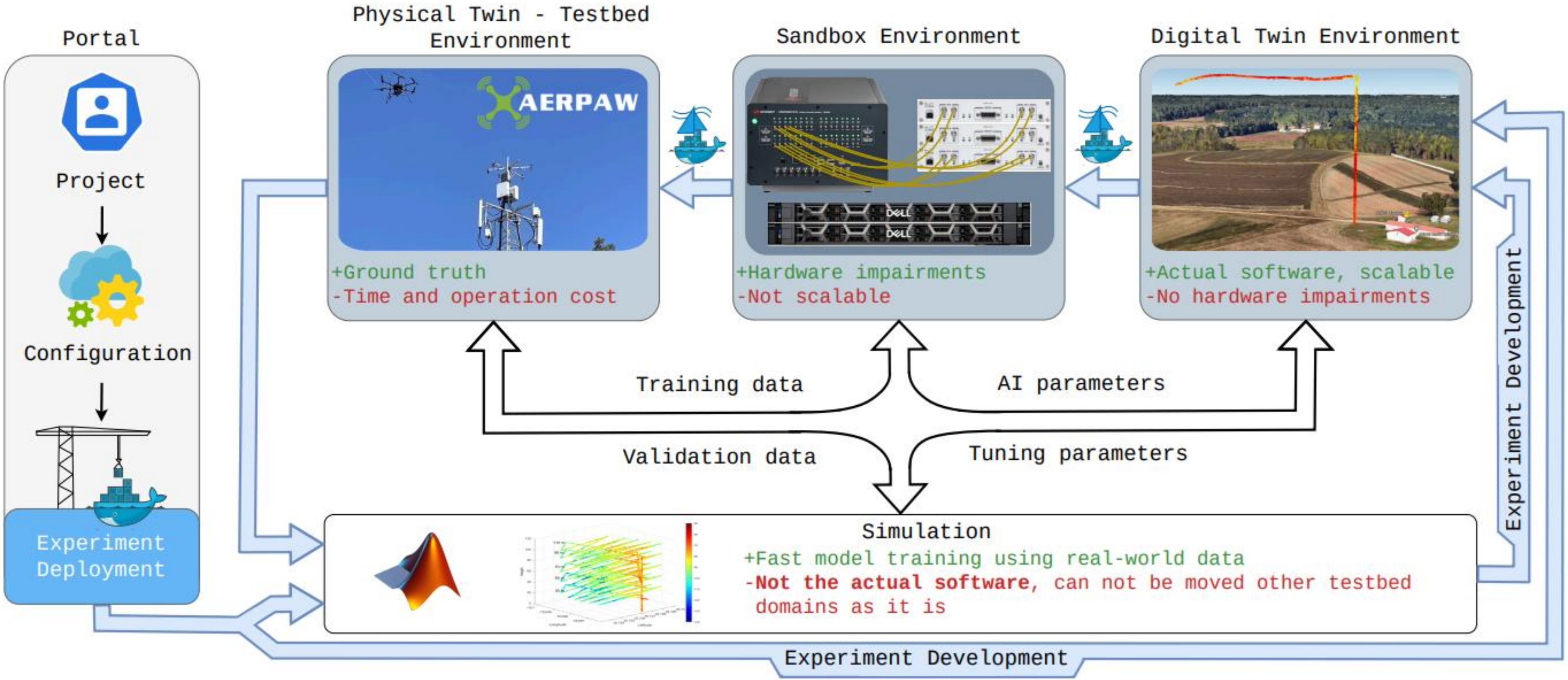
AERPAW Portable Node Equipment

AERPAW Digital Twin as a Development Environment for Canonical Experiments



- A. Gurses, G. Reddy, S. Masrur, O. Ozdemir, I. Guvenc, M. L. Sichitiu, A. Sahin, A. Alkhateeb, M. Mushi, and R. Dutta. "Digital Twins for Supporting AI Research with Autonomous Vehicle Networks", IEEE Commun. Mag., 2025.
- M. S. Hossen, A. Gurses, M. Sichitiu, and I. Guvenc, "Accelerating Development in UAV Network Digital Twins with a Flexible Simulation Framework", in Proc. IEEE ICC Workshops, Montreal, Canada, June 2025.
- J. Moore, A. S. Abdalla, C. Ueltschey, V. Marojevic, A. Gurses, O. Ozdemir, M. L. Sichitiu, and I. Guvenc, "Advancing Experimental Platforms for UAV Communications: Insights from AERPAW'S Digital Twin", in Proc. IEEE VTC Workshops, Washington, DC, Sep. 2024.
- A. Panicker, O. Ozdemir, M. L. Sichitiu, I. Guvenc, R. Dutta, V. Marojevic, and B. Floyd, "AERPAW Emulation Overview and Preliminary Performance Evaluation", Elsevier Computer Communications, Apr. 2021.

AERPAW Workflow: From Portal to Testbed



Portal

Project

Configuration

Experiment Deployment

Physical Twin - Testbed Environment

+Ground truth

-Time and operation cost

Sandbox Environment

+Hardware impairments

-Not scalable

Digital Twin Environment

+Actual software, scalable

-No hardware impairments

Training data

AI parameters

Validation data

Tuning parameters

Simulation

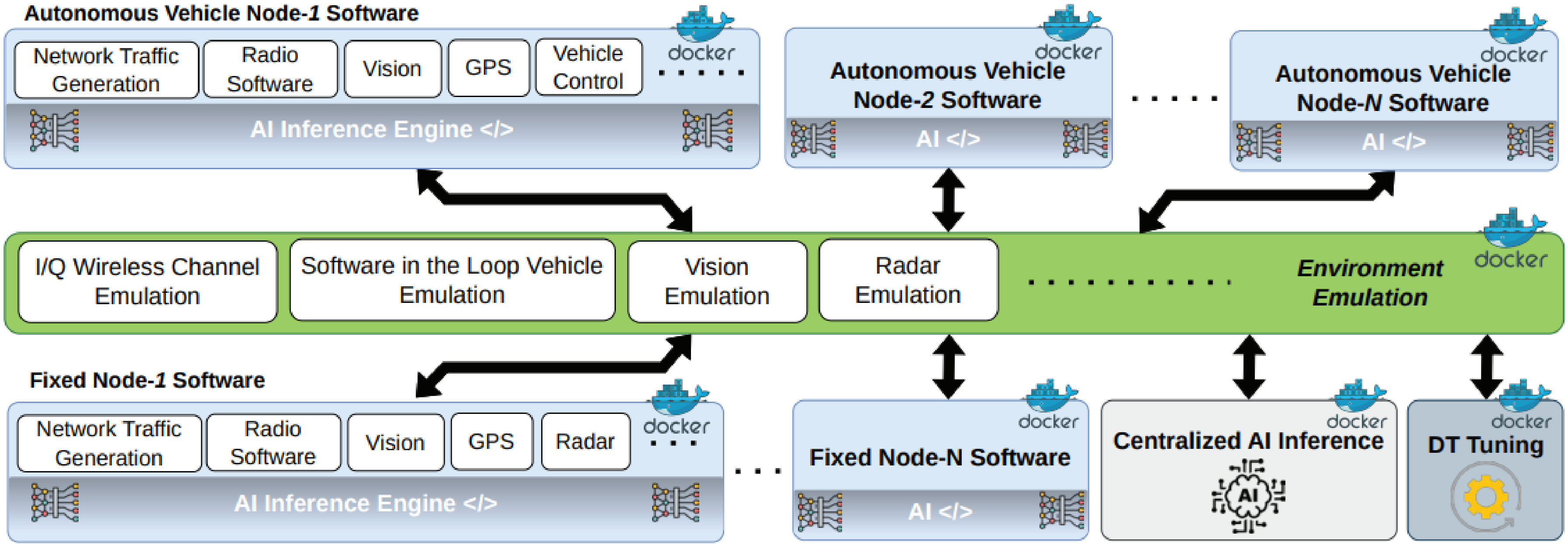
+Fast model training using real-world data

-**Not the actual software**, can not be moved other testbed domains as it is

Experiment Development

Experiment Development

Container Interactions in AERPAW's Digital Twin



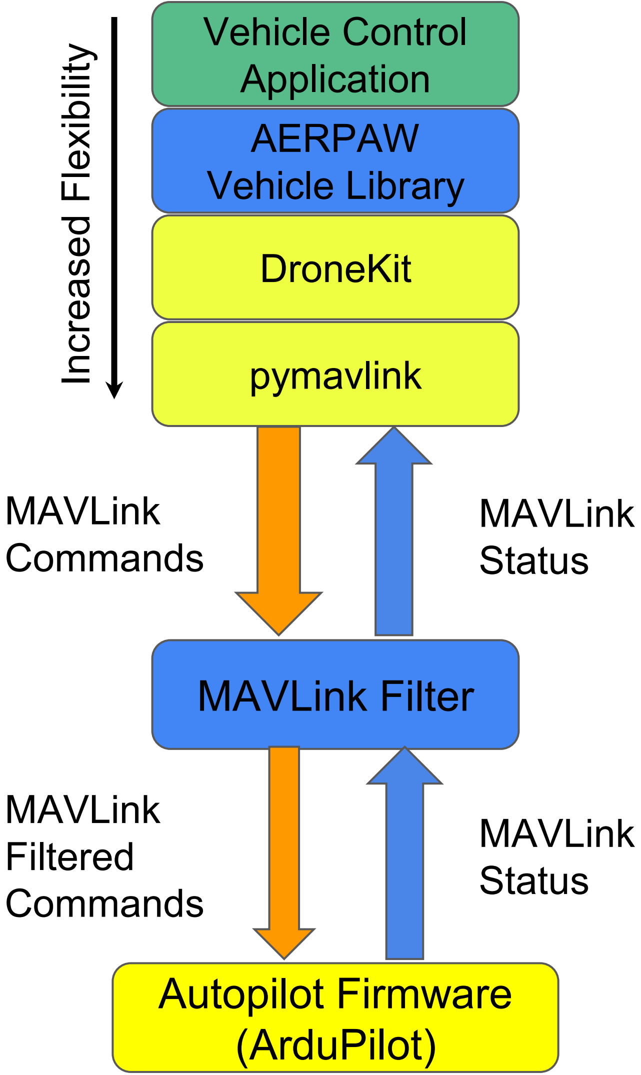
AERPAW UAV Software Interactions

- AERPAW Autopilot: Cube Orange
- Autopilot Firmware: ArduPilot

🟩 Experimenter Code

🟦 AERPAW Code

🟨 Open Source Code



Increased Flexibility

Vehicle Control Application

AERPAW Vehicle Library

DroneKit

pymavlink

MAVLink Commands

MAVLink Status

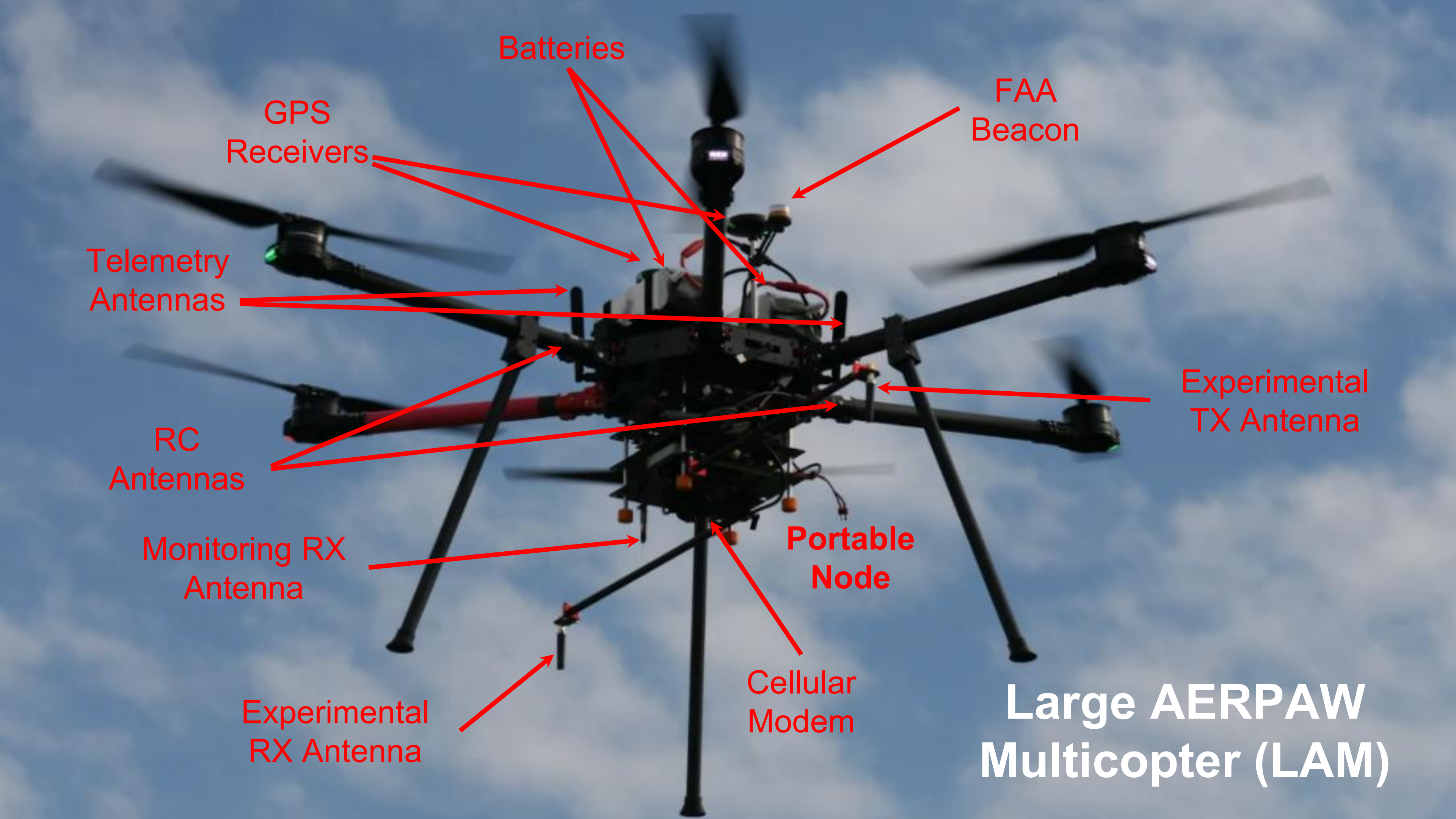
MAVLink Filter

MAVLink Filtered Commands

MAVLink Status

Autopilot Firmware (ArduPilot)

AERPAW LW1 Tower



Batteries

GPS
Receivers

FAA
Beacon

Telemetry
Antennas

Experimental
TX Antenna

RC
Antennas

**Portable
Node**

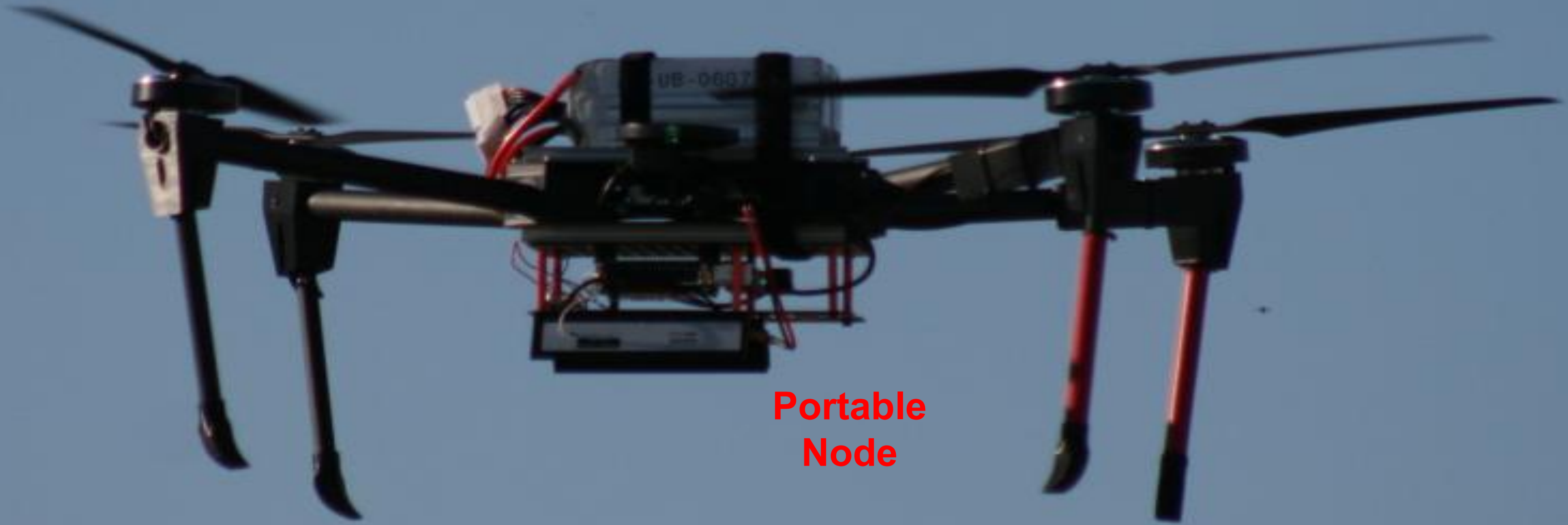
Monitoring RX
Antenna

Cellular
Modem

Experimental
RX Antenna

Large AERPAW Multicopter (LAM)

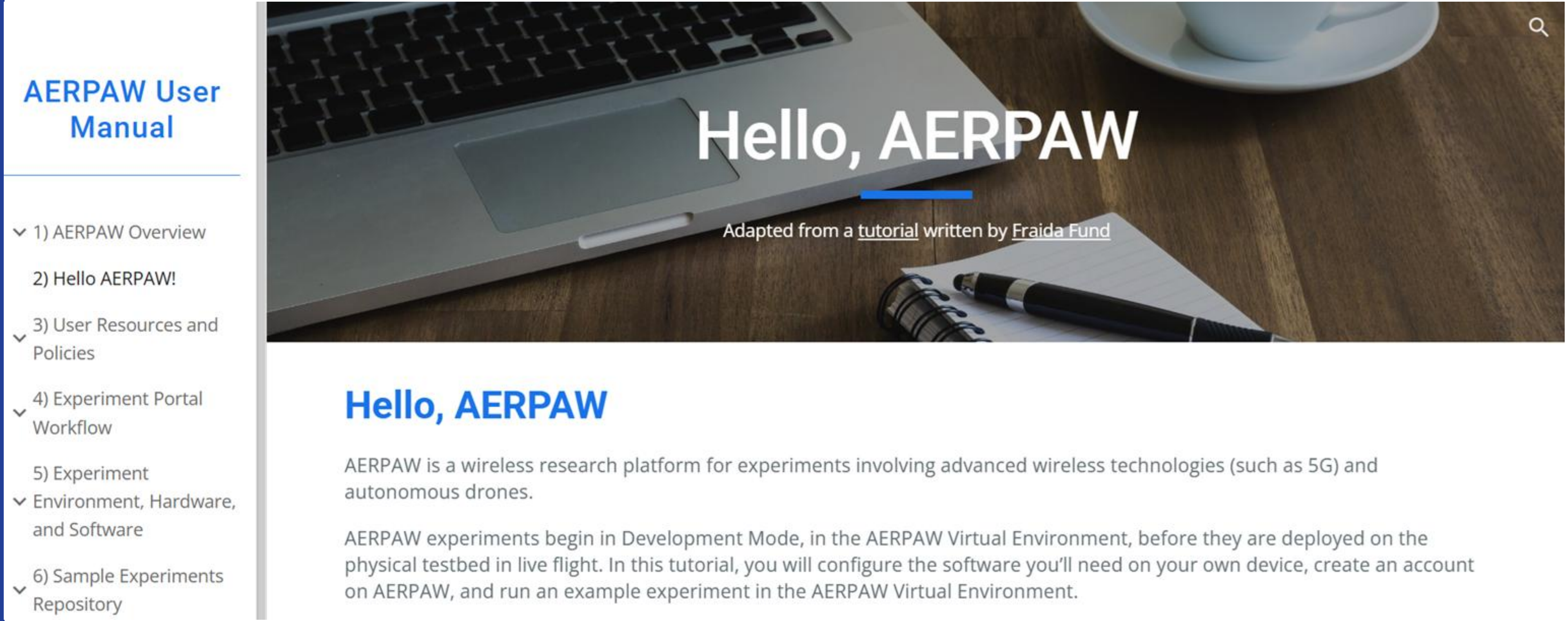
Small AERPAW Multicopter (SAM)



Small AERPAW Rover (SAR)

AERPAW Helikite Platform

Drone Operations Center



Hello, AERPAW

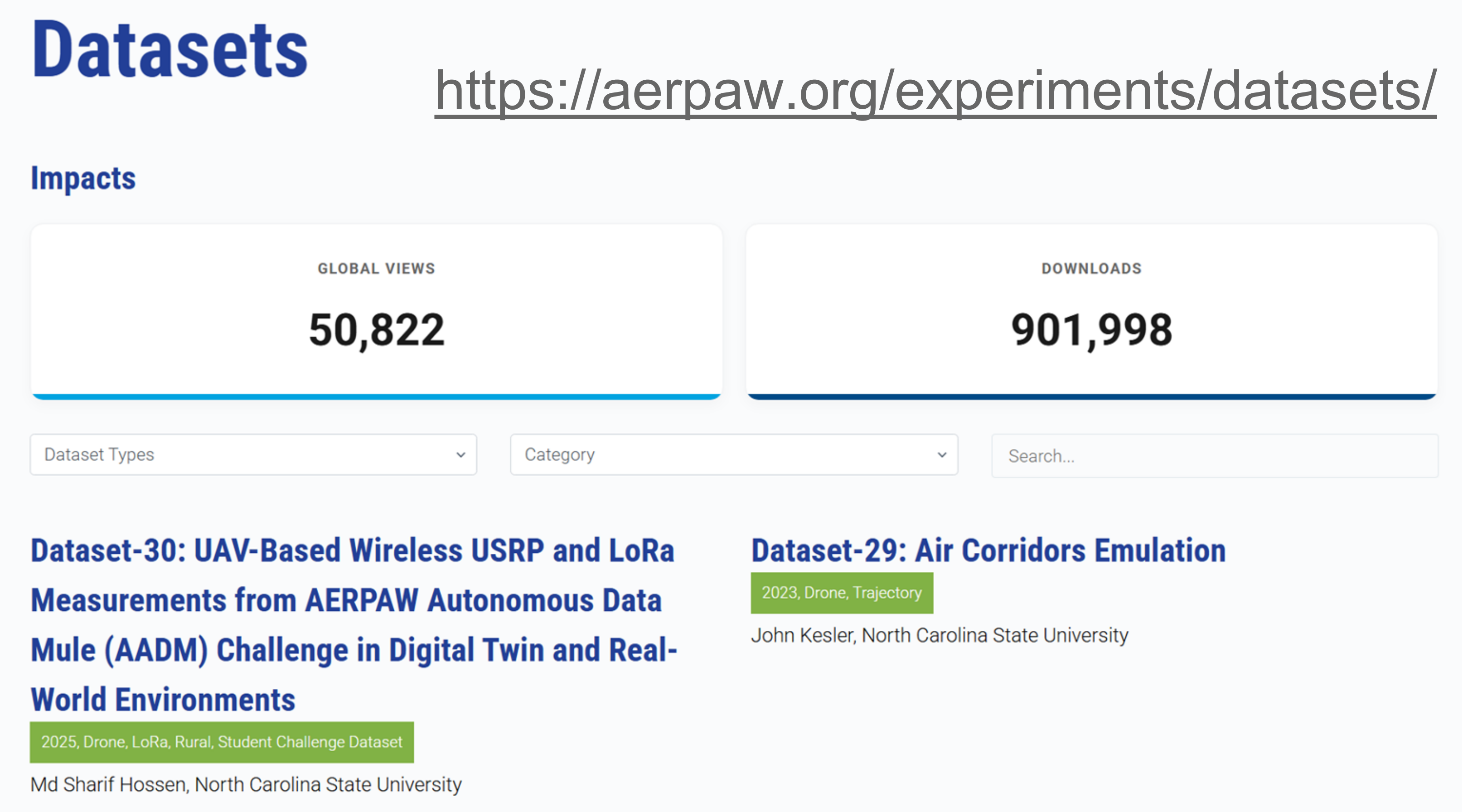
AERPAW is a wireless research platform for experiments involving advanced wireless technologies (such as 5G) and autonomous drones.

AERPAW experiments begin in Development Mode, in the AERPAW Virtual Environment, before they are deployed on the physical testbed in live flight. In this tutorial, you will configure the software you'll need on your own device, create an account on AERPAW, and run an example experiment in the AERPAW Virtual Environment.

