https://aerpaw.org/

PAWR Project Office

AERPAW Platform

A Testbed for versatile mobile NextG Research

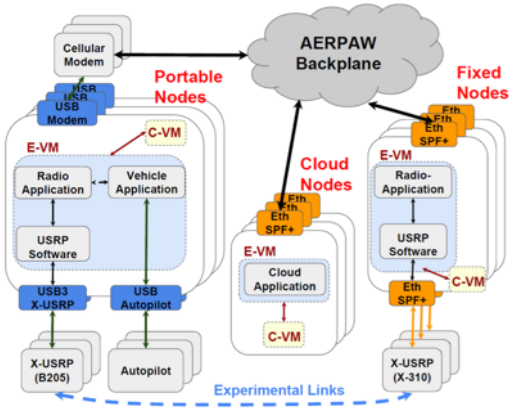
First IEEE NextG Summit
June, 2022

Rudra Dutta, NC State University

NC STATE UNIVERSITY

AERPAW Project Vision and Scope

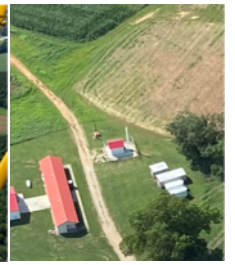
- **Funding:** 3rd NSF PAWR project awarded in Sep. 2019
- **Project Team:** NC State University, WRC, Mississippi State University, RENCI, Purdue University, University of South Carolina
- **AERPAW Vision:** Serve as a unique technological infrastructure, to be used by advanced wireless and UAS researchers
- **Project Heart:** Programmable radios, programmable UAS, on a programmable network



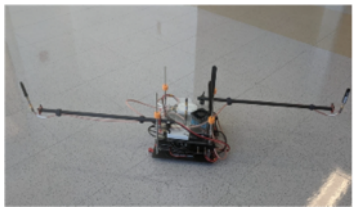












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KEYSIGHT TECHNOLOGIES
COMMSCOPE®
INTERDIGITAL
at&t

Team and Partners

NC STATE UNIVERSITY · wireless research center · Mississippi State University · renci · Purdue University · University of South Carolina

Project Investigators

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

Rudra Dutta
NC State (SDN, architecture, CentMesh)

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NC State (drones, architecture, CentMesh)

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NC State (mmW circuits, arrays)

Tom Zajkowski
NC State (UAS operations, FAA permitting)

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)

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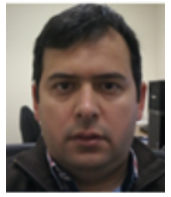
USC (aerial propagation, waveforms)

David Love
Purdue (MIMO, SDRs, agriculture)

Senior Personnel

Lavanya Sridharan
NC State (Project Coordinator)

Ed Rogers
NC State (installations and permits)



Ozgur Ozdemir NC State (SDRs, Keysight, Facebook TG)

Magreth Mushi
NC State (Network Architecture, Platform Operations)

Mike Barts
WRC (RF, Towers, Antennas, Front Ends)

Asokan Ram
WRC (4G/5G Ericsson deployment)

Turker Yilmaz
NC State (SDRs and mmWave Development)

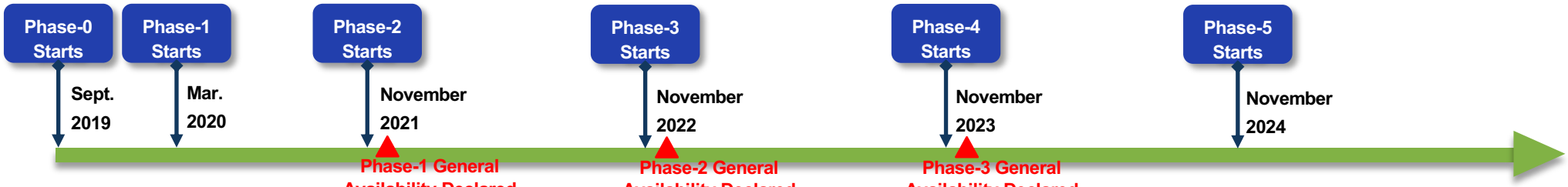
Municipality and Government Partners

Town of Cary · Raleigh · State of North Carolina Department of Transportation

Other Personnel:

- **Postdoctoral Scholars:** Talha F. Rahman, Ender Ozturk
- **PhD Students:** Keith Powell, Anil Gurses, Aly Abdalla, Andrew Yingst, Daniel Brennan, Simran Singh,
- **MS Students:** Ashwin Panicker, Vedashree Chaphekar, Udita Bhattacherjee, Jonah Gandy, Ananya Nunna
- **Other WRC and RENCI Personnel:** Thomas Hoover, Michael Stealey, Erica Fu, Erik Scott, Hannah Hiles
- **ITRE Aviation Personnel/Pilots:** Evan Arnolds, Shawn Deardorff, Michael Picinich
- **Undergrad Students:** Mark Funderburk, John Kessler, Keshav Sridhar, Byron Qi, Joshua Moore

AERPAW Project Timeline and General Availability



Phase 0 + Phase 1 Goals (Sep. 2019 – Nov. 2021)

General Availability:

- 3 Fixed SDR Nodes
- 3 Portable SDR Nodes
- 2 UAVs, 1 UGV
- Experiment Portal
- Initial SDR and Vehicle Control Profiles

Initial Deployment & Testing:

- Keysight RF Sensors
- 6 Terragraph Radios
- LoRa Dongles/Gateways
- Fortem Radar
- 1 Ericsson 4G/5G BS & UEs
- Keysight Propsim Emulator

Phase 2 Goals (Nov. 2021 – Nov. 2022)

General Availability:

- 8 Fixed SDR Nodes
- 13 Portable SDR Nodes
- 6 UAVs, 4 UGVs
- Experiment Portal
- 5 Keysight RF Sensors
- Keysight Propsim Emulator
- 6 Terragraph Radios
- LoRa Dongles/Gateways
- Fortem Radar
- Ericsson 4G/5G BSs/UEs

Initial Deployment & Testing:

- Interdigital mmWave SDRs
- IsoBLUE Radios

Phase 3 Goals (Nov. 2022 – Nov. 2023)

General Availability:

- 16 Fixed SDR Nodes
- 23 Portable SDR Nodes
- 10 UAVs, 6 UGVs, 1 Helikite
- Experiment Portal
- 5 Keysight RF Sensors
- Keysight Propsim Emulator
- 6 Terragraph Radios
- LoRa Dongles/Gateways
- Fortem Radar
- 5 Ericsson 4G/5G BSs/UEs
- Interdigital mmWave SDRs
- IsoBLUE Radios

Phase 4 Goals Nov. 2023 – Nov. 2024

General Availability:

- 16 Fixed SDR Nodes
- 23 Portable SDR Nodes
- 10 UAVs, 6 UGVs, 1 Helikite
- Experiment Portal
- 5+ Keysight RF Sensors
- Keysight Propsim Emulator
- 6 Terragraph Radios
- LoRa Dongles/Gateways
- Fortem Radar
- 5 Ericsson 4G/5G BSs/UEs
- Interdigital mmWave SDRs
- IsoBLUE Radios