AERPAW User Manual Accessible from: https://aerpaw.org/

https://sites.google.com/ncsu.edu/aerpaw-user-manual/2-hello-aerpaw

AERPAW Datasets Summary (1)



Datasets

https://aerpaw.org/experiments/datasets/

Impacts

GLOBAL VIEWS	DOWNLOADS
50,822	901,998

Dataset-30: UAV-Based Wireless USRP and LoRa Measurements from AERPAW Autonomous Data Mule (AADM) Challenge in Digital Twin and Real-World Environments

2025, Drone, LoRa, Rural, Student Challenge Dataset

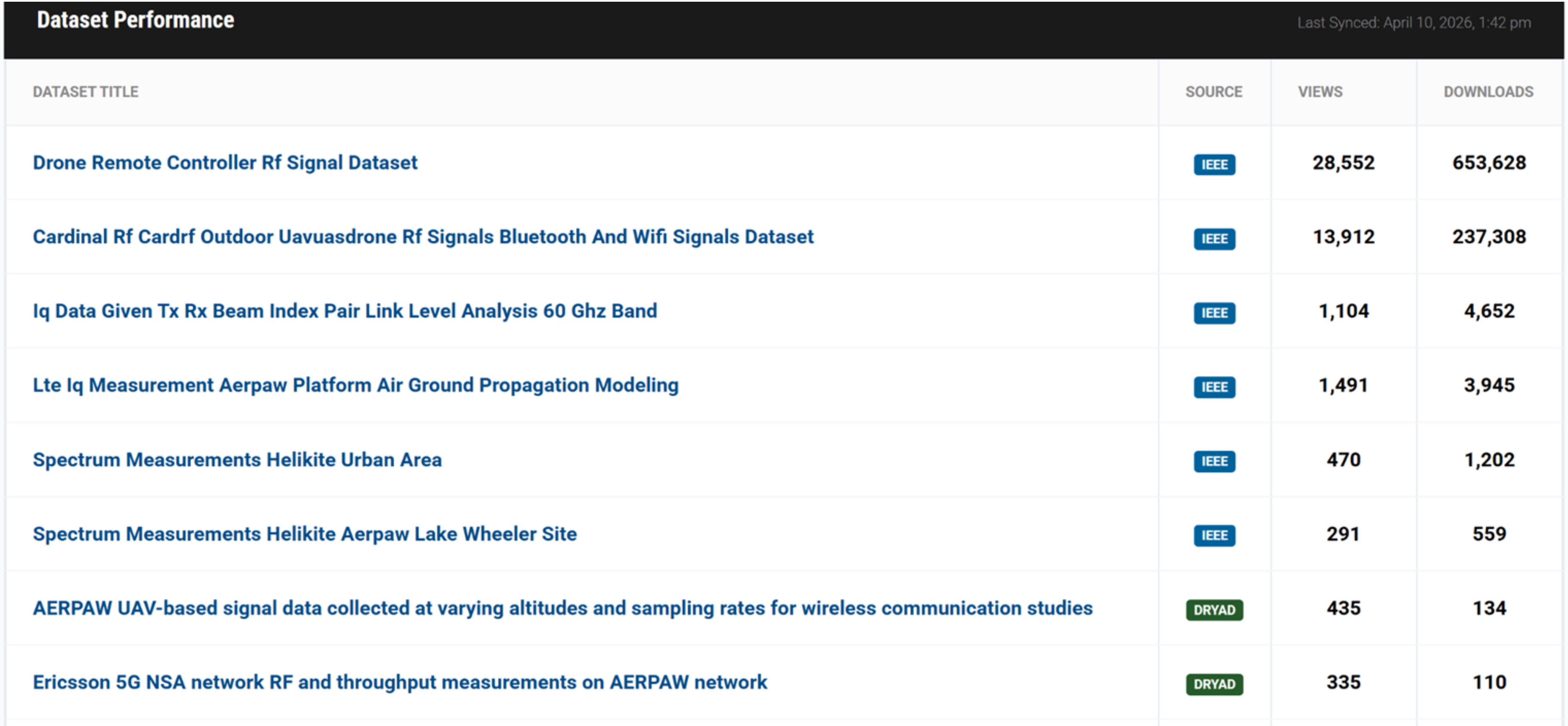
Md Sharif Hossen, North Carolina State University

Dataset-29: Air Corridors Emulation

2023, Drone, Trajectory

John Kesler, North Carolina State University

AERPAW Datasets Summary (2)



Dataset Performance

Last Synced: April 10, 2026, 1:42 pm

DATASET TITLE	SOURCE	VIEWS	DOWNLOADS
Drone Remote Controller Rf Signal Dataset	IEEE	28,552	653,628
Cardinal Rf Cardrf Outdoor Uavuasdrone Rf Signals Bluetooth And Wifi Signals Dataset	IEEE	13,912	237,308
Iq Data Given Tx Rx Beam Index Pair Link Level Analysis 60 Ghz Band	IEEE	1,104	4,652
Lte Iq Measurement Aerpaw Platform Air Ground Propagation Modeling	IEEE	1,491	3,945
Spectrum Measurements Helikite Urban Area	IEEE	470	1,202
Spectrum Measurements Helikite Aerpaw Lake Wheeler Site	IEEE	291	559
AERPAW UAV-based signal data collected at varying altitudes and sampling rates for wireless communication studies	DRYAD	435	134
Ericsson 5G NSA network RF and throughput measurements on AERPAW network	DRYAD	335	110

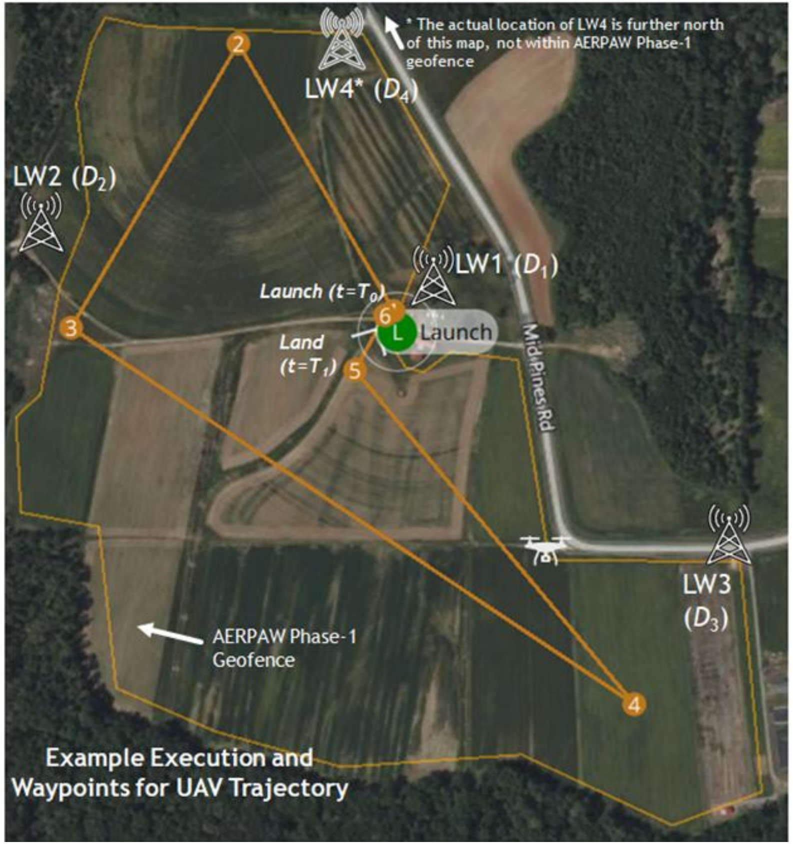
AERPAW Community Workshop, May 2025

- Florida Atlantic University (5)
- University of North Texas (4)
- Missouri University of Science and Technology (3)
- Florida International University (3)
- University of Central Florida (3)
- University of Missouri - Columbia (2)
- New York University (2)
- University at Buffalo (2)
- University of New Mexico (2)
- Mississippi State University (2)
- Georgia State University (2)
- University of Colorado Boulder (2)
- Worcester Polytechnic Institute
- Southern Methodist University
- University of Texas at Arlington
- University of Massachusetts Amherst
- Oregon State University
- University of Arizona
- Durham Technical Community College
- Iowa State University
- University of Georgia
- University of Utah
- Florida Gulf Coast University
- University of Miami
- Kennesaw State University
- Sonoma State University
- Aalto University

47 Student Attendees from 27 universities (43 students funded by NSF support)

https://aerpaw.org/aerpaw-community-workshop-2025/

AERPAW Autonomous Data Mule (AADM) Challenge



Example Execution and Waypoints for UAV Trajectory

- UAV should optimize its trajectory to download data from a number of towers, land back as soon as possible
- **Number of teams participating: 22**

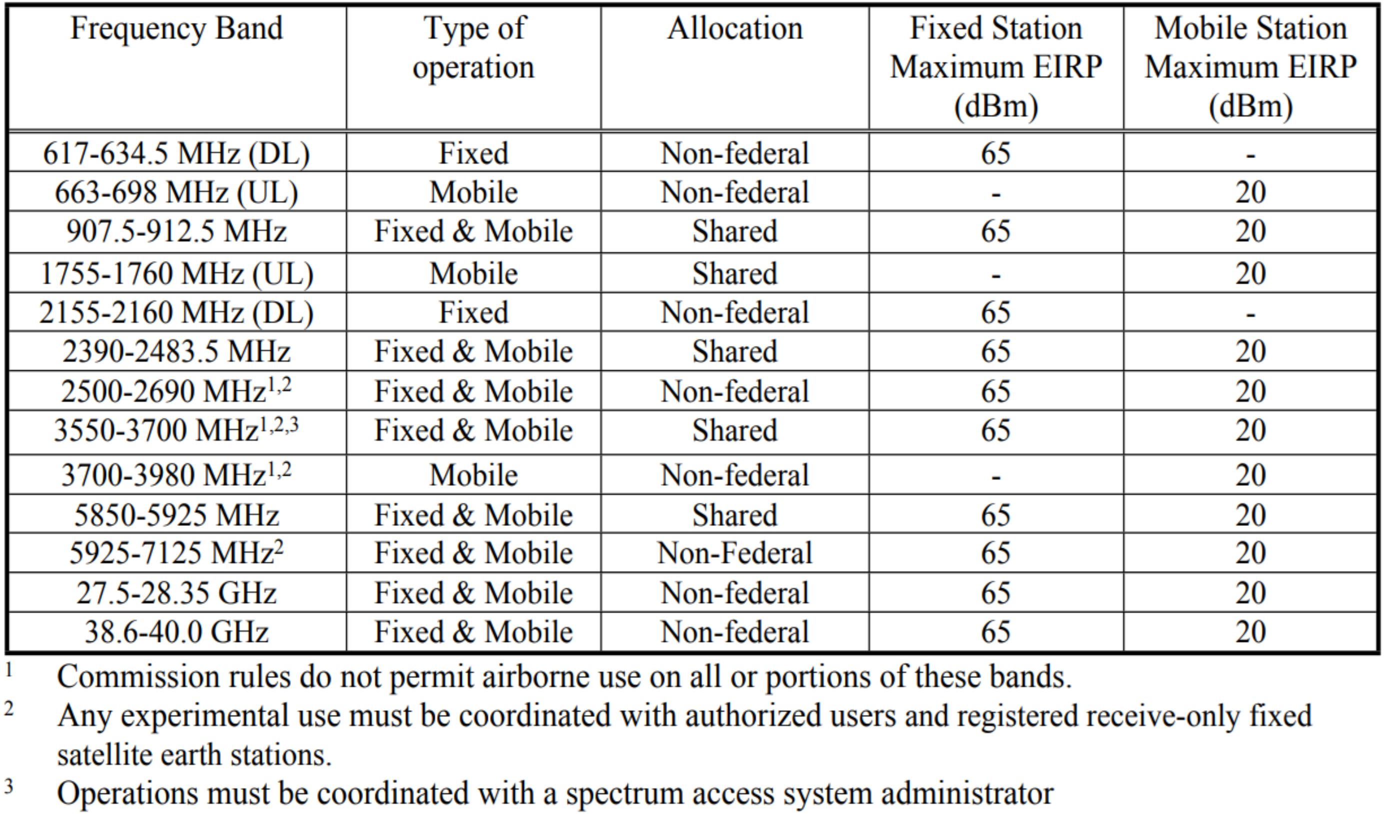
Winners:

1) Influx, University of Utah
2) Neural Flyers, North Carolina State University
3) IMPRESS@UGA, University of Georgia
4) WiMNet, Columbia University

https://aerpaw.org/aerpaw-aadm-challenge/

Student Award Sponsors

AERPAW’s Current FCC Innovation Zone



Frequency Band	Type of operation	Allocation	Fixed Station Maximum EIRP (dBm)	Mobile Station Maximum EIRP (dBm)
617-634.5 MHz (DL)	Fixed	Non-federal	65	-
663-698 MHz (UL)	Mobile	Non-federal	-	20
907.5-912.5 MHz	Fixed & Mobile	Shared	65	20
1755-1760 MHz (UL)	Mobile	Shared	-	20
2155-2160 MHz (DL)	Fixed	Non-federal	65	-
2390-2483.5 MHz	Fixed & Mobile	Shared	65	20
2500-2690 MHz[1,2]	Fixed & Mobile	Non-federal	65	20
3550-3700 MHz[1,2,3]	Fixed & Mobile	Shared	65	20
3700-3980 MHz[1,2]	Mobile	Non-federal	-	20
5850-5925 MHz	Fixed & Mobile	Shared	65	20
5925-7125 MHz[2]	Fixed & Mobile	Non-Federal	65	20
27.5-28.35 GHz	Fixed & Mobile	Non-federal	65	20
38.6-40.0 GHz	Fixed & Mobile	Non-federal	65	20

[1] Commission rules do not permit airborne use on all or portions of these bands.

[2] Any experimental use must be coordinated with authorized users and registered receive-only fixed satellite earth stations.

[3] Operations must be coordinated with a spectrum access system administrator

THE WHITE HOUSE
WASHINGTON

UNLEASHING AMERICAN DRONE DOMINANCE

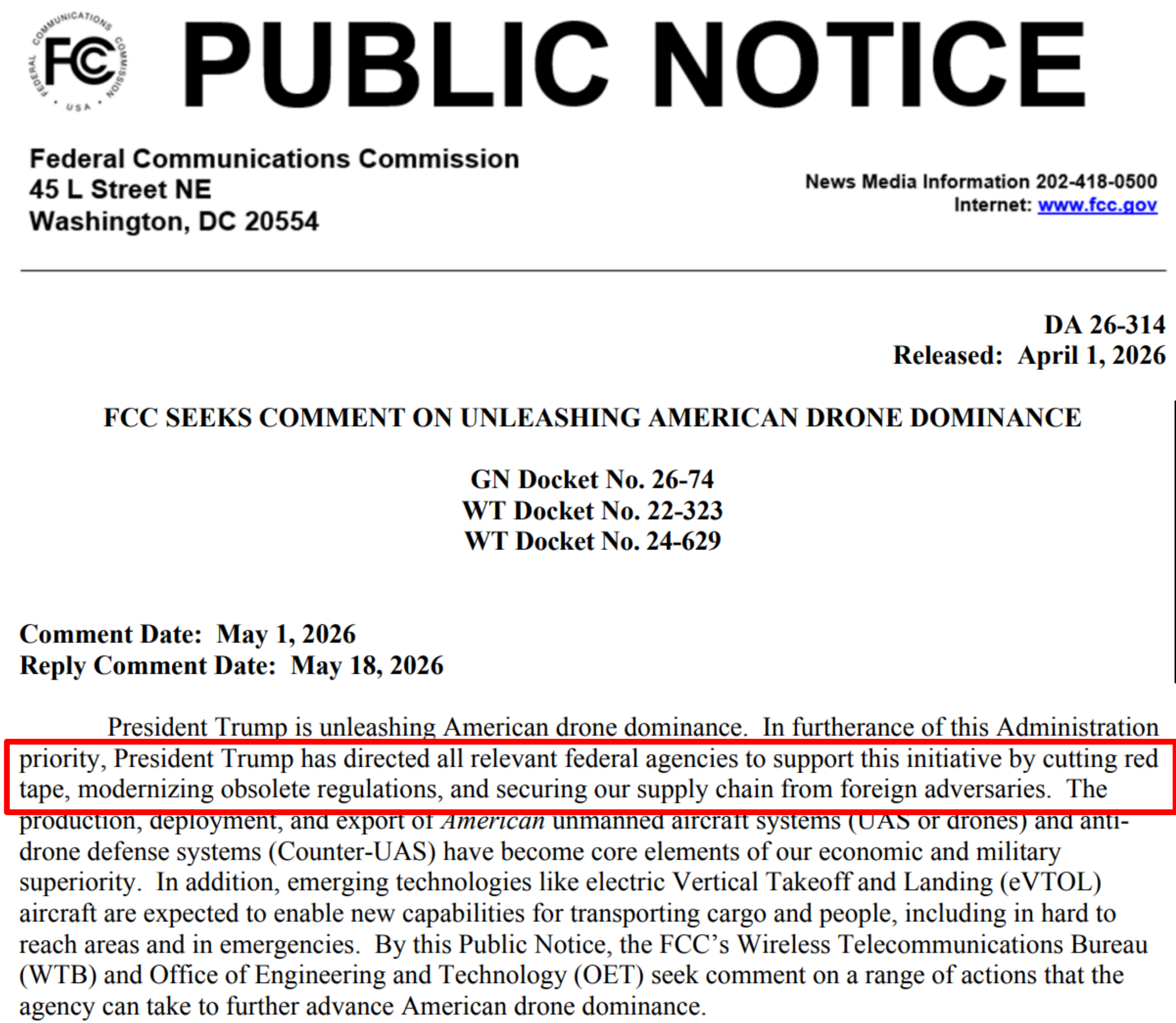
Executive Orders | June 6, 2025

By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered:

Section 1. Purpose. Unmanned aircraft systems (UAS), otherwise known as drones, enhance United States productivity, create high-skilled jobs, and are reshaping the future of aviation. Drones are already transforming industries from logistics and infrastructure inspection to precision agriculture, emergency response, and public safety. Emerging technologies such as electric Vertical Takeoff and Landing (eVTOL) aircraft promise to modernize methods for cargo delivery, passenger transport, and other advanced air mobility capabilities.

The United States must accelerate the safe commercialization of drone technologies and fully integrate UAS into the National Airspace System. The time has come to accelerate testing and to enable routine drone operations, scale up domestic production, and expand the export of trusted, American-manufactured drone technologies to global markets.

https://www.whitehouse.gov/presidential-actions/2025/06/unleashing-american-drone-dominance/



PUBLIC NOTICE

Federal Communications Commission
45 L Street NE
Washington, DC 20554

News Media Information 202-418-0500
Internet: www.fcc.gov

DA 26-314
Released: April 1, 2026

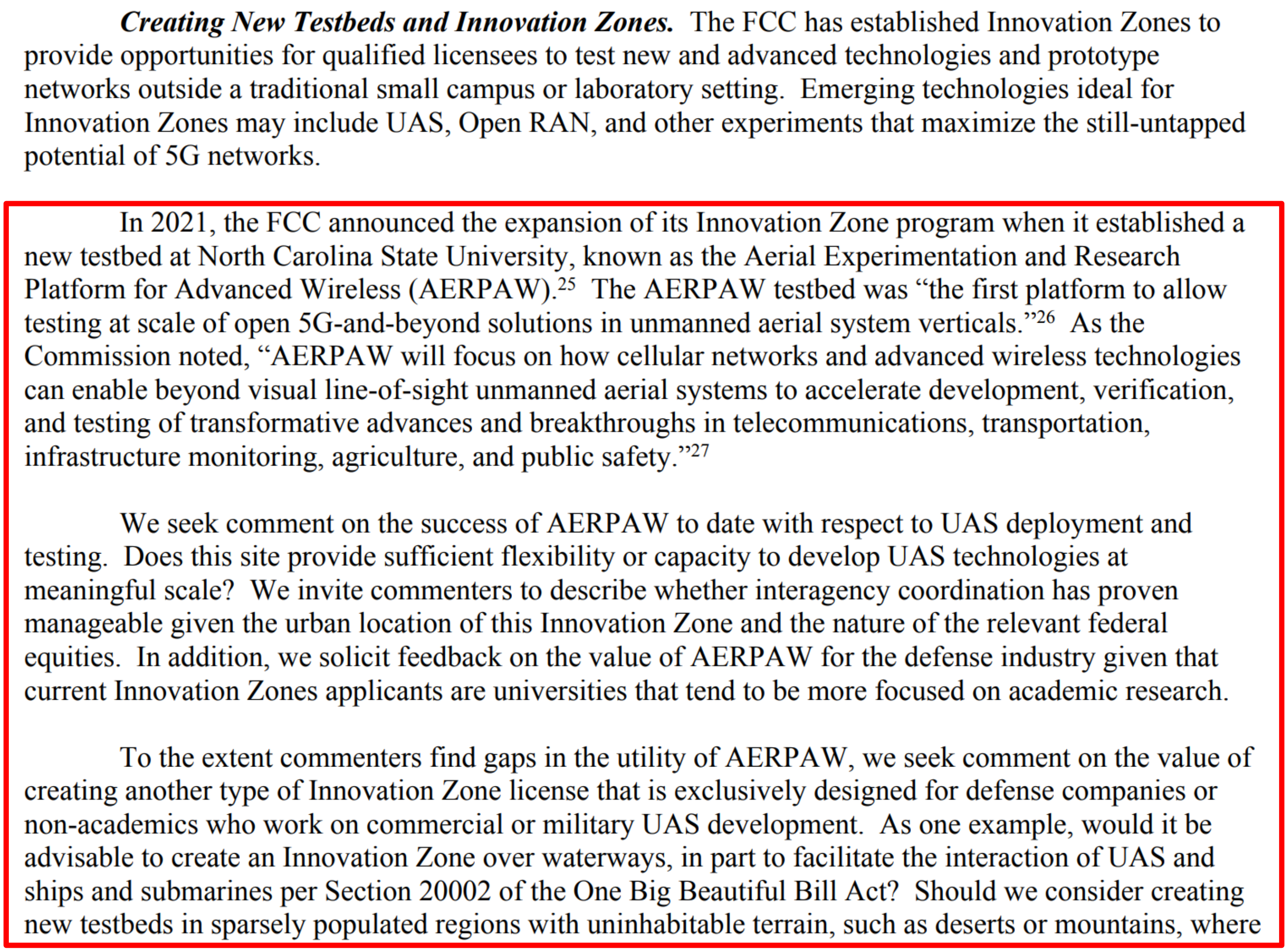
FCC SEEKS COMMENT ON UNLEASHING AMERICAN DRONE DOMINANCE

GN Docket No. 26-74
WT Docket No. 22-323
WT Docket No. 24-629

Comment Date: May 1, 2026
Reply Comment Date: May 18, 2026

President Trump is unleashing American drone dominance. In furtherance of this Administration priority, President Trump has directed all relevant federal agencies to support this initiative by cutting red tape, modernizing obsolete regulations, and securing our supply chain from foreign adversaries. The production, deployment, and export of *American* unmanned aircraft systems (UAS or drones) and anti-drone defense systems (Counter-UAS) have become core elements of our economic and military superiority. In addition, emerging technologies like electric Vertical Takeoff and Landing (eVTOL) aircraft are expected to enable new capabilities for transporting cargo and people, including in hard to reach areas and in emergencies. By this Public Notice, the FCC's Wireless Telecommunications Bureau (WTB) and Office of Engineering and Technology (OET) seek comment on a range of actions that the agency can take to further advance American drone dominance.

You can submit your comments at: https://www.fcc.gov/ecfs/search/search-filings/results?q=(proceedings.name:(%2226-74%22))



Creating New Testbeds and Innovation Zones. The FCC has established Innovation Zones to provide opportunities for qualified licensees to test new and advanced technologies and prototype networks outside a traditional small campus or laboratory setting. Emerging technologies ideal for Innovation Zones may include UAS, Open RAN, and other experiments that maximize the still-untapped potential of 5G networks.

In 2021, the FCC announced the expansion of its Innovation Zone program when it established a new testbed at North Carolina State University, known as the Aerial Experimentation and Research Platform for Advanced Wireless (AERPAW).[25] The AERPAW testbed was "the first platform to allow testing at scale of open 5G-and-beyond solutions in unmanned aerial system verticals."[26] As the Commission noted, "AERPAW will focus on how cellular networks and advanced wireless technologies can enable beyond visual line-of-sight unmanned aerial systems to accelerate development, verification, and testing of transformative advances and breakthroughs in telecommunications, transportation, infrastructure monitoring, agriculture, and public safety."[27]

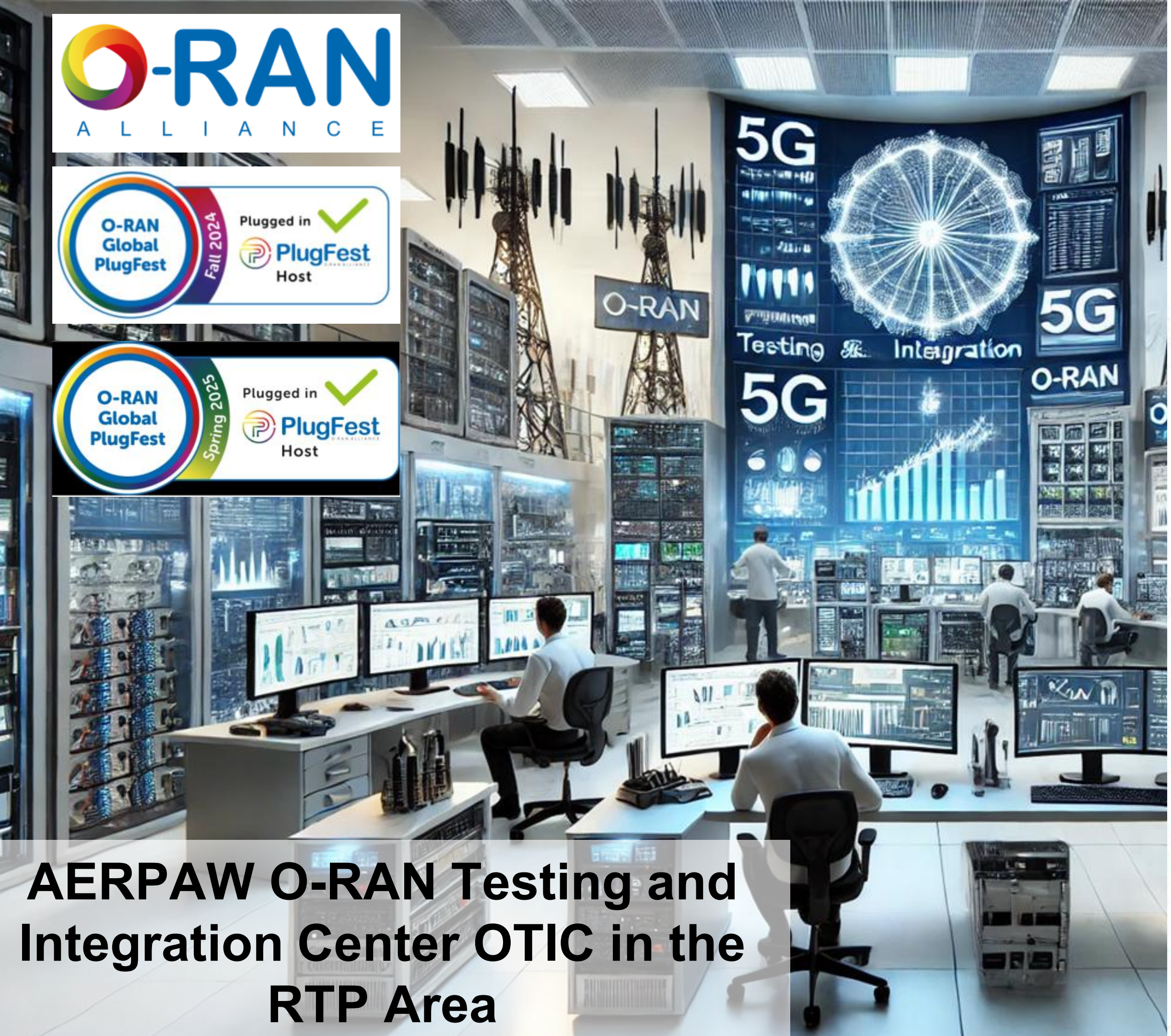
We seek comment on the success of AERPAW to date with respect to UAS deployment and testing. Does this site provide sufficient flexibility or capacity to develop UAS technologies at meaningful scale? We invite commenters to describe whether interagency coordination has proven manageable given the urban location of this Innovation Zone and the nature of the relevant federal equities. In addition, we solicit feedback on the value of AERPAW for the defense industry given that current Innovation Zones applicants are universities that tend to be more focused on academic research.

To the extent commenters find gaps in the utility of AERPAW, we seek comment on the value of creating another type of Innovation Zone license that is exclusively designed for defense companies or non-academics who work on commercial or military UAS development. As one example, would it be advisable to create an Innovation Zone over waterways, in part to facilitate the interaction of UAS and ships and submarines per Section 20002 of the One Big Beautiful Bill Act? Should we consider creating new testbeds in sparsely populated regions with uninhabitable terrain, such as deserts or mountains, where

O-RAN ALLIANCE

O-RAN Global PlugFest Fall 2024 Plugged in PlugFest Host

O-RAN Global PlugFest Spring 2025 Plugged in PlugFest Host



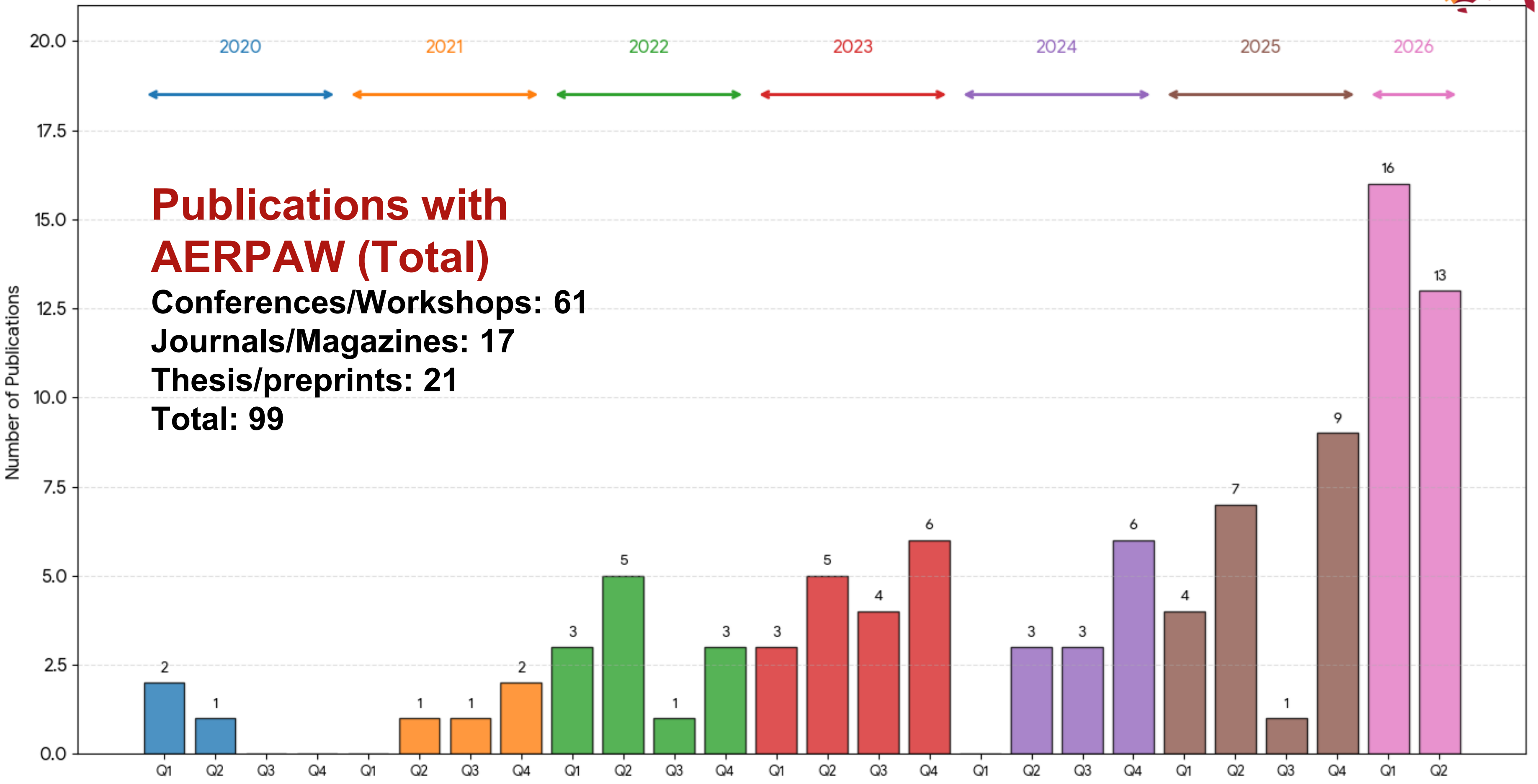
AERPAW O-RAN Testing and Integration Center OTIC in the RTP Area

Outline

- NSF AERPAW Platform Overview
- **Research Examples from AERPAW**
- Fusion of Radar and Passive RF Sensing
- 5G ISAC based UAV Detection and Tracking

AERPAW Total Publications per Quarter (2020 - April 2026)

Data on Publications with AERPAW: https://aerpaw.org/publications/



Publications with AERPAW (Total)

Conferences/Workshops: 61

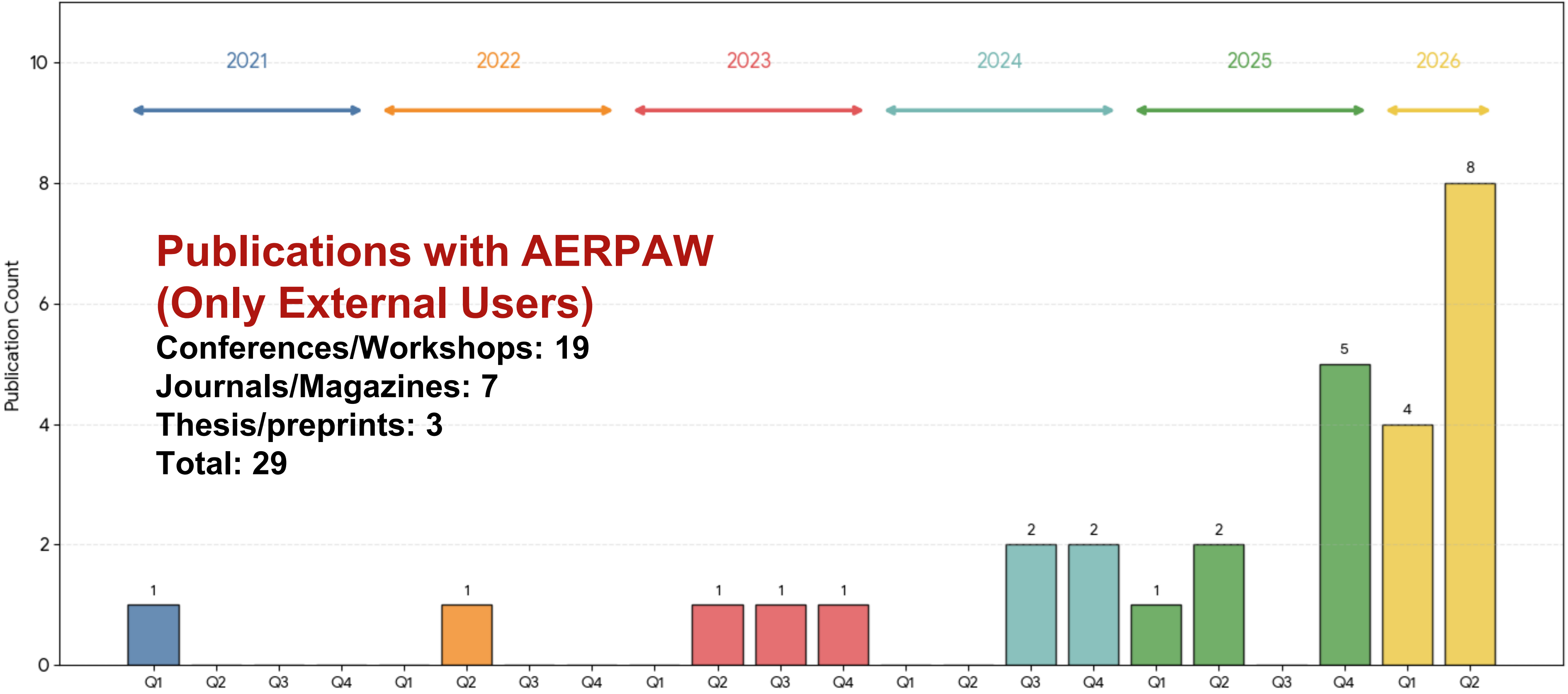
Journals/Magazines: 17

Thesis/preprints: 21

Total: 99

External/Bolded AERPAW Publications per Quarter (2021 - April 2026)

Data on Publications with AERPAW: https://aerpaw.org/publications/



Publications with AERPAW (Only External Users)

Conferences/Workshops: 19
Journals/Magazines: 7
Thesis/preprints: 3
Total: 29

AERPAW Representative User Highlights (1)

Joseph Camp, SMU: 3D antenna radiation patterns measured in an anechoic chamber via the AERPAW testbed are used to evaluate the proposed **3D antenna modeling concept** (see AERPAW Dataset-7). Ray trace over UAV flight trajectory to provide corresponding real-world measurements and ray-trace simulation data (see AERPAW Dataset-21)

Recent AERPAW Publications:

- ACM MobiSys, 2026
- IEEE INFOCOM, 2026
- IEEE DySPAN, 2026

Gunes Karabulut-Kurt, Polytechnic Montreal: Used the AERPAW UAV Air-to-Ground (A2G) dataset, containing 3D positioning and multi-frequency signal measurements. Outdoor measurements provided the diverse terrain and "noisy" data needed to prove the flexibility of an **AI based aerial propagation modeling** technique (PIKAN) flexibility over rigid theoretical models.

Recent AERPAW Publications:

- IEEE AeroConf, 2026
- IEEE Trans. Wireless Commun., 2026 (in prep.)

Prasad Calyam, U. Missouri: Tailored their **UAV trajectory planning** framework explicitly for the AERPAW **Autonomous Aerial Data Mule** (AADM) Challenge, where UAVs must collect data from multiple ground stations and return within a fixed energy budget. AERPAW Phase-1 deployment maps (Lake Wheeler site) are used to simulate realistic UAV-to-station communication networks and flight corridors.

Recent AERPAW Publications:

- IEEE/ACM Edge Computing Symp., 2026
- IEEE ITS Journal (in review)

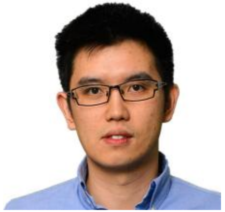
AERPAW Representative User Highlights (2)

Ahmed Ibrahim, FIU: Trained their ML models for **UAV trajectory optimization** in the AERPAW emulator and then move directly to the outdoor testbed with minimal software changes. By using AERPAW's predefined "Portable Nodes" and UAV configurations, the team ensured their results were repeatable and comparable to other research on the platform.

Recent AERPAW Publications:

- ACM WinTech, 2025
- IEEE Commun. Mag., 2026 (submitted)

Shih-Chun Lin, NC State: AERPAW's outdoor field environment was used to validate the self-healing **NTN algorithms** under realistic long-range propagation. AERPAW's programmable nodes allowed the team to emulate varying network conditions and validate that the swarm could maintain connectivity despite active signal degradation.



Recent AERPAW Publications:

- IEEE INFOCOM Workshop, 2026

Mehmet Kurum, University of Georgia: Developed a UAS-based **microwave radiometer system** integrated with AERPAW to collect real-world interference data with ground truth. AERPAW provides aerial and ground nodes with realistic **5G interference scenarios**, and supports controlled experiments with varying transmission power, mobility, frequency bands, and multi-user interference conditions.

Recent AERPAW Publications:

- IEEE Transactions on Geoscience and Remote Sensing, 2025

AERPAW Representative User Highlights (3)

Ali Gurbuz, NC State: 5G networks are used as passive RF illuminators for UAV detection through **integrated sensing and communications (ISAC)**. The AERPAW 5G Ericsson base station (3355 MHz) transmitting SSB signals was used for detecting the UAVs.

Recent AERPAW Publications:

- IEEE DySpan 2026

Fraida Fund, NYU: Turned the AERPAW Find-a-Rover (AFAR) challenge into an interactive assignment for **machine learning class**. Students run experiments in real time, observe how their models behaved, and make informed decisions. 18 students in summer 2024, 90 in spring 2025.

Adopted Teaching Materials:

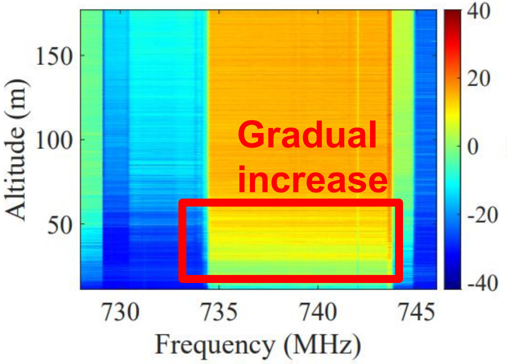
- Kennesaw University - EE3702
- 11 other instructors elsewhere ready to use the curriculum

Keiwan Soltani, Missouri University of S&T: Stress-tested AERPAW UAVs to high speeds, evaluating **power consumption through ESC/motor data**. Executed experiments seamlessly on AERPAW's 7 sq km outdoor testbed, accessed custom, low-level telemetry (ESC/dataflash logs) enabled by AERPAW's open hardware/software frameworks.

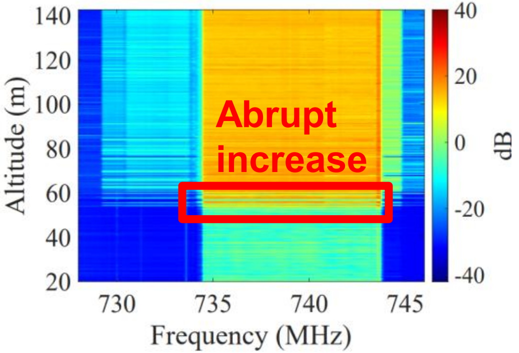
Recent AERPAW Publications:

- IEEE Transactions on Emerging Topics in Computing, 2026 (submitted)

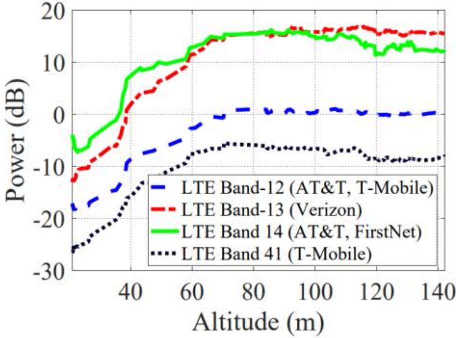
Spectrum Occupancy Measurements and Modeling in Rural & Urban Areas (1)



LTE band 12 (DL, Rural)

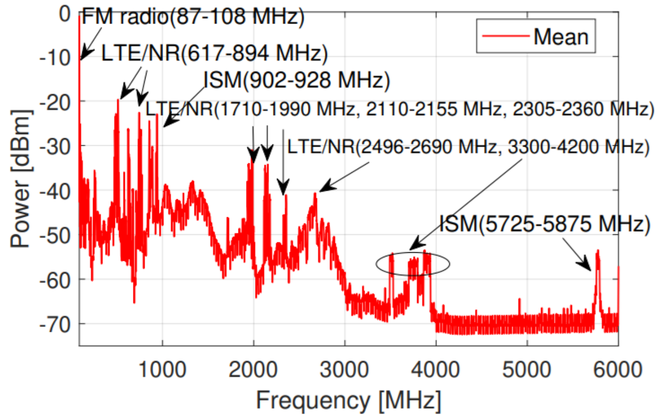


LTE band 12 (DL, Urban)



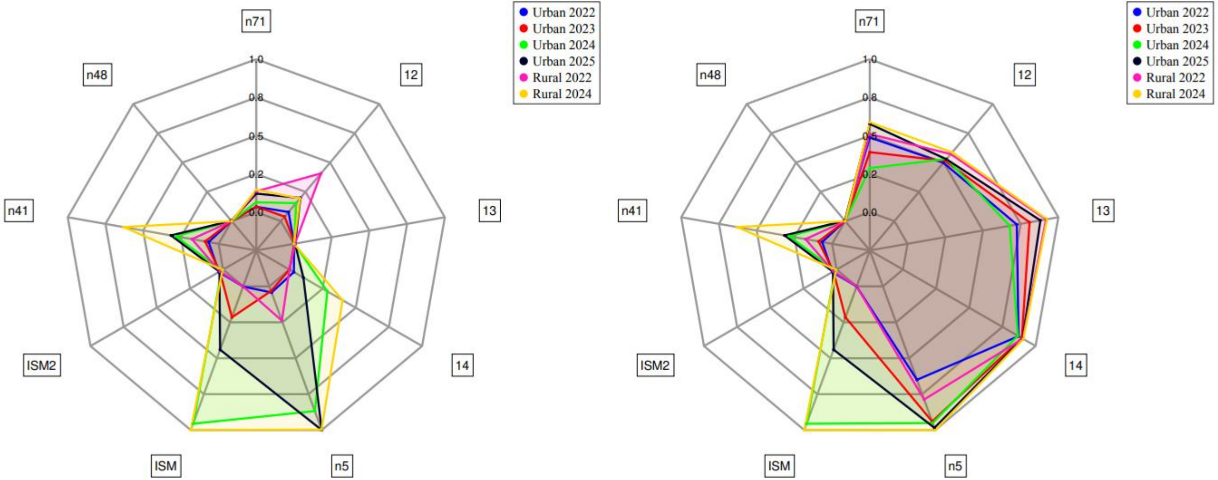
DL Urban

- S. J. Maeng and I. Guvenc, “Altitude-Dependent Cellular Spectrum Occupancy: from Measurements to Stochastic Geometry Models”, IEEE Internet of Things Journal, May 2025.
- S. J. Maeng, A. F. Raouf, O. Ozdemir, T. Zajkowski, M. Mushi, M. L. Sichitiu, R. Dutta, and I. Guvenc, “Altitude-Dependent Sub-6 GHz Wireless Spectrum: Survey, Measurements, Trends, and Modeling”, submitted to Elsevier Computer Communications, Oct. 2025.
- S. J. Maeng, A. H. F. Raouf, I. Guvenc, O. Ozdemir, M. Sichitiu, and R. Dutta, “Key Observations from Altitude-Dependent Sub-6 GHz Spectrum Measurements at AERPAW”, in Proc. IEEE DySpan Workshops, Washington, DC, May 2024.
- A. H. F. Raouf, S. J. Maeng, I. Guvenc, O. Ozdemir, and M. Sichitiu, “Cellular Spectrum Occupancy Probability in Urban and Rural Scenarios at Various UAS Altitudes“, in Proc. IEEE Personal, Indoor, Mobile Radio Communications (PIMRC), Toronto, Canada, Sep. 2023.
- A. H. F. Raouf, S. J. Maeng, I. Guvenc, O. Ozdemir, and M. L. Sichitiu, “Spectrum Monitoring and Analysis in Urban and Rural Environments at Different Altitudes”, in Proc. IEEE Veh. Technol. Conf. (VTC), Florence, Italy, June 2023.
- D. Lee, S. J. Maeng, and I. Guvenc. "Stochastic Geometry Analysis of Asymmetric Uplink Interference for Urban UAV-RC Networks." submitted to IEEE Commun. Letters, Oct. 2025.



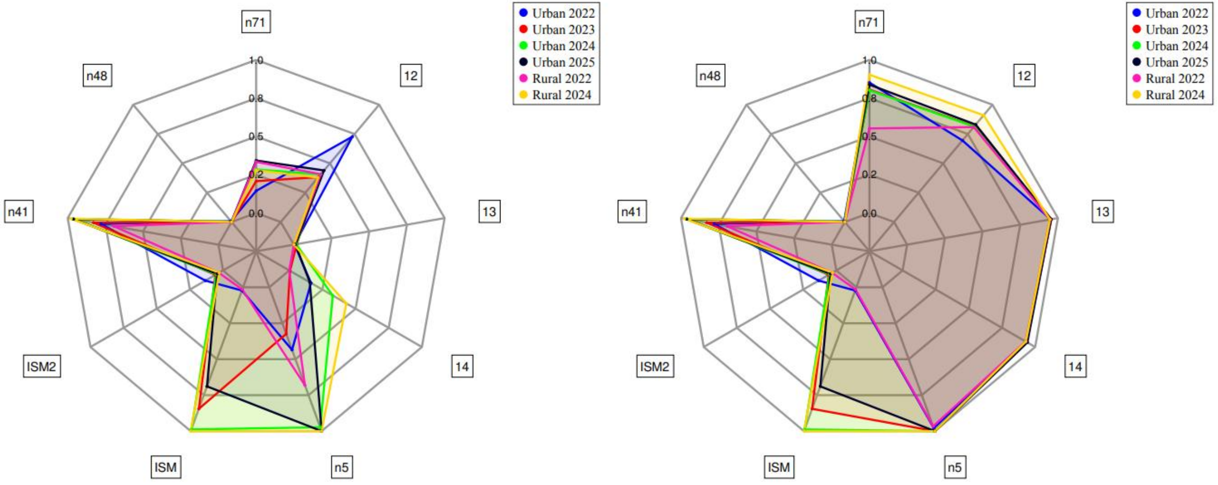
Spectrum Occupancy Measurements and Modeling in Rural & Urban Areas (2)

S. J. Maeng, A. F. Raouf, O. Ozdemir, T. Zajkowski, M. Mushi, M. L. Sichitiu, R. Dutta, and I. Guvenc, “Altitude-Dependent Sub-6 GHz Wireless Spectrum: Survey, Measurements, Trends, and Modeling”, submitted to Elsevier Computer Communications, Oct. 2025. https://www.techrxiv.org/doi/full/10.36227/techrxiv.173747664.46669225



(a) UL with $t = -45$ dBm and altitude of below 50 m.

(b) DL with $t = -45$ dBm and altitude of below 50 m.



(c) UL with $t = -45$ dBm and altitude of above 50 m.

(d) DL with $t = -45$ dBm and altitude of above 50 m.