Phase 5 Goals Nov. 2024 – Nov. 2025

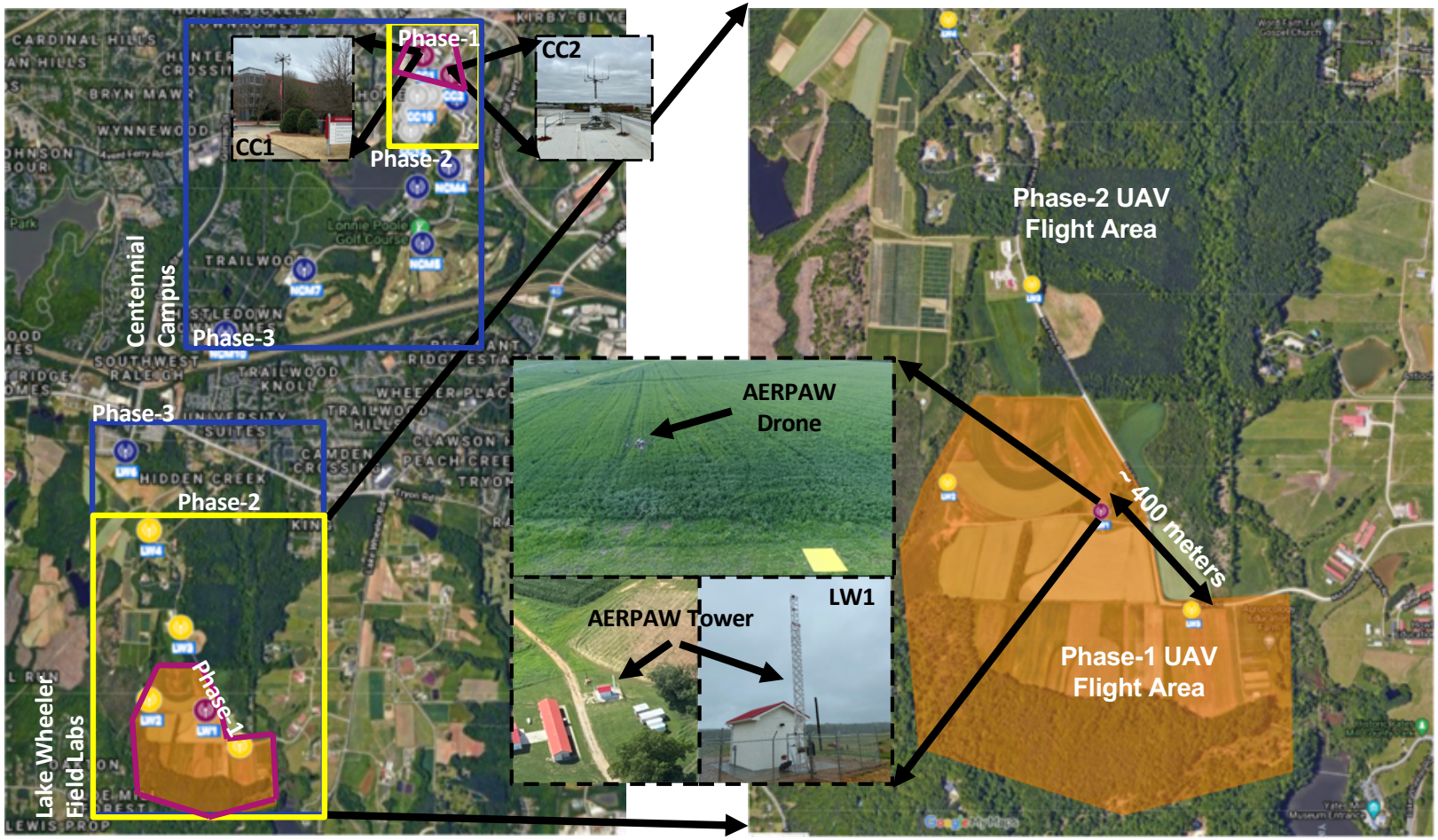
General Availability:

- 16 Fixed SDR Nodes
- 23 Portable SDR Nodes
- 10 UAVs, 6 UGVs, 1 Helikite
- Experiment Portal
- 5+ Keysight RF Sensors
- Keysight Propsim Emulator
- 6 Terragraph Radios
- LoRa Dongles/Gateways
- Fortem Radar
- 5 Ericsson 4G/5G BSs/UEs
- Interdigital mmWave SDRs
- IsoBLUE Radios