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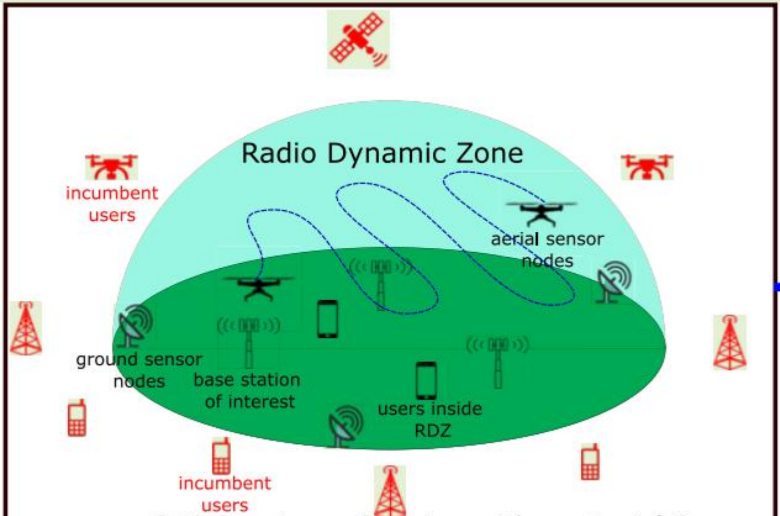
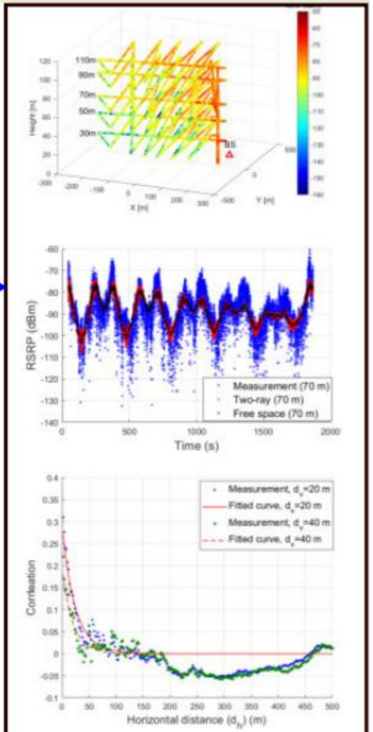
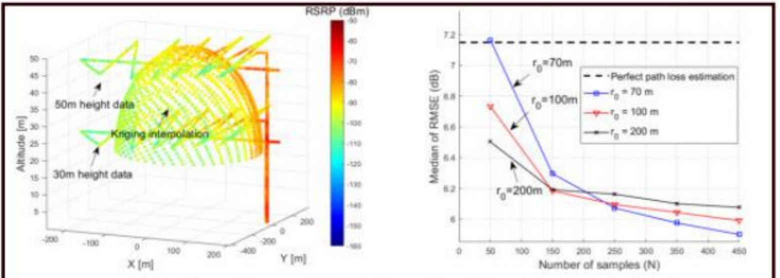
3D Radio Environment Maps (REMs)



3-D Spectrum Sensing with an Aerial Sensor



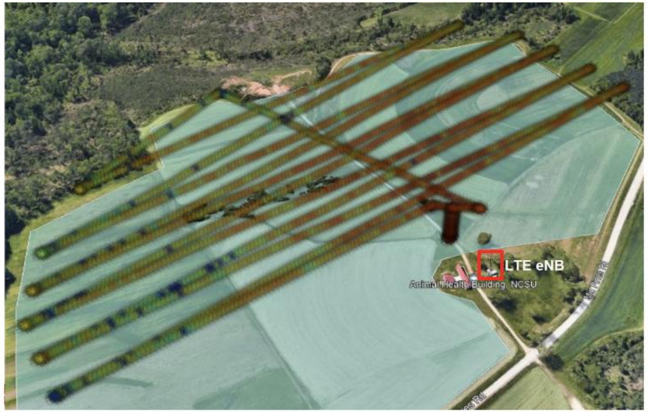
Received Signal & Spatial Correlation Analysis

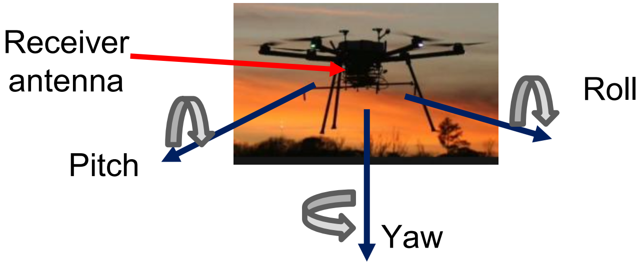


Kriging-Based 3D Radio Map Interpolation

- M. Rahman, S. J. Maeng, I. Guvenc, and C.-W. Wong, “3D Spectrum Awareness for Radio Dynamic Zones Using Kriging and Matrix Completion”, in Proc. IEEE DySpan, Washington, DC, May 2024.
- S. J. Maeng, O. Ozdemir, I. Guvenc, M. L. Sichitiu, “Kriging-Based 3-D Spectrum Awareness for Radio Dynamic Zones Using Aerial Spectrum Sensors”, IEEE Sensors, Feb. 2024.
- S. J. Maeng, O. Ozdemir, I. Guvenc, M. L. Sichitiu, M. Mushi, and R. Dutta, “LTE I/Q Data Set for UAV Propagation Modeling, Communication, and Navigation Research“, IEEE Commun. Mag., Sept. 2023.
- S. J. Maeng, O. Ozdemir, I. Guvenc, M. Sichitiu, R. Dutta, M. Mushi, and Monisha Ghosh, “SDR-Based 5G NR C-Band I/Q Monitoring and Surveillance in Urban Area Using a Helikite“, in Proc. IEEE ICIT23, April 2023.
- S. J. Maeng, O. Ozdemir, I. Guvenc, M. Sichitiu, R. Dutta, and M. Mushi, “AERIQ: SDR-Based LTE I/Q Measurement and Analysis Framework for Air-to-Ground Propagation Modeling“, in Proc. IEEE Aerospace Conference, Big Sky, MO, Mar. 2023.
- G. Reddy, I. Guvenc, M. L. Sichitiu, A. Bhuyan, B. Petersen, J. Abrahamson, "TransfoREM: Transformer aided 3D Radio Environment Mapping", submitted to IEEE ICC, Oct. 2025.

Tilt-Aware UAV Propagation and Shadow Fading Correlation Modeling





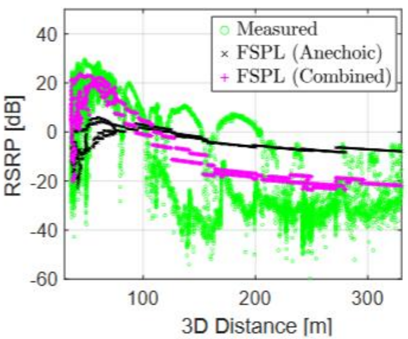
Learn combined antenna pattern from measurements

$$\mathrm{FSPL} = 20\log_{10}(r) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right)$$

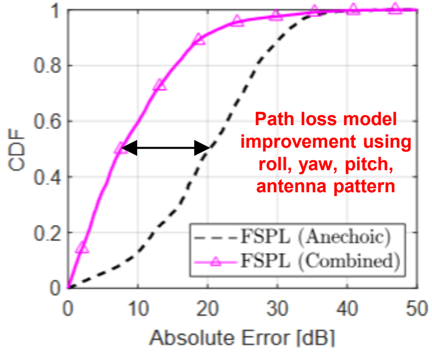
$$\mathrm{P_{Rx}}\left(\phi_\mathrm{u},\theta_\mathrm{u},\phi_\mathrm{g},\theta_\mathrm{g}\right) = \mathrm{P_{Tx}} - \mathrm{FSPL} + \mathrm{G_{uav}}\left(\phi_\mathrm{g},\theta_\mathrm{g}\right) + \mathrm{G_{gs}}\left(\phi_\mathrm{u},\theta_\mathrm{u}\right)$$

$$\mathrm{P_{Rx}}\left(\phi_\mathrm{u},\theta_\mathrm{u}\right) = \mathrm{P_{Tx}} - \mathrm{FSPL} + \boxed{\mathrm{G_{com}}\left(\phi_\mathrm{u},\theta_\mathrm{u}\right)}$$

- M. Rahman, I. Guvenc, M. Sichitiu, J. A. Abrahamson, A. Mishra, A. Bhuyan, "**Tilt-Aware Correlation Modeling of Shadow Fading for UAV-Based Spectrum Sensing**", in Proc. IEEE Asilomar 2025.
- M. Rahman, I. Güvenç, J. A. Abrahamson, A. Bhuyan, "Characterization of the Combined Effective Radiation Pattern of UAV-Mounted Antennas and Ground Station", submitted to IEEE Antennas and Propagation Letters, Sep. 2025.
- M. Rahman, S. J. Maeng, İ. Güvenç, C.-W. Wong, M. Sichitiu, J. A. Abrahamson, and A. Bhuyan, “UAV-based 3D spectrum sensing using kriging and matrix completion: Insights on altitude, bandwidth, trajectory, and antenna patterns,” *IEEE Sensors Journal*, submitted for publication, Sep. 2025.



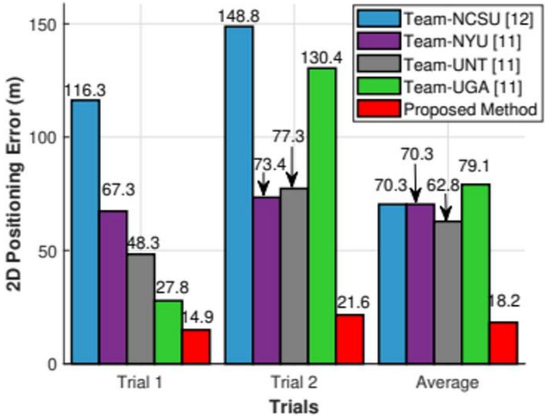
(a) A1, Learned from A2



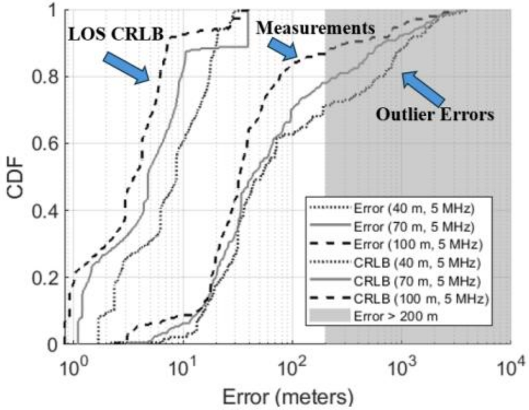
Path loss model improvement using roll, yaw, pitch, antenna pattern

(c) A1, Learned from A2

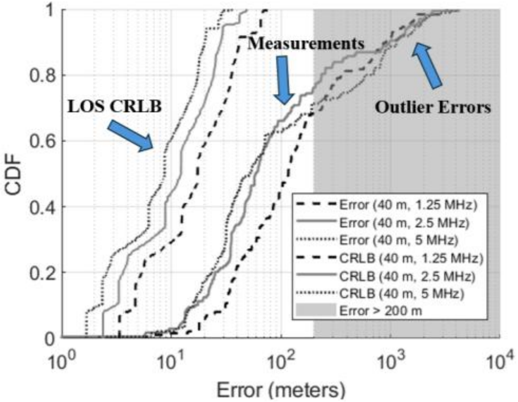
A 3D Clustering-Based Deep Learning Model for UAV-Based RF Source Localization (3)



Deep Learning (ResNet) provides better localization accuracy



Effect of altitude on RF sensor based localization

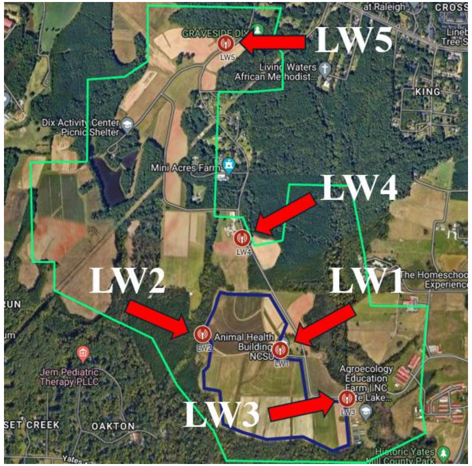


Effect of bandwidth on RF sensor based localization

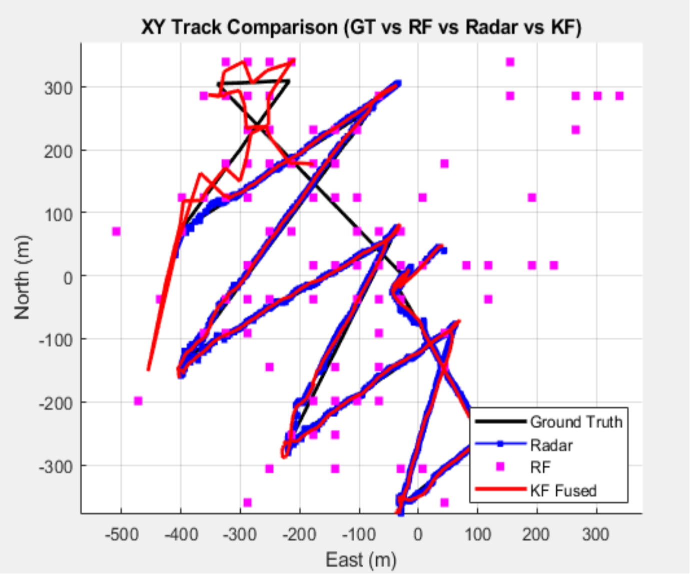
- S. Masrur, O. Ozdemir, A. Gurses, I. Guvenc, M. L. Sichitiu, R. Dutta, Magreth Mushi et al. “Collection: Datasets from AFAR Challenge,” submitted to IEEE Data Descriptions, May 2025 (arXiv preprint arXiv:2505.06823).
- S. Masrur and I. Guvenc, “Bridging Simulation and Reality: A 3D Clustering-Based Deep Learning Model for UAV-Based RF Source Localization”, in Proc. IEEE ICC Workshops, Montreal, Canada, June 2025.
- B. Chatterjee, S. Chaudhari, L. Zhizhen, Y. Liu and R. Dutta, “Wireless Signal Source Localization by Unmanned Aerial Vehicle Using AERPAW Digital Twin and Testbed,” 2024 IFIP Networking Conference (IFIP Networking), Thessaloniki, Greece, 2024, pp. 666-671.
- H. Kwon and I. Guvenc, “RF Signal Source Search and Localization Using an Autonomous UAV with Predefined Waypoints“, in Proc. IEEE Veh. Technol. Conf. (VTC), Florence, Italy, June 2023.
- C. Dickerson, S. Masrur, J. Dickerson, O. Ozdemir, and I. Guvenc, “Impact of Altitude, Bandwidth, and NLOS Bias on TDOA-Based 3D UAV Localization: Experimental Results and CRLB Analysis”, in Proc. IEEE ICC Workshops, Montreal, Canada, June 2025.
- D. Lee, O. Ozdemir, A. Ram, and I. Guvenc, "Analysis and Prediction of Coverage and Channel Rank for UAV Networks in Rural Scenarios with Foliage", IEEE Open J. Veh. Technol., Aug. 2025.

Integrated Sensing and Communications (ISAC) for Drones

Keysight N6841A RF Sensor for Spectrum Monitoring

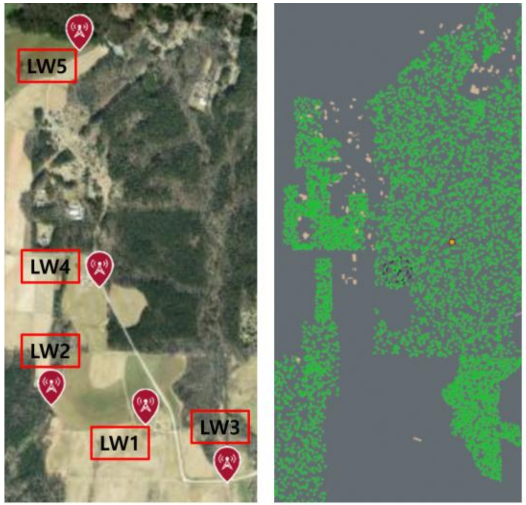


Fortem R20 radar

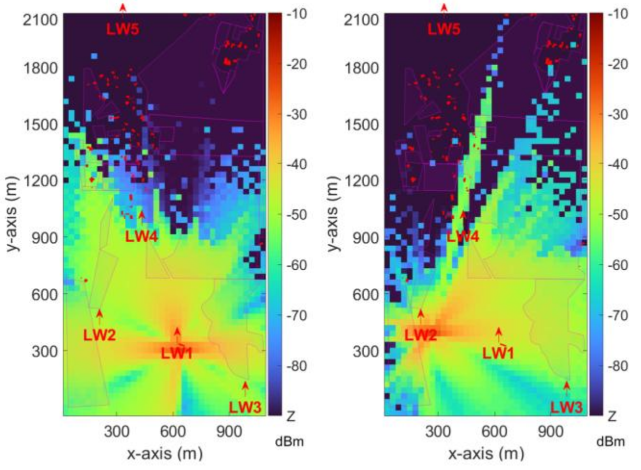


Cole Dickerson, Sean Kearney, Sultan Manjur, Ismail Guvenc, Sevgi Gurbuz, Ali Gurbuz, Ozgur Ozdemir, Mihail Sichitiu, "Leveraging Cellular ISAC and Passive RF Sensing for UAV Detection and Tracking", in Proc. IEEE Asilomar, Oct. 2025.

Ray Tracing Analysis and Passive Localization (1)

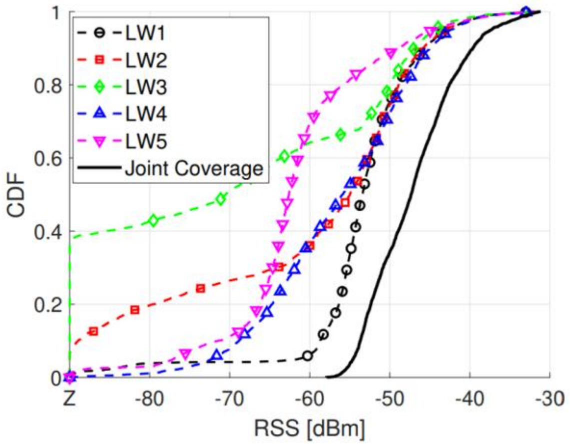


(a) Satellite view (b) Blender scene

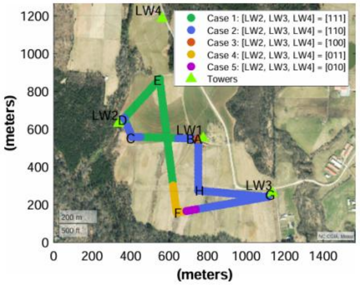


(a) LW1 (b) LW2

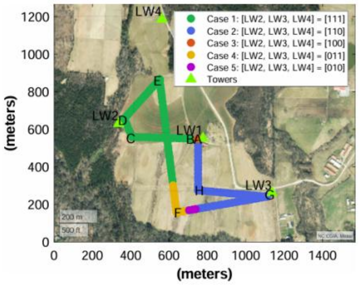
Coverage at 30 m UAV altitude



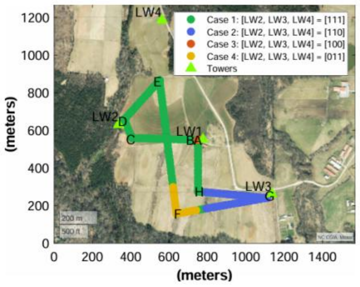
Tree model in Blender



40 m Altitude



70 m Altitude

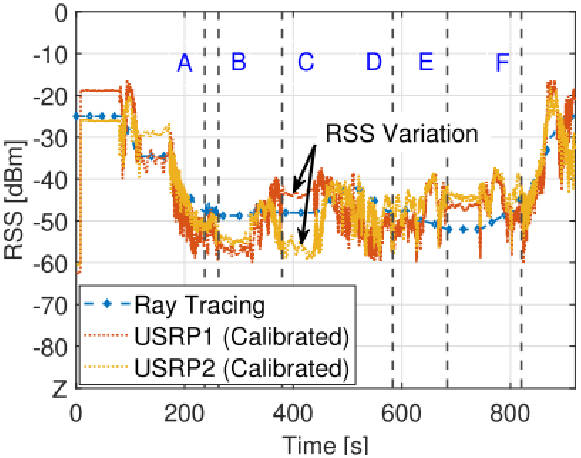


100 m Altitude

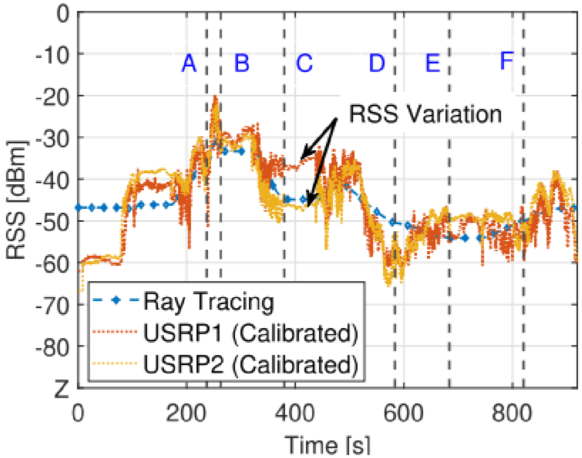
Ray tracing based coverage of different fixed nodes at UAV height of 110m at Lake Wheeler.

D. Lee, O. Ozdemir, A. Ram, and I. Guvenc, "Analysis and Prediction of Coverage and Channel Rank for UAV Networks in Rural Scenarios with Foliage", IEEE Open J. Veh. Technol., Aug. 2025.

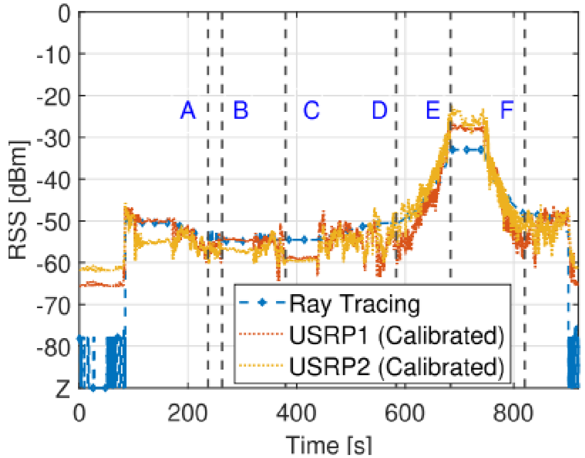
Ray Tracing Analysis and Passive Localization (2)



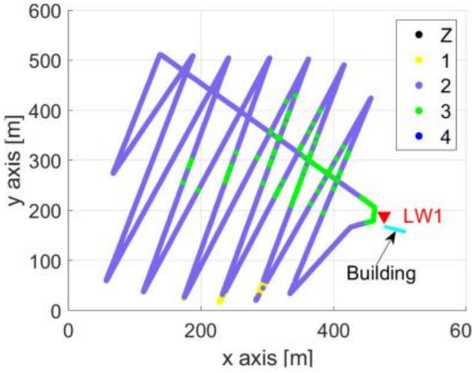
(a) LW1



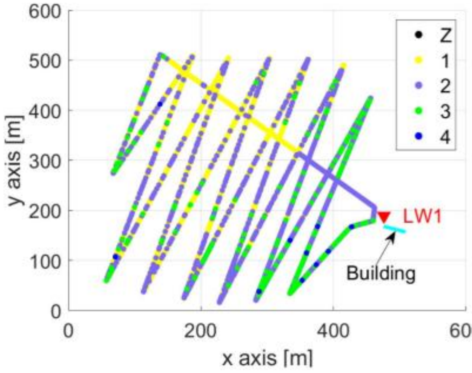
(b) LW2



(c) LW3



(a) 5G NR RI measurement



(b) RT simulation with K_3

Ray tracing based coverage of different fixed nodes at UAV height of 110m at Lake Wheeler.
D. Lee, O. Ozdemir, A. Ram, and I. Guvenc, "Analysis and Prediction of Coverage and Channel Rank for UAV Networks in Rural Scenarios with Foliage", IEEE Open J. Veh. Technol., Aug. 2025.

Outline

- NSF AERPAW Platform Overview
- Research Examples from AERPAW
- **Fusion of Radar and Passive RF Sensing***
- 5G ISAC based UAV Detection and Tracking

* C. Dickerson, S. Kearney, S. Manjur, I. Guvenc, S. Gurbuz, A. Gurbuz, O. Ozdemir, and M. Sichitiu, "Leveraging Cellular ISAC and Passive RF Sensing for UAV Detection and Tracking", in Proc. IEEE Asilomar Conference, Oct. 2025.

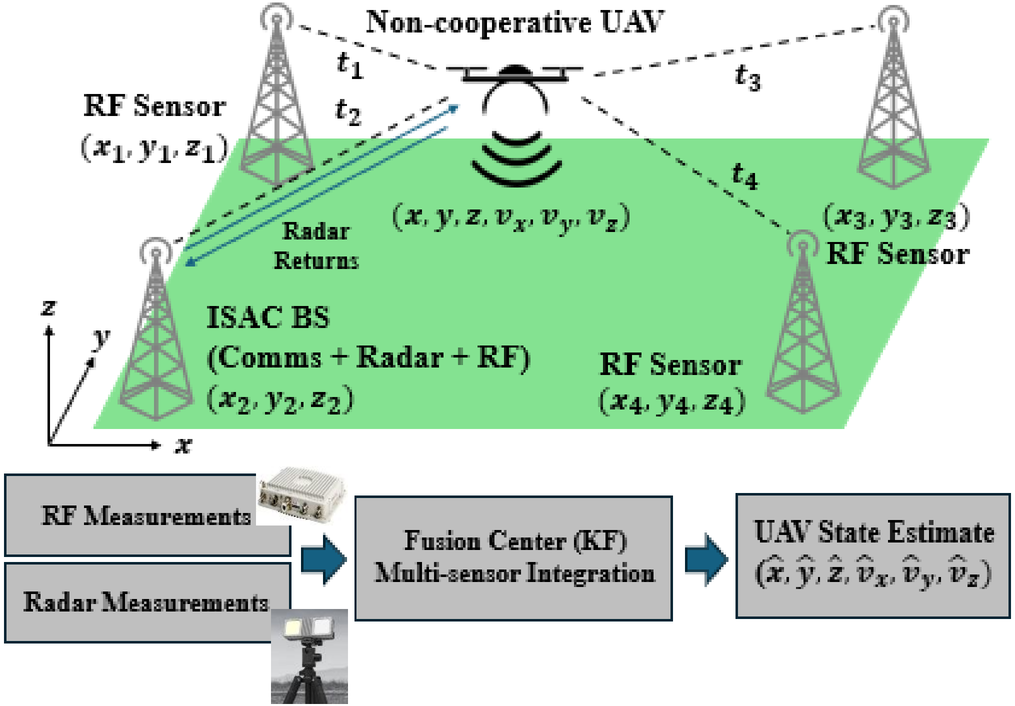
Motivation and Problem

- UAV presence near critical infrastructure is growing
- Conventional approaches for sensing drones have shortcoming
- Need robust, **multi-modal** tracking that works in real deployment

T. Prevot, J. Rios, P. Kopardekar, J. R. III, M. Johnson, and J. Jung, "**UAS traffic management (UTM) concept of operations to safely enable low altitude flight operations**," in *AIAA Aviation Forum*, Jun. 2016.

UAV Tracking and Sensor Fusion Scenario

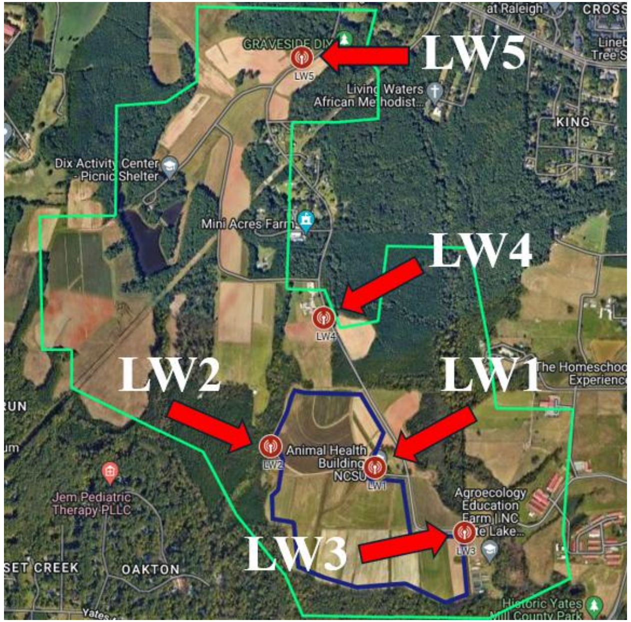
- **Goal:** Fuse heterogenous radar and RF measurements for 3D UAV state estimation
- **Output:** Estimated UAV trajectory
- **Radar:** Provides range, azimuth, and elevation angles
- **RF Sensor:** Provide TDOA-based position estimates
- **Fusion Center:** Kalman filter combining both modalities



AERPAW Testbed for 5G Wireless and UAV Communications

- **AERPAW:** Aerial Experimentation and Research Platform for Advanced Wireless
- Supports safe, repeated UAV experiments with:
  - Remote flight control & logging
  - Configurable wireless nodes (5G/LTE/SDRs/radar)
  - Flexible flight corridors and operational airspace
- Enables end-to-end data collection, including:
  - UAV telemetry (GPS, IMU)
  - RF signal measurements
  - Radar detections and tracking logs

AERPAW UAV with an SDR payload

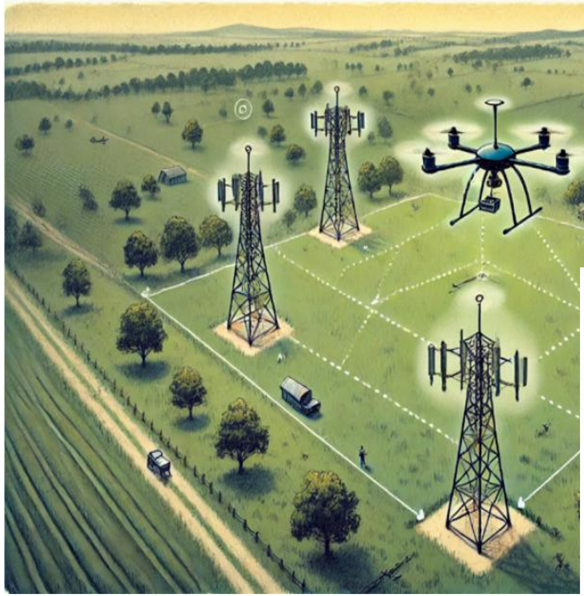


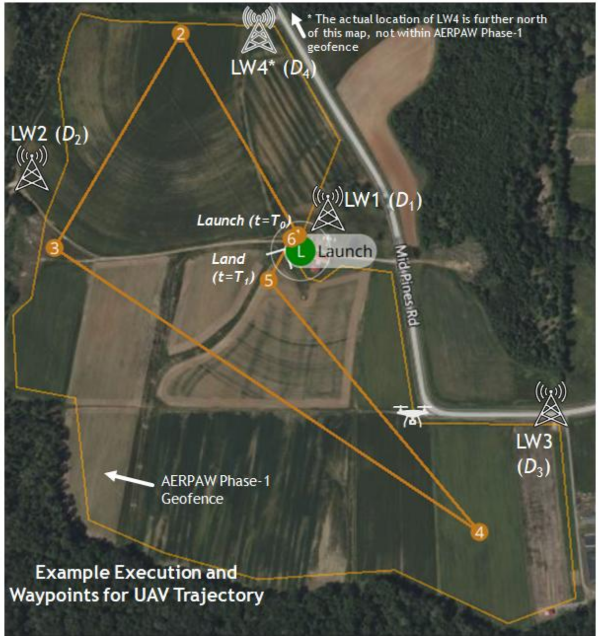
AERPAW sensor layout at Lake Wheeler, also showing building and vegetation

https://aerpaw.org/

AERPAW Autonomous Data Mule (AADM) Challenge Dataset

- Data from AADM Student Challenge (Sept. 2025)
- Participated by 16 student teams
- Sensors recorded:
  - UAV telemetry (GPS, IMU)
  - Keysight RF Sensor TDOA geolocation
  - Fortem R20 radar tracking
  - LoRa RSSI/SNR
  - USRP signal & throughput
- Enables ground-truth aligned performance evaluation
- Datasets to be posted publicly on https://datadryad.org/ soon





Example Execution and Waypoints for UAV Trajectory

https://aerpaw.org/aerpaw-aadm-challenge

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Keysight N6841A RF Sensor for Spectrum Monitoring

- Deployed at AERPAW LW2-LW5 and CC1
- **Frequency range:** 20 MHz - 6 GHz
- **Maximum real-time bandwidth:** 20 MHz
- Integrated GPS for location tagging and time-synchronous applications
- 4.8-second signal LOOKback at 20 MHz BW for detecting short-duration and interference signals
- **Use cases:** Automated spectrum monitoring, signal intercept and classification, RF signal source geolocation

Keysight N6841A RF Sensor

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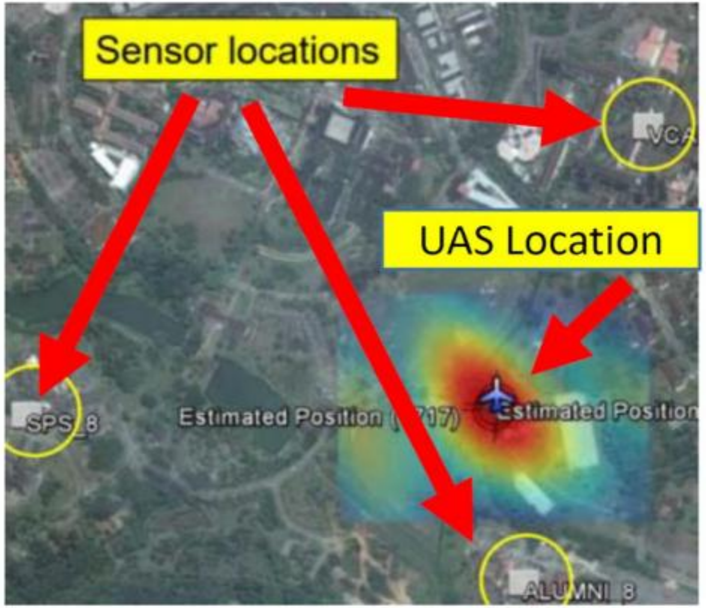
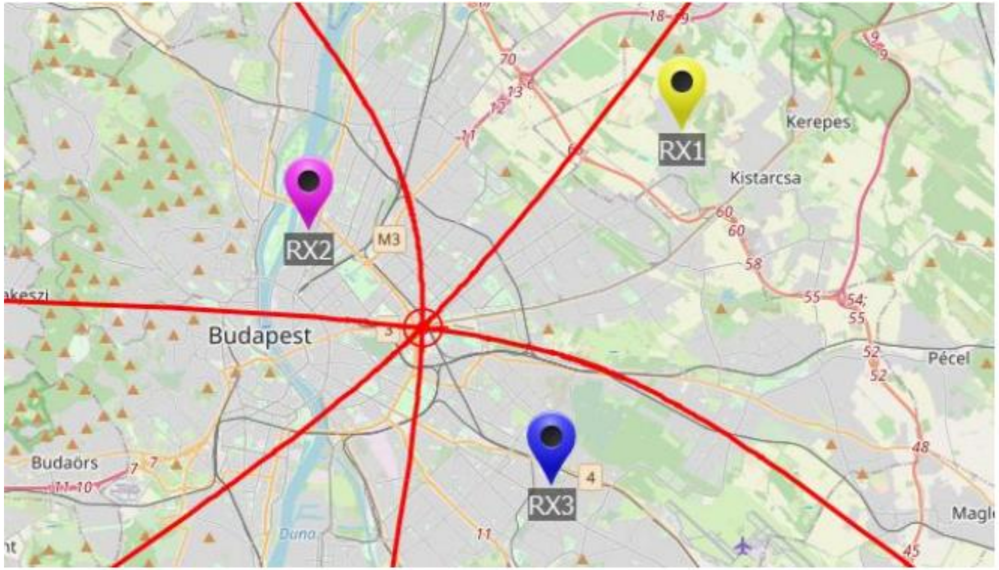
Keysight N6841A RF Sensor for TDOA Based Localization





Fortem R20 Tracking Radar

- **Frequency:** 15.4-16.7 GHz (Ku-band and FR3)
- **Field of View:** Up to 120° azimuth x 60° elevation
- **Range Resolution:** ~1m (180 MHz bandwidth)
- **Tracking Range:**
  - Small quadrotor (Phantom-class): 0.75-1.0 km
  - Larger UAVs (Matrice-class): up to ~1.3 km
- **Outputs:** Range, Doppler, azimuth/elevation angle, RCS, lat/long, classification outputs
- **Track Update Range:** 64 ms to 1.3 s (configurable)

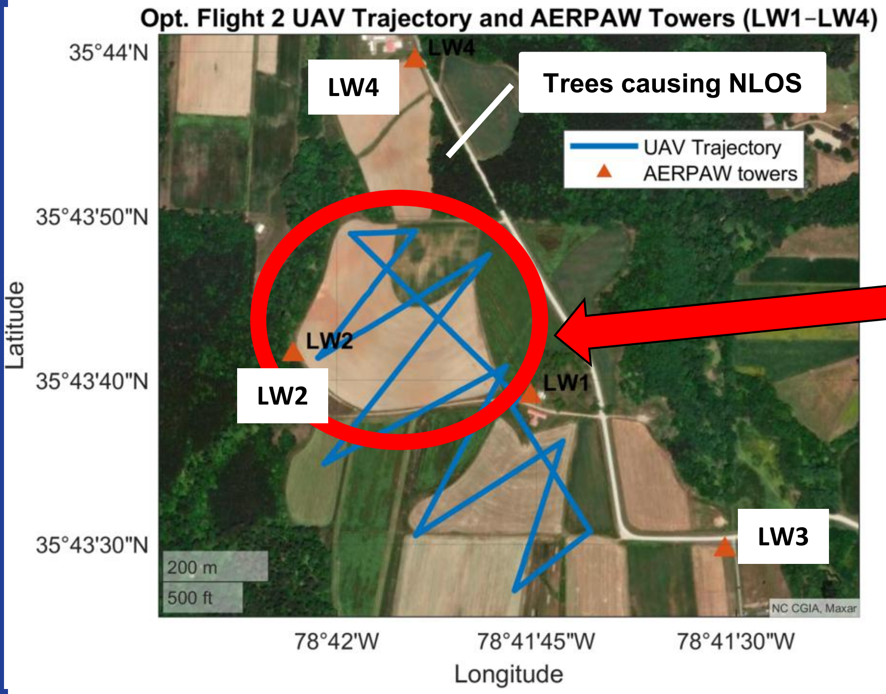
Fortem R20 radar

Fortem R20 as a Proxy for 6G ISAC Measurements

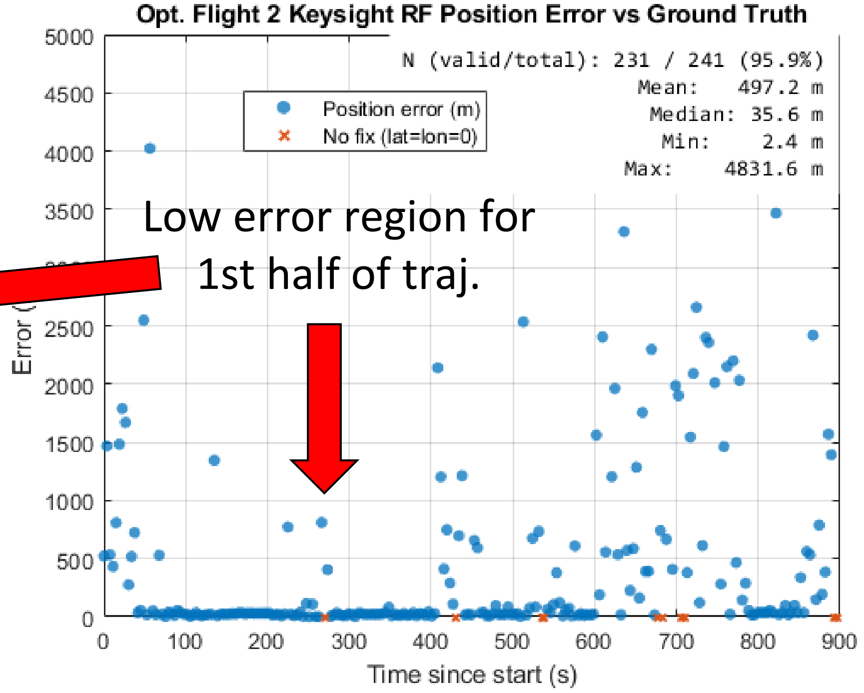
- FR3 band (15-17 GHz) -> aligns with 6G ISAC research spectrum
- Same sensing observables: range, Doppler, angle
- Deployed at similar height as other AERPAW towers (10 meters)
- Core physics identical: propagation, scattering, geometry, tracking
- Difference: ISAC waveforms = comm-optimized, not radar-optimized
- Still useful to study real-world sensing performance at the FR3 spectrum

Fortem R20 deployed at 10 meters next to AERPAW LW3

Standalone Keysight RF Sensor Geolocation Performance



Trees causing NLOS



Low error region for 1st half of traj.

Decent performance for 1st half of trajectory, errors are quite high afterwards due to NLOS (for LW4 and LW5), poor geometry, etc.

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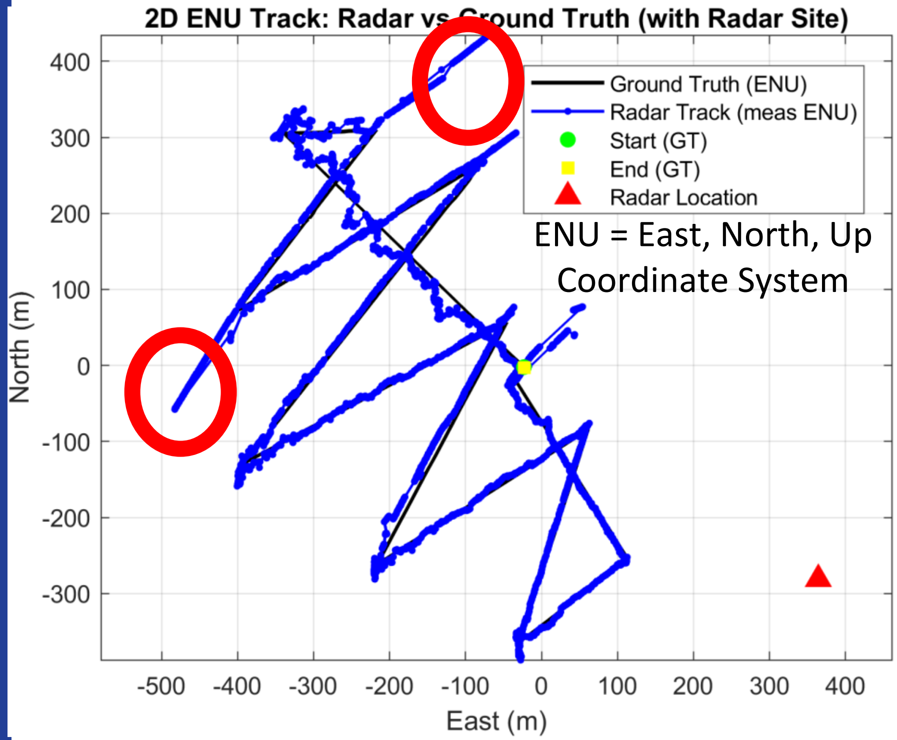
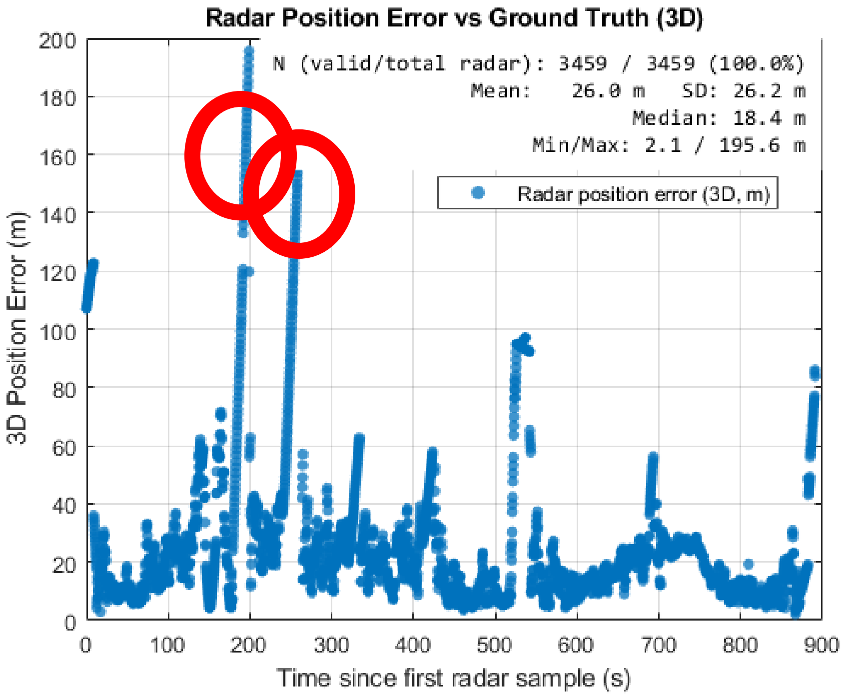
Standalone Fortem R20 Tracking Performance

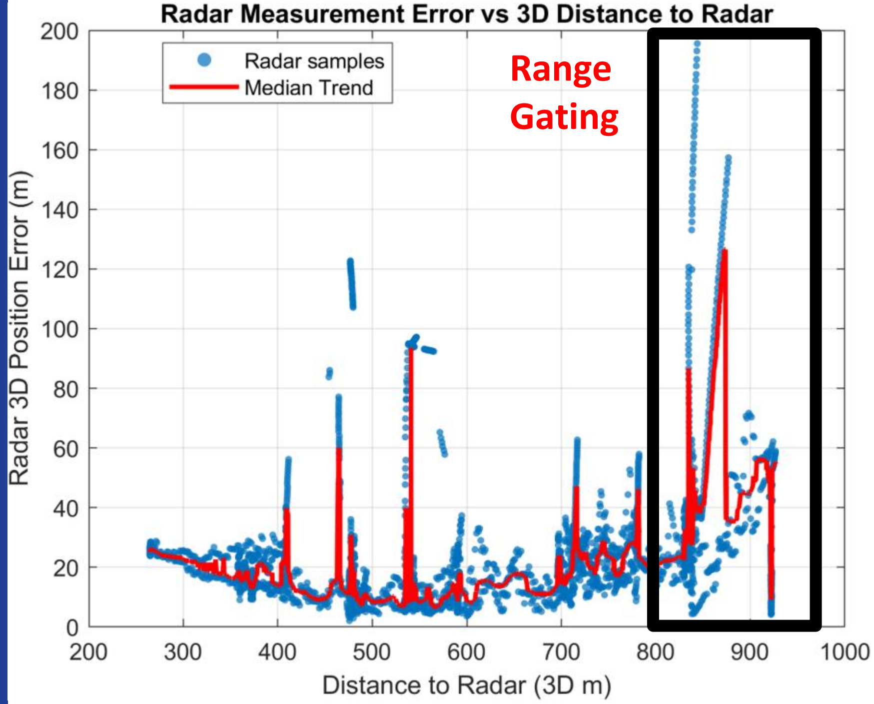


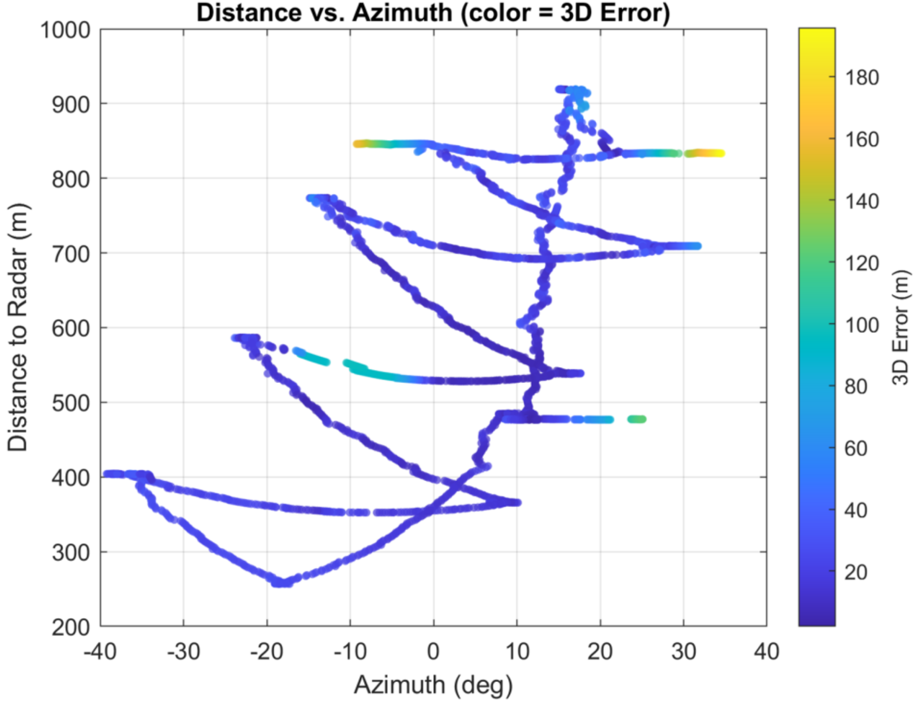
ENU = East, North, Up Coordinate System



- All errors under 100m, struggles most at corners of zigzags which is where peaks occur in position error vs. ground truth

Radar Errors vs. UAV to Radar Distance

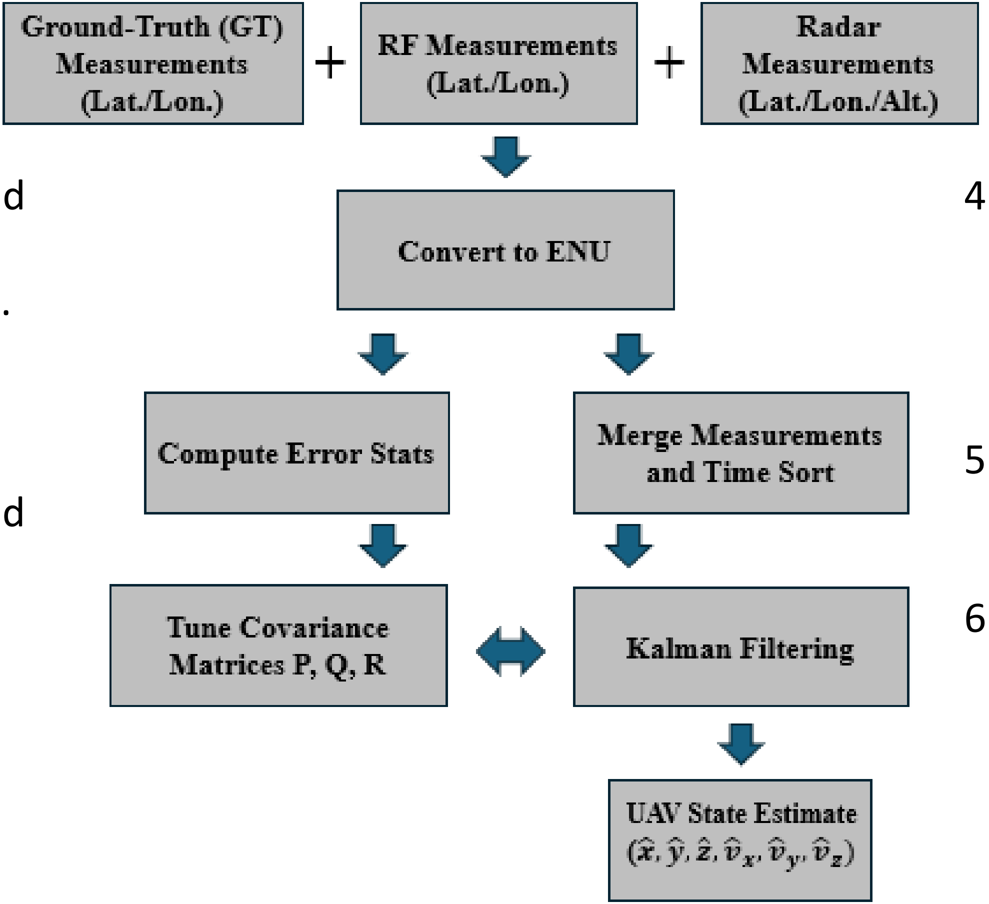




- Radar 3D position error stays low (<25m) inside ~600-700m
- Error increases sharply beyond ~800m, motivating range gating

UAV Tracking & Sensor Fusion Workflow

1. Collect RF, radar, and GT data
2. Convert lat./lon./alt. to a common ENU coordinate frame
3. Compute errors between sensors and GT in ENU and tune covariance matrices (**P, Q, R**)



Ground-Truth (GT) Measurements (Lat./Lon.) + RF Measurements (Lat./Lon.) + Radar Measurements (Lat./Lon./Alt.)

Convert to ENU

Compute Error Stats

Merge Measurements and Time Sort

Tune Covariance Matrices P, Q, R

Kalman Filtering

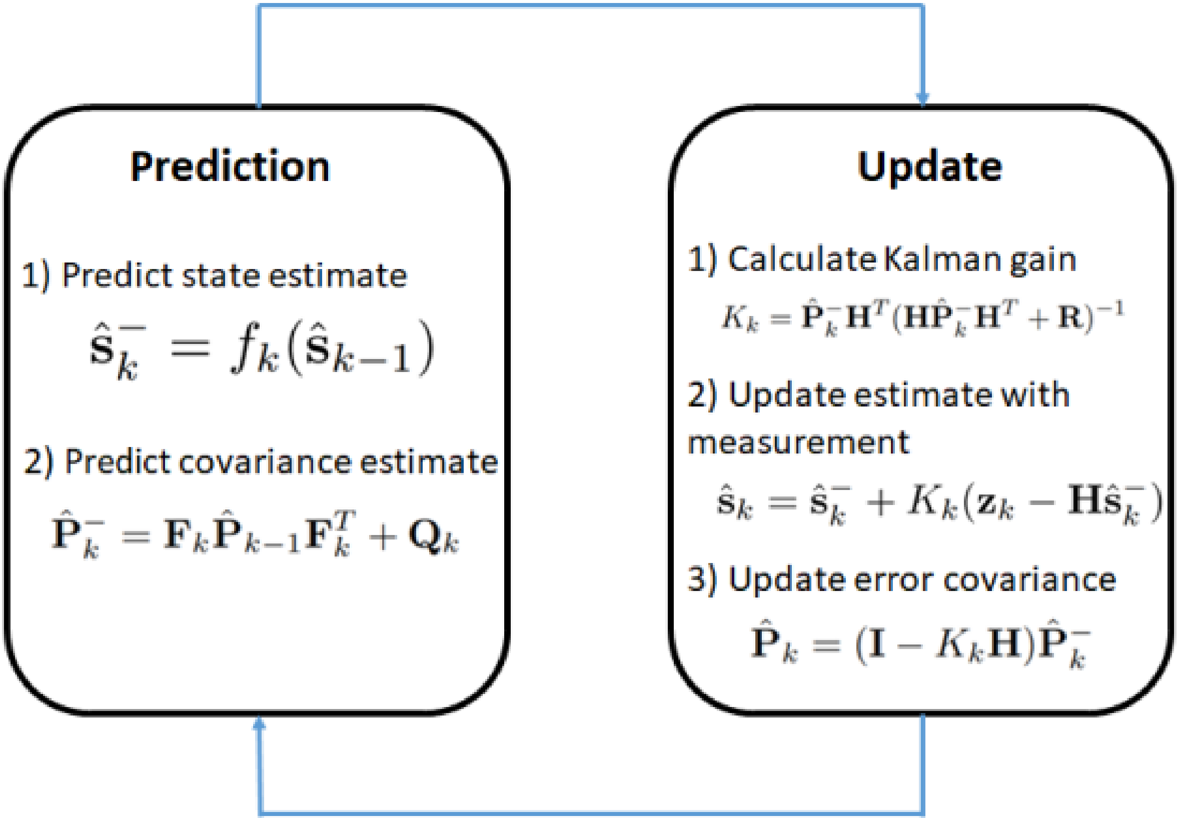
UAV State Estimate $(\hat{x}, \hat{y}, \hat{z}, \hat{v}_x, \hat{v}_y, \hat{v}_z)$

4.) Integrate radar and RF sensor measurements into a single, ordered timeline

5.) Apply Kalman filtering for multi-sensor fusion

6.) Output UAV state estimates

Baseline Constant-Velocity (CV) Kalman Filter



Prediction

1) Predict state estimate

$$\hat{\mathbf{s}}_k^- = f_k(\hat{\mathbf{s}}_{k-1})$$

2) Predict covariance estimate

$$\hat{\mathbf{P}}_k^- = \mathbf{F}_k\hat{\mathbf{P}}_{k-1}\mathbf{F}_k^T + \mathbf{Q}_k$$

Update

1) Calculate Kalman gain

$$K_k = \hat{\mathbf{P}}_k^-\mathbf{H}^T(\mathbf{H}\hat{\mathbf{P}}_k^-\mathbf{H}^T + \mathbf{R})^{-1}$$

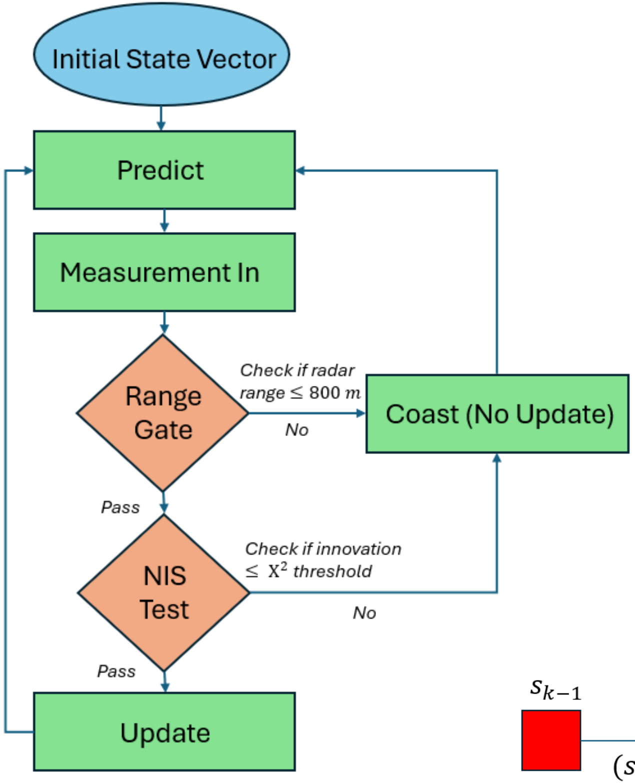
2) Update estimate with measurement

$$\hat{\mathbf{s}}_k = \hat{\mathbf{s}}_k^- + K_k(\mathbf{z}_k - \mathbf{H}\hat{\mathbf{s}}_k^-)$$

3) Update error covariance

$$\hat{\mathbf{P}}_k = (\mathbf{I} - K_k\mathbf{H})\hat{\mathbf{P}}_k^-$$

Modified CV-Kalman Filter with Range and NIS Gating



- **Range Gate:** Limits radar updates to reliable detection ranges (≤ 800 m) where SNR and angular accuracy are stable
  - Prevents distant, low-SNR radar returns from degrading the filter
- **Normalized Innovation Squared (NIS) Gating:** Rejects measurements inconsistent with predicted state using a $\mathbf{X}^2$-based statistical test
  - Ensures only physically plausible, high-confidence updates are used and helps to catch outlier RF sensor measurements
- **Coasting:** When either gate fails, the filter propagates forward without update to maintain track continuity

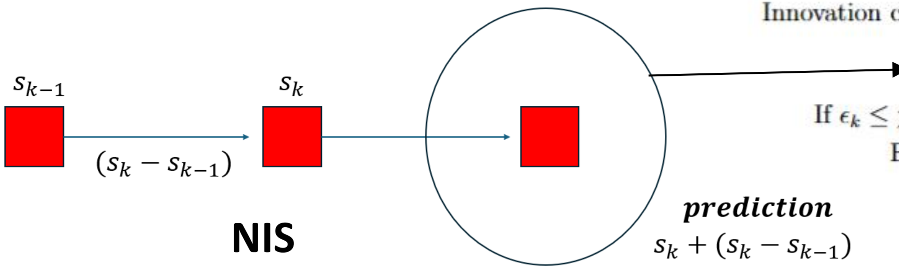
Innovation (measurement residual): $\nu_k = z_k - H_k \hat{x}_{k|k-1}$

Innovation covariance: $S_k = H_k P_{k|k-1} H_k^T + R_k$

NIS: $\epsilon_k = \nu_k^T S_k^{-1} \nu_k$

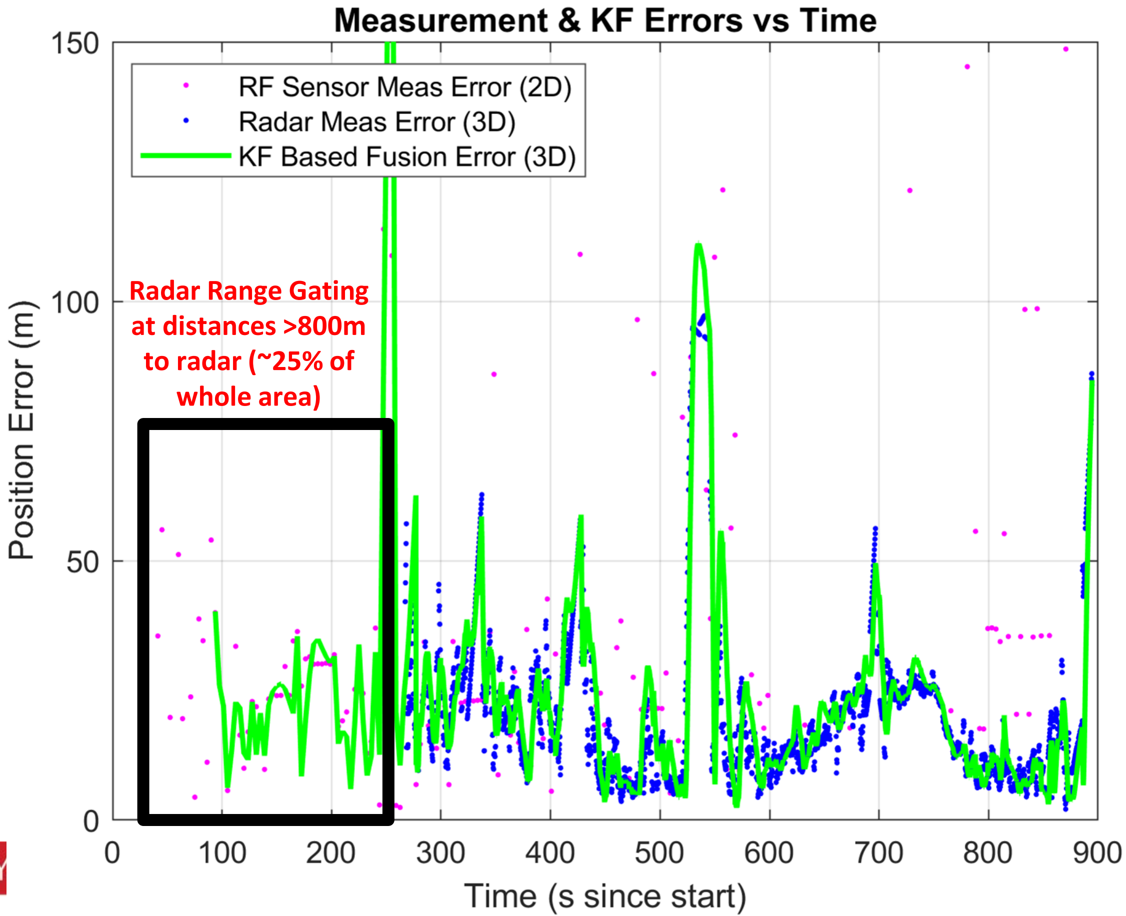
If $\epsilon_k \le \chi^2_{\text{threshold}} \Rightarrow$ Accept (Update)

Else $\Rightarrow$ Reject (Coast)



NIS Gating

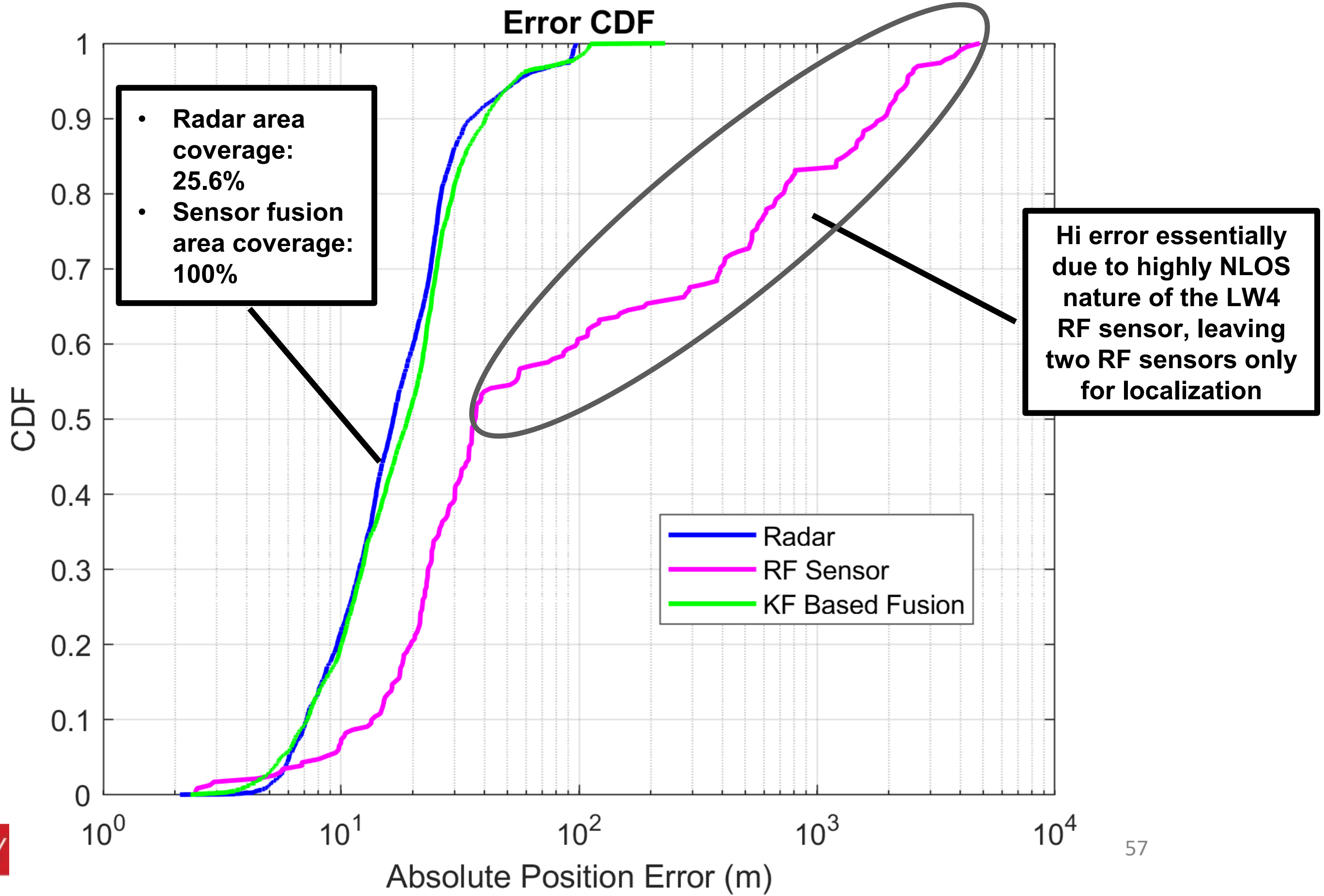
RF Sensor, Radar, and KF Error vs. Time



Radar Range Gating at distances >800m to radar (~25% of whole area)

NC STATE UNIVERSITY

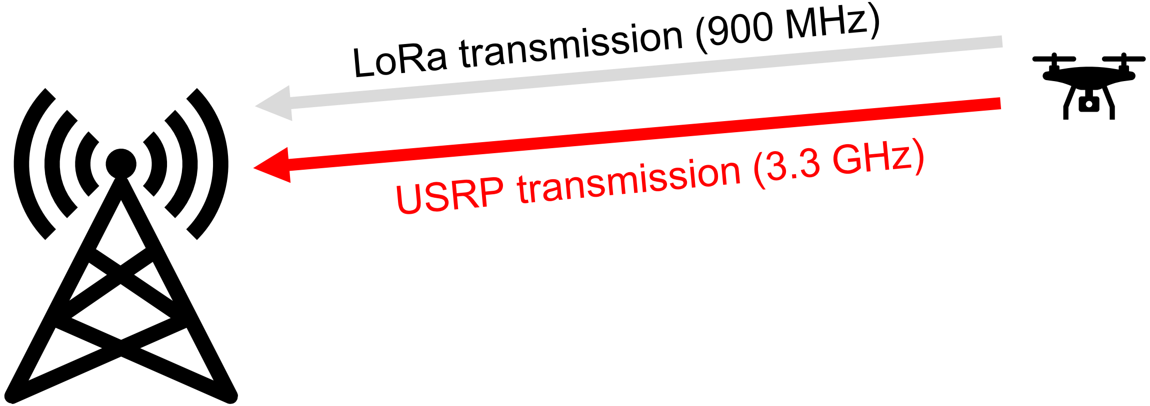
CDFs of RF Sensor, Radar, and KF Output



- **Radar area coverage: 25.6%**
- **Sensor fusion area coverage: 100%**

Hi error essentially due to highly NLOS nature of the LW4 RF sensor, leaving two RF sensors only for localization

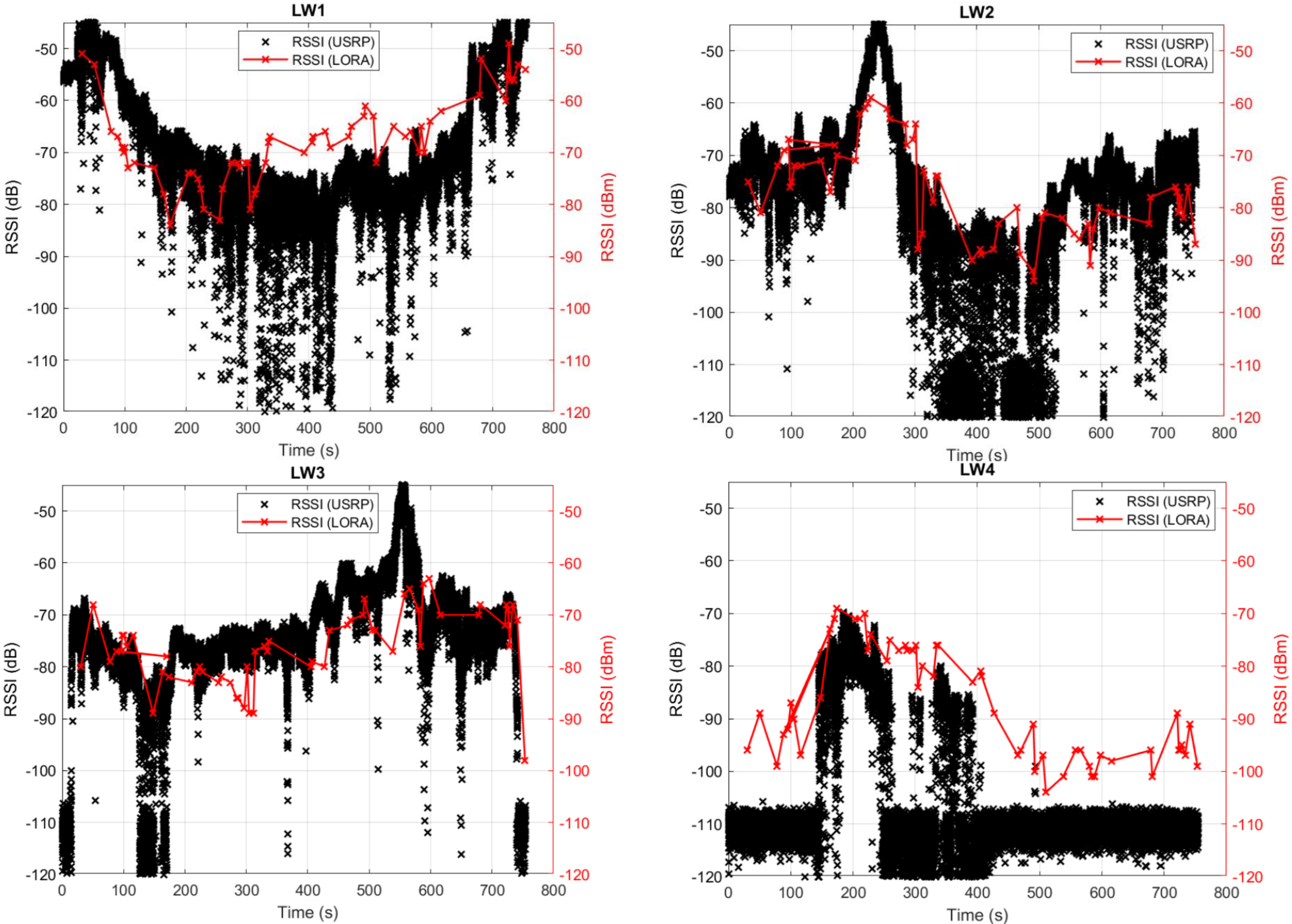
Simultaneous LoRa and USRP Measurements



- Can be used to transmit location information through “Remote ID”
- How are fading and blockage patterns different?

Signal Strength vs Time

- LoRa signals propagate better through obstacles, do not have as severe deep fades
- Deep fades at USRP signal are potential reason high errors in RF sensor based localization



Key Takeaways and Future Work

Radar

RF Sensing

(TDOA - USRP)

Collect multi-modal data: radar (ISAC proxy), TDOA, RSS

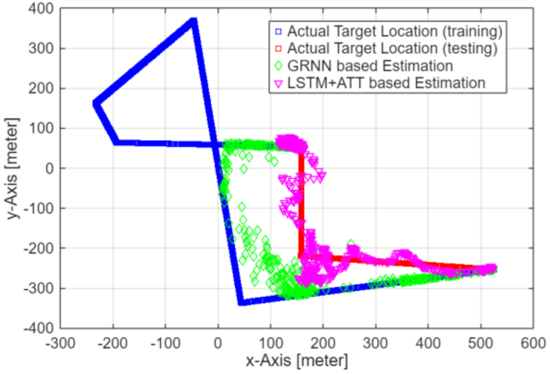
Develop AI-driven fusion and tracking models

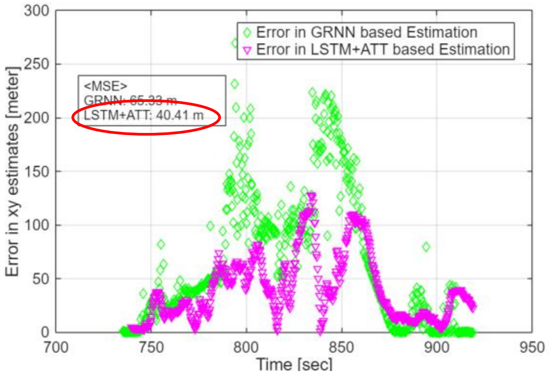
Quantify gains from **AI-based** multi-modal **ISAC fusion** vs standalone sensing and traditional methods

Move toward real ISAC-based sensing systems

Early Learning-Based Results

RSS1&RSS2 for LW1-4 (8 features)





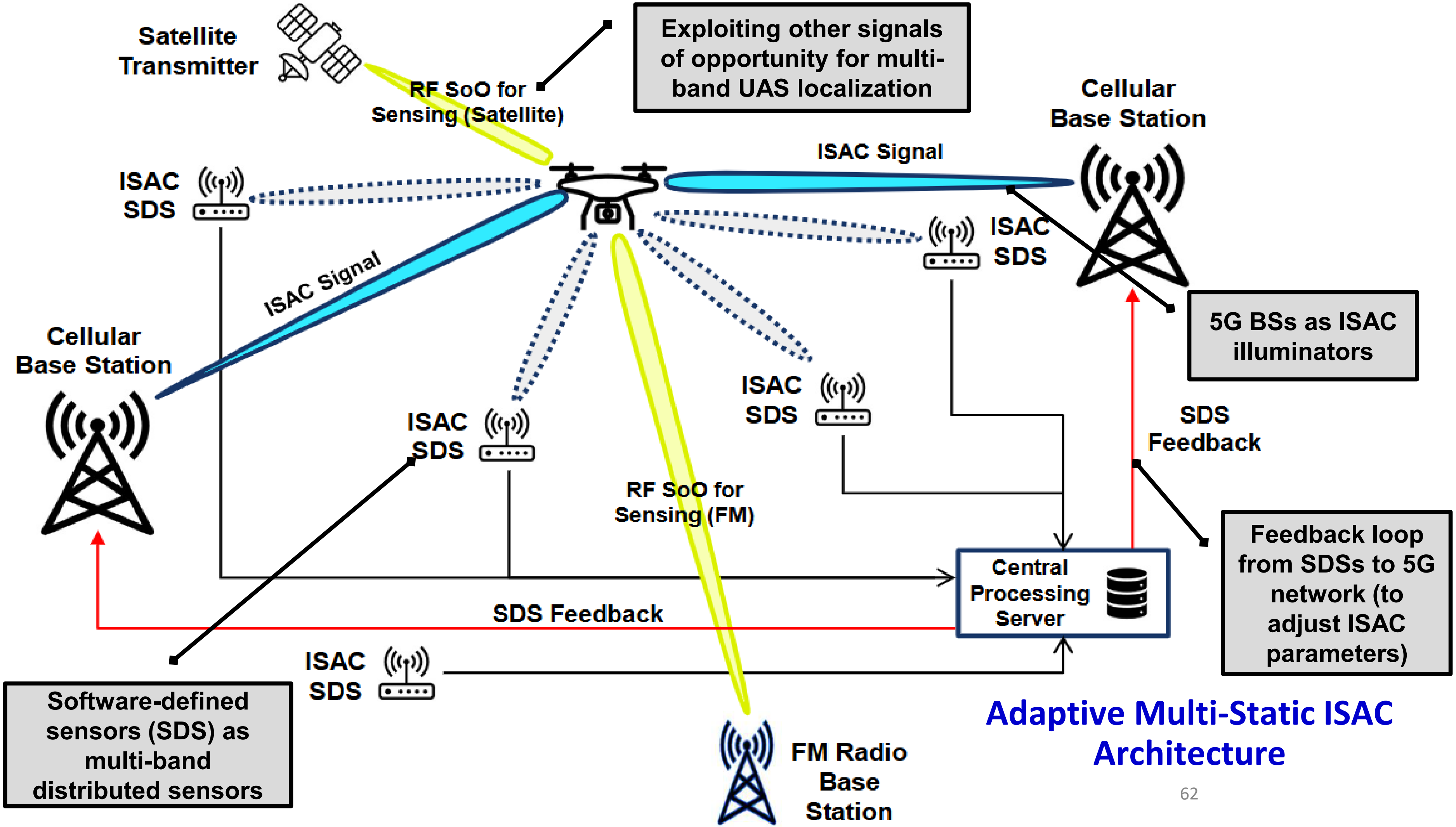
- **No single sensor or radar is sufficient to localize/track.**
- Fusion delivers **radar-level accuracy** with **full trajectory coverage.**
- **Multi-modal sensing** is the path to **reliable real-world UAV tracking**

Outline

- NSF AERPAW Platform Overview
- Research Examples from AERPAW
- Fusion of Radar and Passive RF Sensing
- **5G ISAC based Multi-Static UAV Detection and Tracking***

* C. Dickerson, W. Khawaja, and I. Guvenc, “**Adaptive Multi-Static ISAC for Load-Aware UAV Detection and Tracking in Contested RF Environments**,” in submission to *AIAA/IEEE Digital Avionics Systems Conf. (DASC)*, Orlando, FL, USA, Sept. 2026.

Adaptive Multi-Static ISAC Architecture



Exploiting other signals of opportunity for multi-band UAS localization

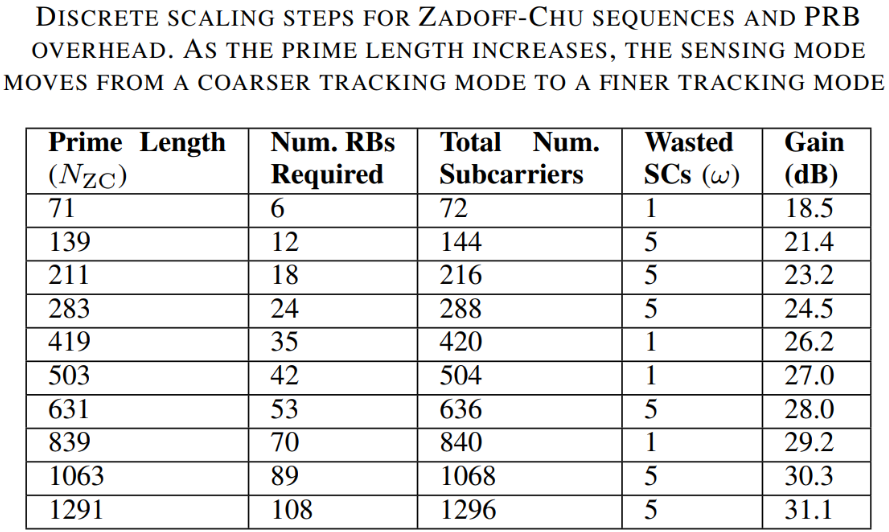
5G BSs as ISAC illuminators

Feedback loop from SDSs to 5G network (to adjust ISAC parameters)

Software-defined sensors (SDS) as multi-band distributed sensors

Schedule Zadoff-Chu Sequences for Sensing

- Use of SSBs, SRS, and other sequences for sensing:
    - Can not typically control their waveform parameters for sensing purposes (precoders, bandwidth, periodicity)
- Alternative:
    - Schedule sensing resources explicitly
    - Zadoff-Chu sequences
    - Can only have specific lengths (not multiples of 12 subcarriers PRB size in 5G)
    - Can control precoding (like user-specific beamforming) and sequence length adaptively

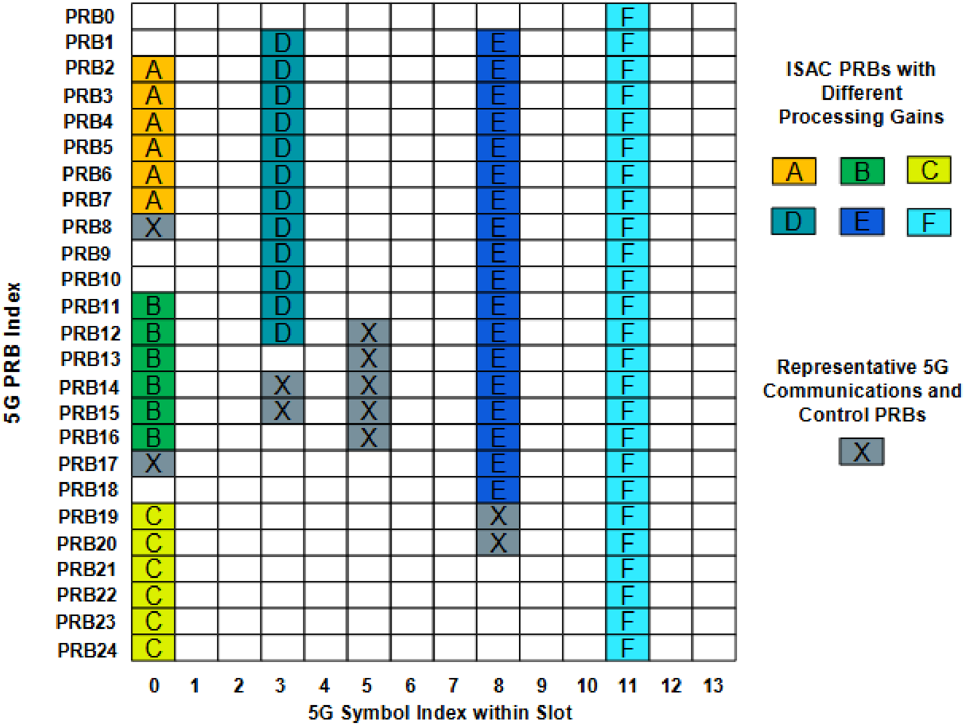


DISCRETE SCALING STEPS FOR ZADOFF-CHU SEQUENCES AND PRB OVERHEAD. AS THE PRIME LENGTH INCREASES, THE SENSING MODE MOVES FROM A COARSER TRACKING MODE TO A FINER TRACKING MODE

Prime Length (N_{ZC})	**Num. RBs Required**	**Total Num. Subcarriers**	**Wasted SCs** (ω)	**Gain (dB)**
71	6	72	1	18.5
139	12	144	5	21.4
211	18	216	5	23.2
283	24	288	5	24.5
419	35	420	1	26.2
503	42	504	1	27.0
631	53	636	5	28.0
839	70	840	1	29.2
1063	89	1068	5	30.3
1291	108	1296	5	31.1

Load-Aware Resource Allocation and Beam Management

Time-Frequency Allocation



5G PRB Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13
PRB0												F		
PRB1				D					E			F		
PRB2	A			D					E			F		
PRB3	A			D					E			F		
PRB4	A			D					E			F		
PRB5	A			D					E			F		
PRB6	A			D					E			F		
PRB7	A			D					E			F		
PRB8	X			D					E			F		
PRB9				D					E			F		
PRB10				D					E			F		
PRB11	B			D					E			F		
PRB12	B			D		X			E			F		
PRB13	B					X			E			F		
PRB14	B			X		X			E			F		
PRB15	B			X		X			E			F		
PRB16	B					X			E			F		
PRB17	X								E			F		
PRB18									E			F		
PRB19	C								X			F		
PRB20	C								X			F		
PRB21	C											F		
PRB22	C											F		
PRB23	C											F		
PRB24	C											F		

5G Symbol Index within Slot

ISAC PRBs with Different Processing Gains

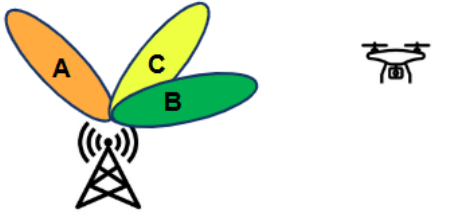
A B C

D E F

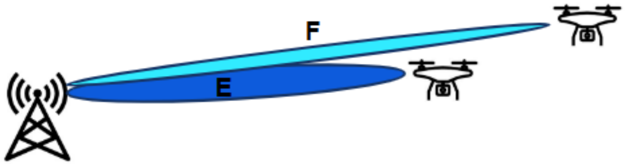
Representative 5G Communications and Control PRBs

X

Spatial Adaptation

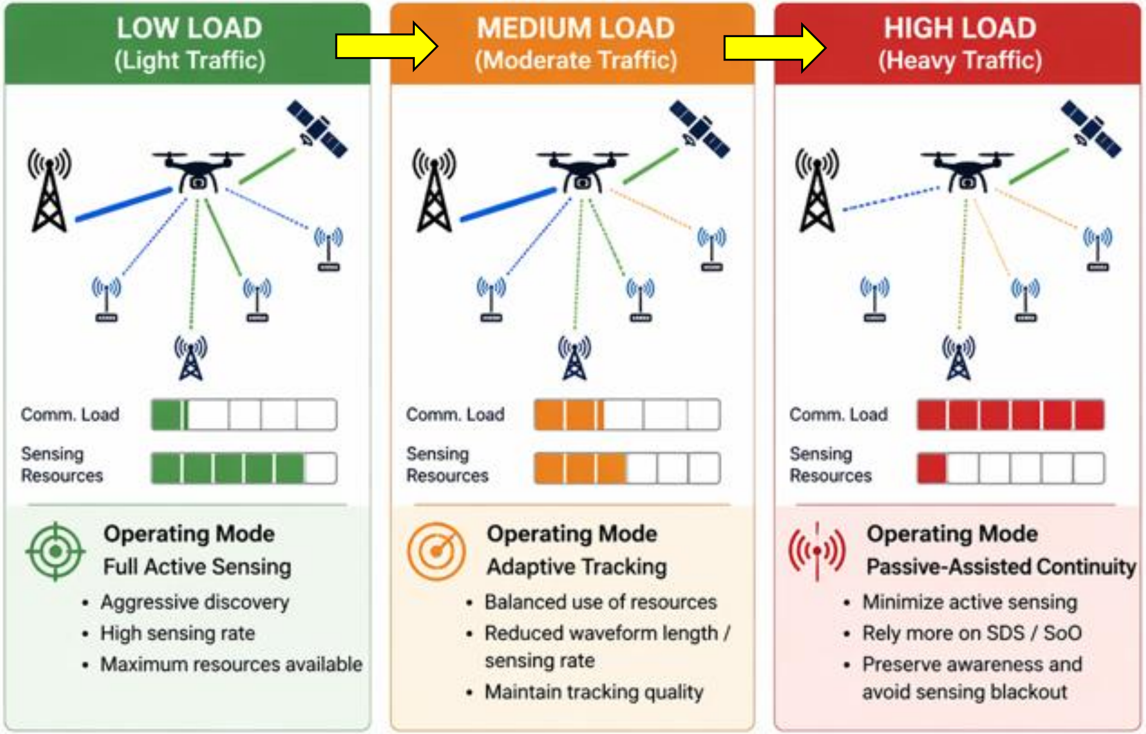


(a) Coarse Discovery with smaller bandwidth sensing beams



(b) Precision tracking with sensing beams

Practical ISAC Challenges Under Dynamic Network Load



Operating Mode
Full Active Sensing

- Aggressive discovery
- High sensing rate
- Maximum resources available

Operating Mode
Adaptive Tracking

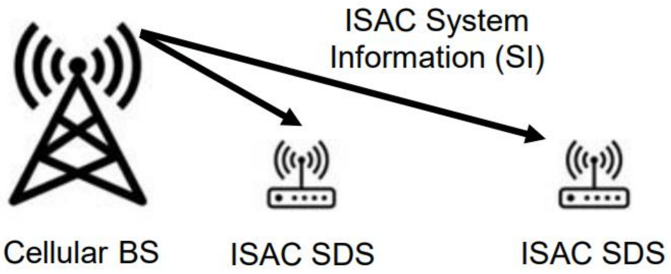
- Balanced use of resources
- Reduced waveform length / sensing rate
- Maintain tracking quality

Operating Mode
Passive-Assisted Continuity

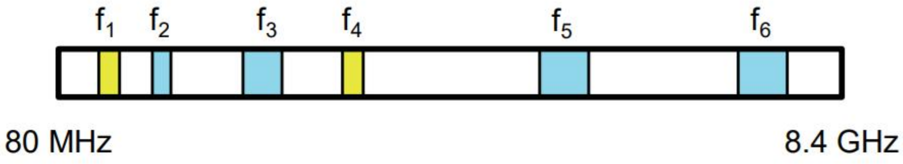
- Minimize active sensing
- Rely more on SDS / SoO
- Preserve awareness and avoid sensing blackout

- 5G ISAC sensing and communications compete for **shared PRBs/airtime**
- Time-frequency resources are finite and demand-dependent, requiring **elastic reallocation**
- Static sensing policies may overconsume resources or underperform during congestion
- Adaptive control is needed to balance throughput, QoS, and tracking performance

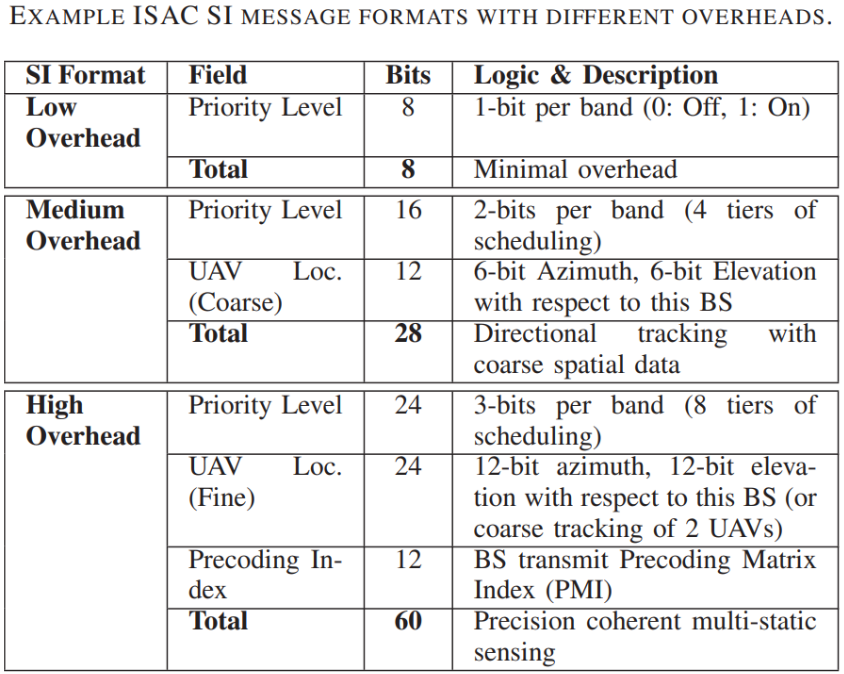
5G BSs Transmit System Information to Control Sensing Parameters



(a) Cellular network periodically broadcasts ISAC related system information to all ISAC SDS within coverage



(b) Example set of bands to scan, that are advertised by the ISAC SI transmitted by the cellular network.

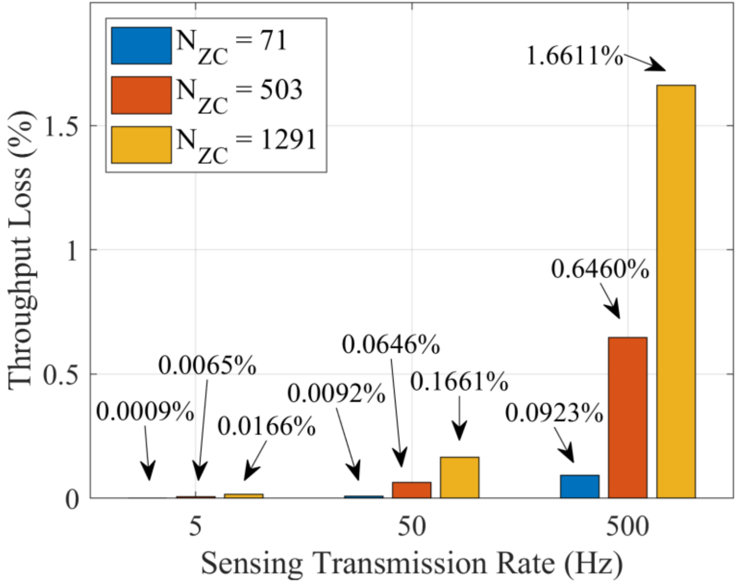


EXAMPLE ISAC SI MESSAGE FORMATS WITH DIFFERENT OVERHEADS.

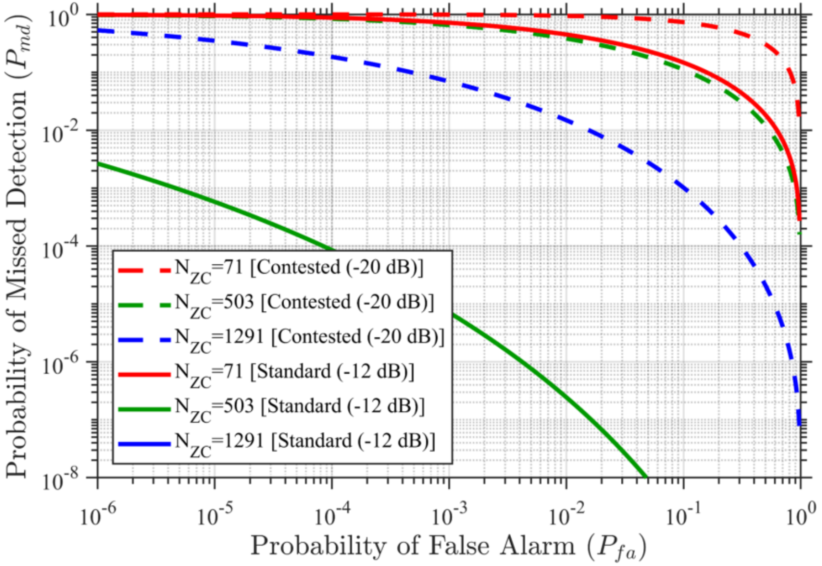
SI Format	Field	Bits	Logic & Description
Low Overhead	Priority Level	8	1-bit per band (0: Off, 1: On)
	Total	**8**	Minimal overhead
Medium Overhead	Priority Level	16	2-bits per band (4 tiers of scheduling)
	UAV Loc. (Coarse)	12	6-bit Azimuth, 6-bit Elevation with respect to this BS
	Total	**28**	Directional tracking with coarse spatial data
High Overhead	Priority Level	24	3-bits per band (8 tiers of scheduling)
	UAV Loc. (Fine)	24	12-bit azimuth, 12-bit elevation with respect to this BS (or coarse tracking of 2 UAVs)
	Precoding Index	12	BS transmit Precoding Matrix Index (PMI)
	Total	**60**	Precision coherent multi-static sensing

Adaptive Zadoff-Chu Waveform Scheduling: Sensing Gain vs Overhead

Cost: Communication Overhead



Benefit: Improved Detection

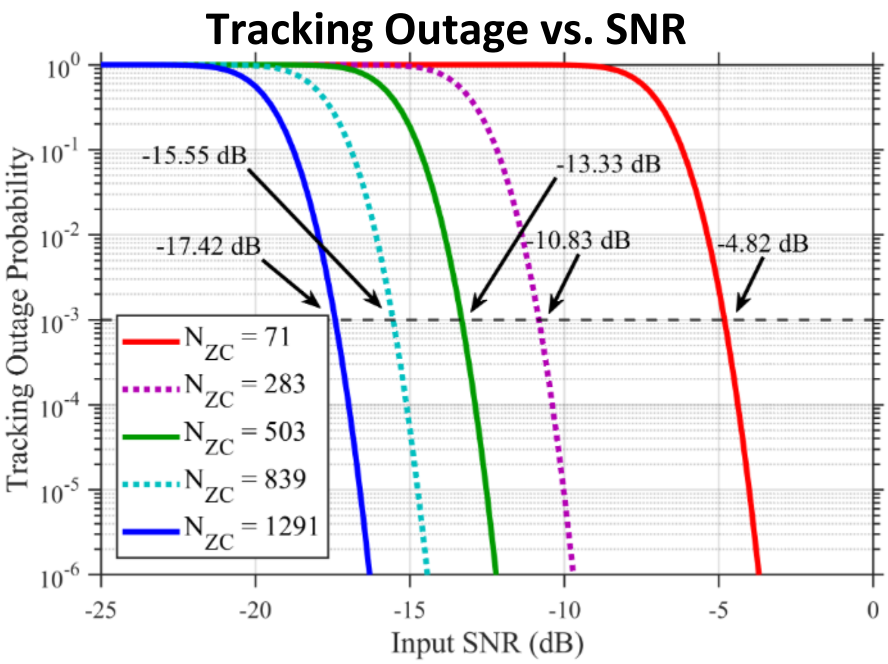


- Zadoff-Chu sequences provide structured sensing waveforms for ISAC
- Increasing **N_{ZC}** yields higher coherent gain and stronger detection performance
- Increasing **N_{ZC}** also increases throughput overhead
- We need to adapt **N_{ZC}** to current load and sensing needs

Processing Gain

$$\mathrm{SNR}_{\mathrm{eff}} = \mathrm{SNR}_{\mathrm{in}} + 10\log_{10}(N_{ZC}).$$

Graceful Tracking Performance Under Degraded Conditions



Detection Model → $P_{\mathrm{d}} = Q_1\left(\sqrt{2\gamma}, \sqrt{-2\ln P_{\mathrm{fa}}}\right),$

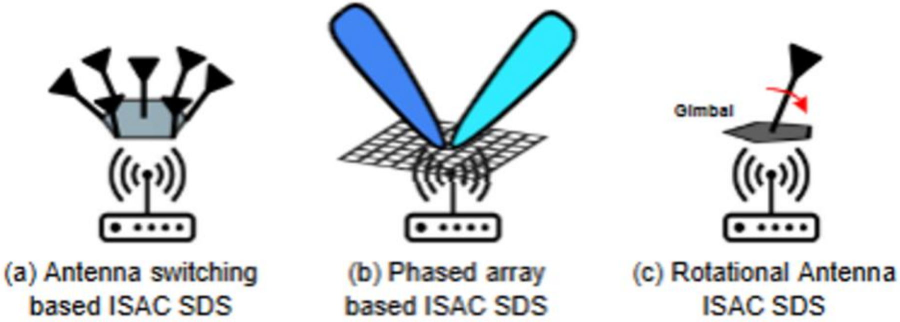
Effective SNR → $\gamma = 10^{\mathrm{SNR}_{\mathrm{eff}}/10}.$

Continuity Prob. → $P_{\mathrm{cont}}^{5G} = \sum_{k=M}^{N_{5\mathrm{G}}} \binom{N_{5\mathrm{G}}}{k} P_d^k \left(1 - P_d\right)^{N_{5\mathrm{G}}-k}$

Outage Prob. → $P_{\mathrm{out}}^{5G} = 1 - P_{\mathrm{cont}}^{5G}$

- N_{5G}: Number of attempts for detection
- M: minimum number of attempts that is sufficient for achieving desired probability of detection

Different SDS Architectures for Directional Sensing



(a) Antenna switching based ISAC SDS

(b) Phased array based ISAC SDS

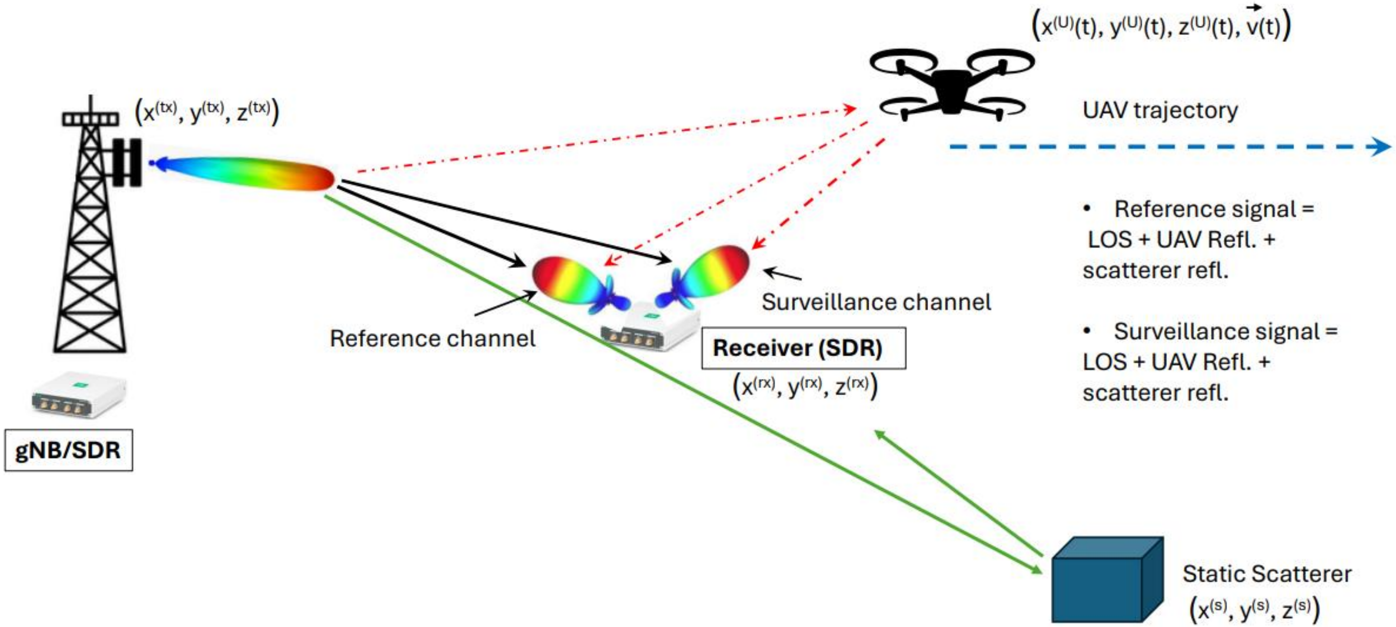
(c) Rotational Antenna ISAC SDS

Design challenges:

- Wideband (600 MHz – 6 GHz) spectrum support for antenna patterns and array designs
- Directional monitoring, guided by system information and SDS feedback
- SWaP-C considerations (size, weight, power, cost)

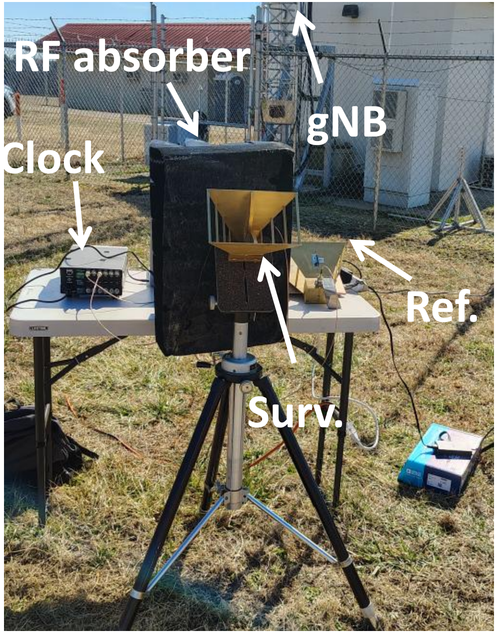
Passive ISAC using Ericsson BS SSB at AERPAW (1)

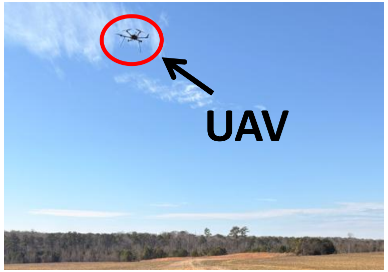
- The AERPAW Ericson 5G base station (3355 MHz) transmitting SSB signals was used for UAV detection.
- AERPAW UAVs were flown and illuminated by 5G SSB signals and detected using SDR-based ISAC processing (ongoing work).

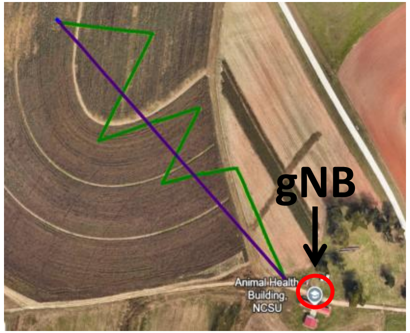


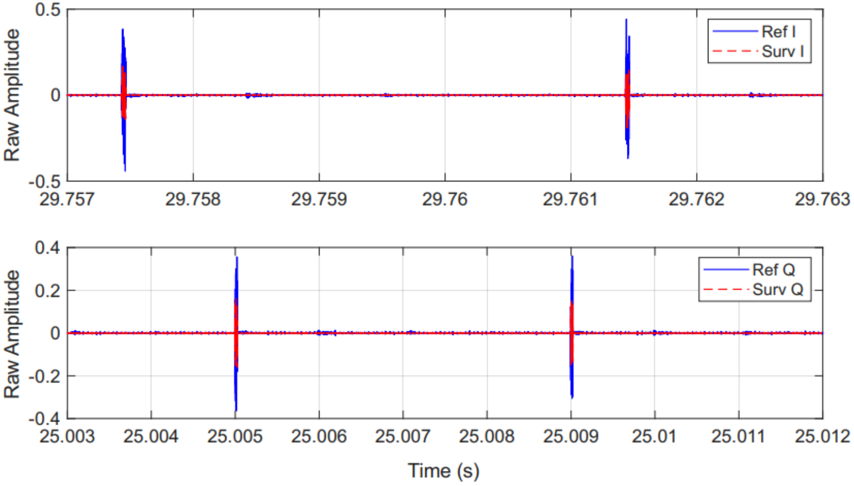
Passive ISAC using Ericsson BS SSB at AERPAW (2)

Experiments and Results





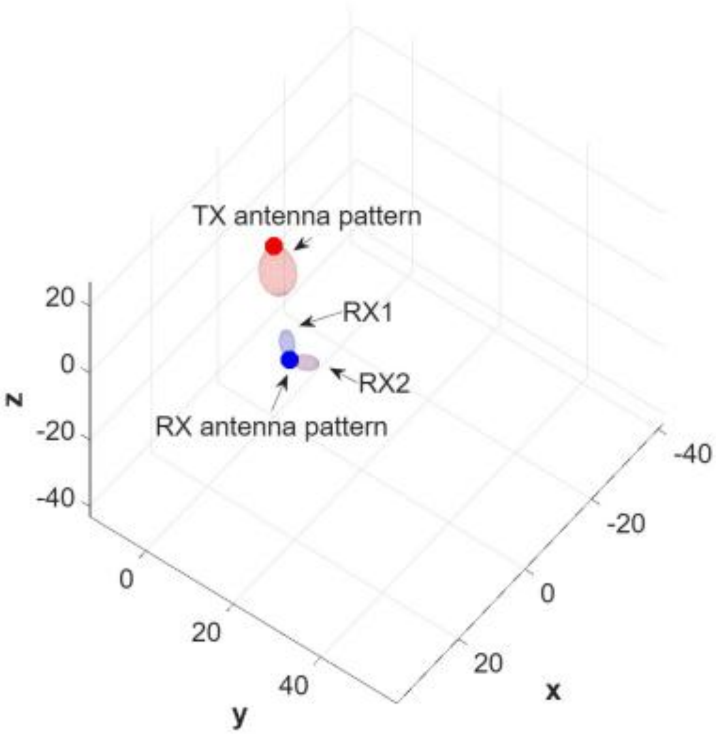


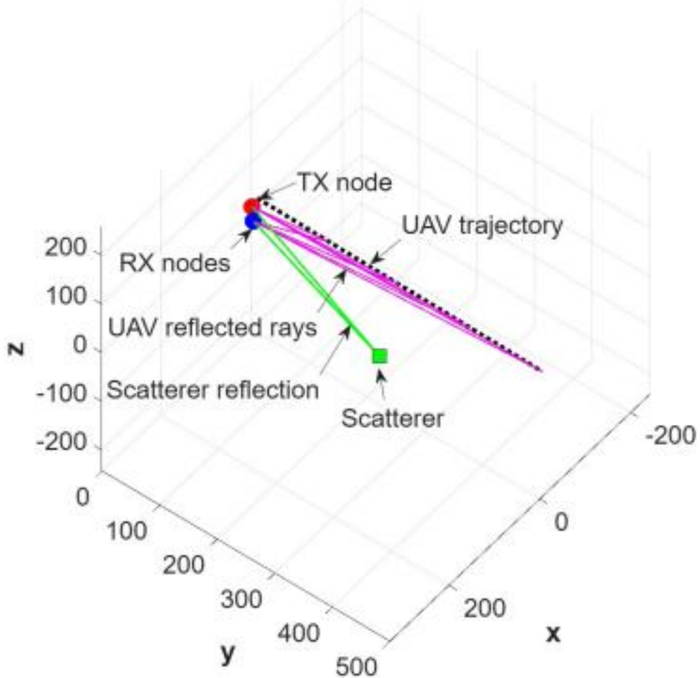


Reflected power from drone was weak, working on improvements

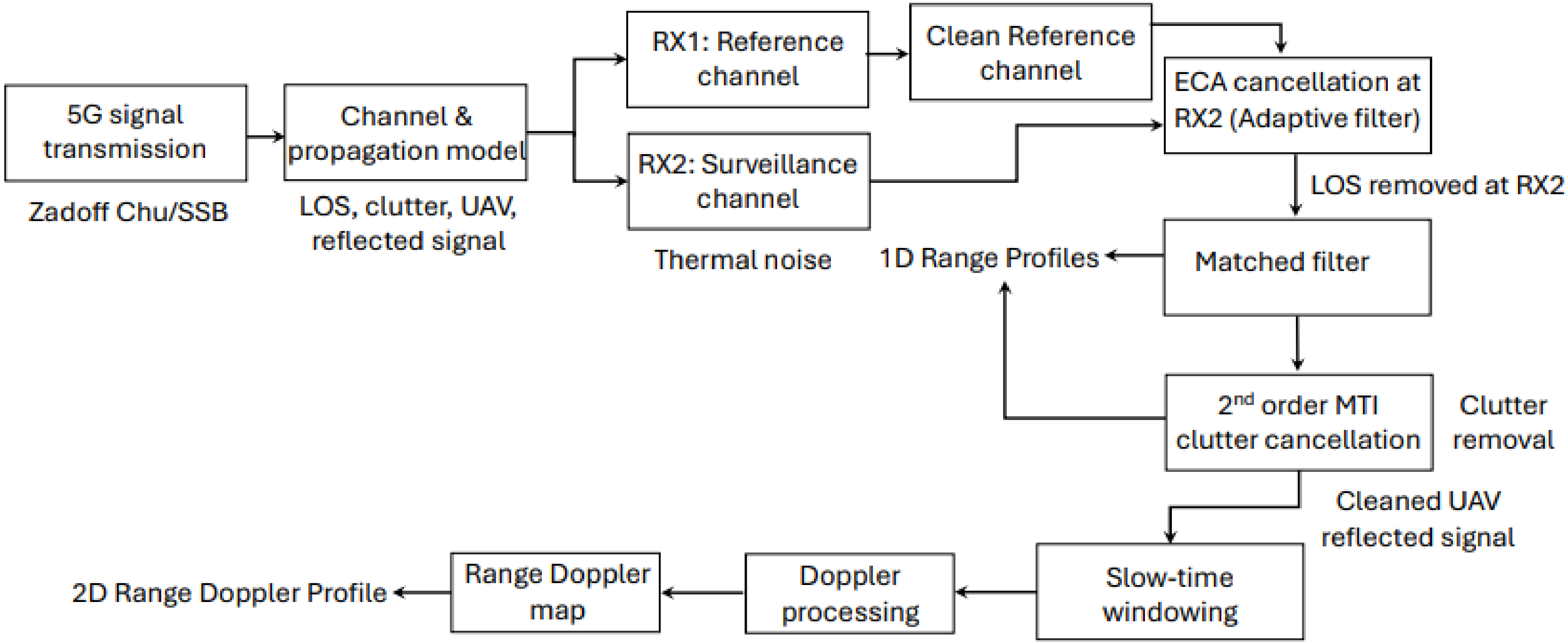
(direct link still received strongly at surveillance antenna, needs isolation)

Simulation Setup Same as that at AERPAW Experiment





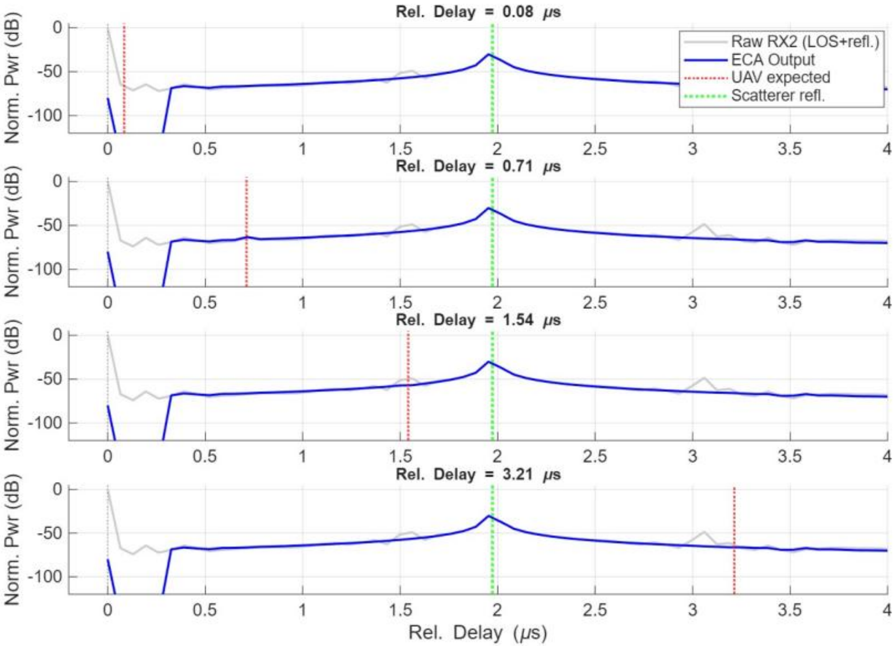
Processing Chain for Simulations



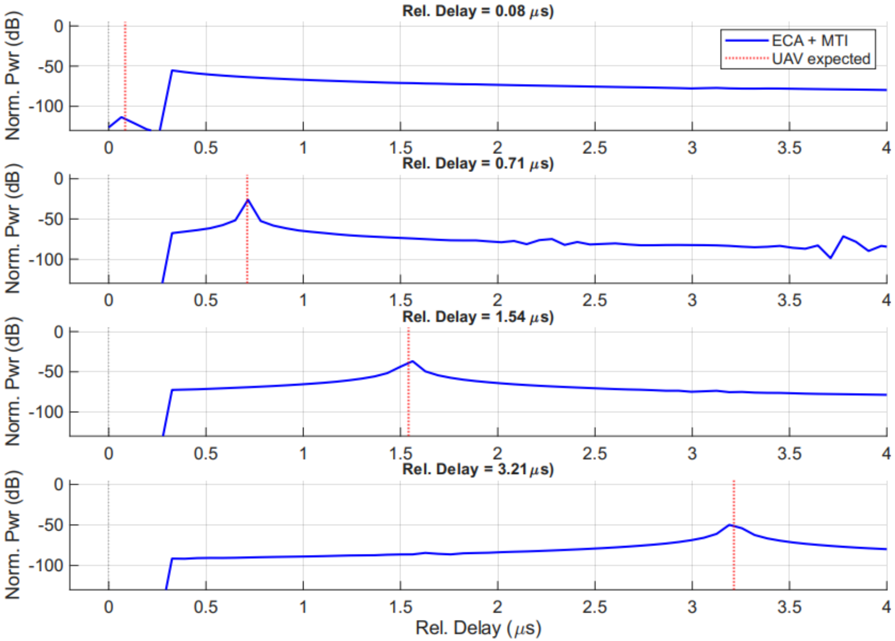
ECA: Cancels direct signal from BS, **MTI:** cancels reflected signal from static scatterer(s)

Simulation Results Using ZC Sequence

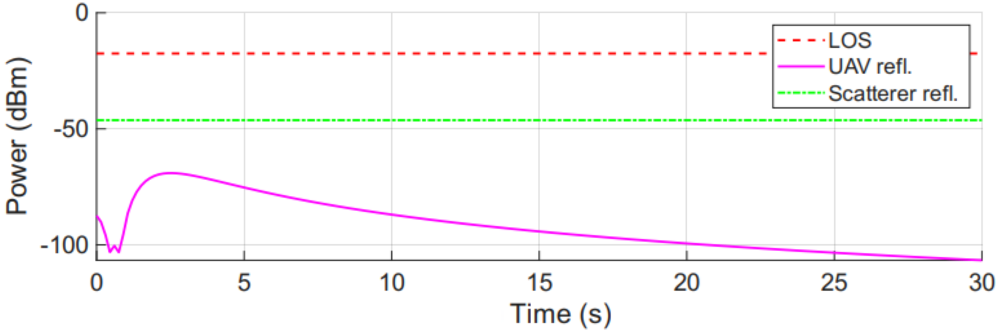
With scatterer (building) signal present



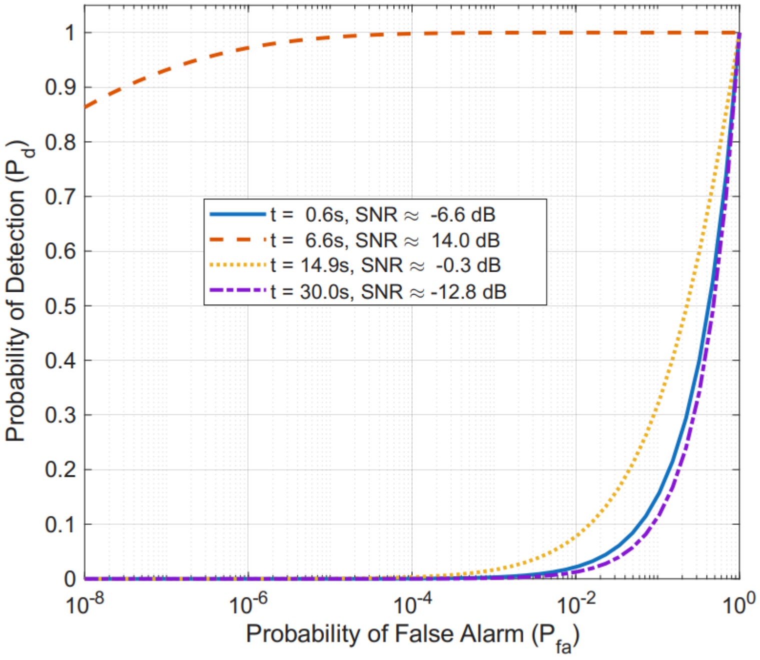
After cancellation of the scatterer signal



P_d vs P_{fa} at Different SNRs of the UAV flight

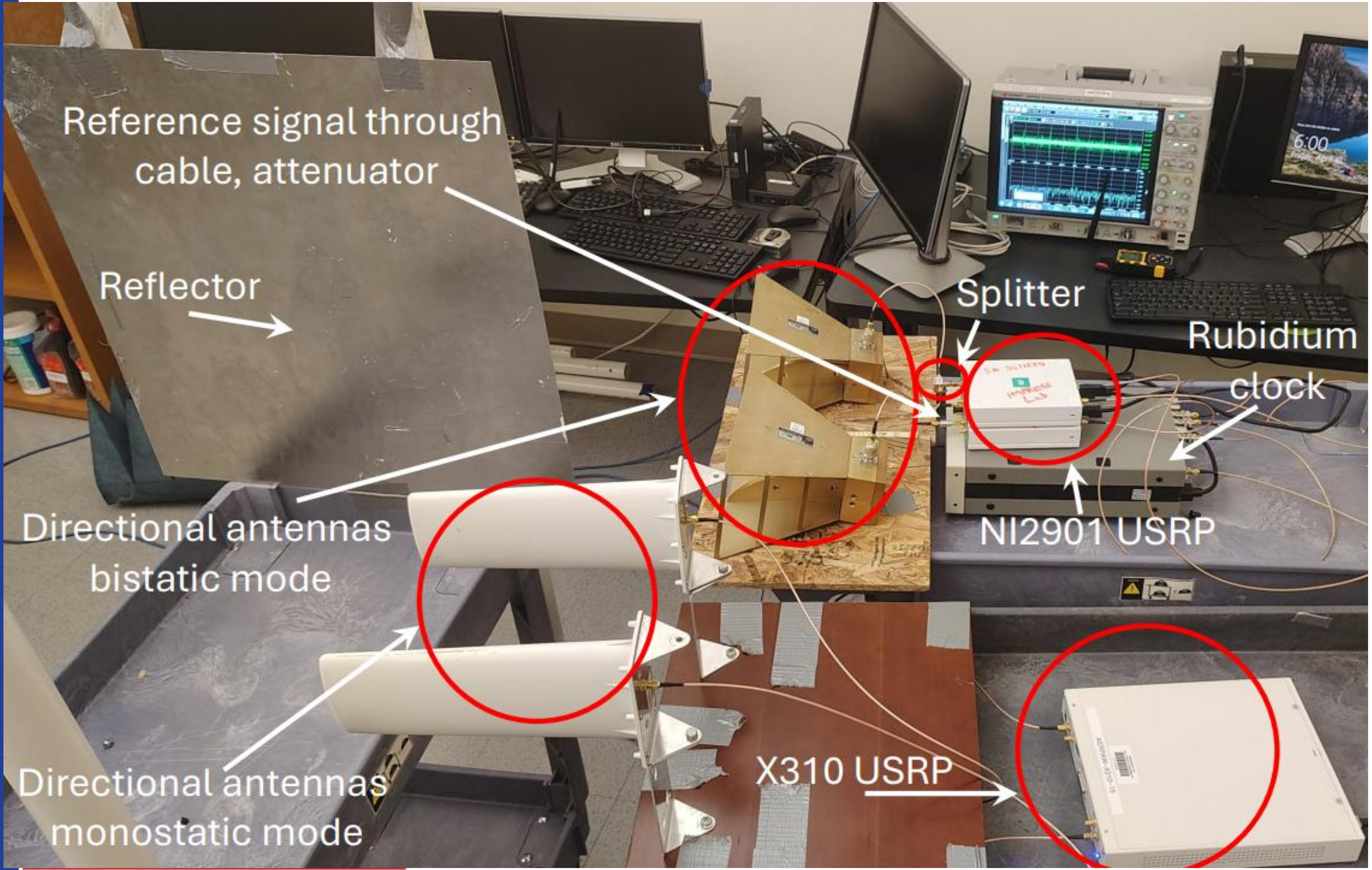


Received power vs. UAV flight time
(fluctuations in UAV reflected power mainly due to antenna pattern and reflection angle)



Indoor Tracking with Dynamic Zadoff-Chu Adaptation: Hardware Setup

(Video Demonstration for Tracking Performance)



WolfSky RF Sensing Systems: From Lab to Real-World Security

Our Vision

- Scalable protection for airports, stadiums, prisons, and critical infrastructure
- Lower-cost sensing using existing wireless infrastructure
- Evidence-grade tracking with multi-modal resilience

We're Interested In

- Customer discovery conversations (supporting NSF National I-Corps program)
- Research partnerships
- Pilot programs

WOLFSKY
RF SENSING SYSTEMS

For more details, reach out to: Cole Dickerson (CEO)
jcdicker@ncsu.edu

Contact Email: aerpaw-contact@ncsu.edu

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