Phase-4 and Phase-5: Full-Scale Platform Operations

Will support bring-your-own-device (BYOD) experiments on a case-by-case basis

AERPAW Deployment Areas

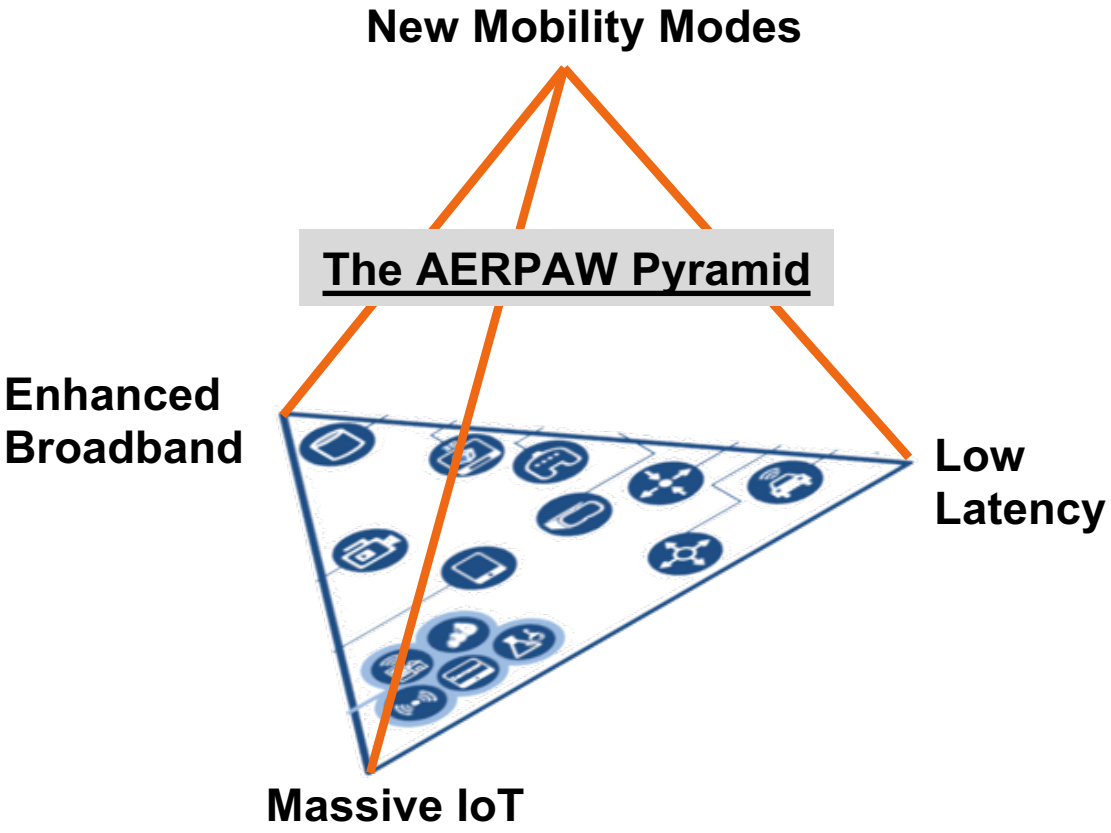


Late 2021 (Phase-1, 3 new fixed nodes)

Late 2022 (Phase-2, 5 new fixed nodes)

Late 2023 (Phase-3, 8 new fixed nodes)

AERPAW's Vision for a New Paradigm



- Advanced wireless to enable new UAS capabilities
- Advanced UAS to enable new wireless services
- Will also support other fixed and mobile experiments

Fixed Node Equipment

NI Software Defined Radios (Every Fixed Node)

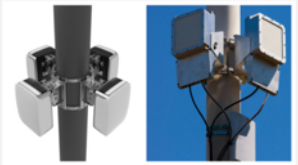
2x Directional antenna

2x SFP

Fiber

Keysight RF Sensors

Facebook Terragraph Radios (Centennial Campus)



Ericsson 4G/5G Base Station (Lake Wheeler)

Fortem Drone Detection Radars

LoRa IoT Equipment

Compute: Dell 5820 with Intel Xeon Processor

CC1

CC2

LW1

AERPAW Phase-1 Fixed Nodes (3)

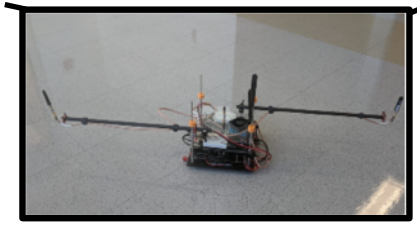
Portable Node Equipment

NI Software Defined Radios

Mobile Phones

LoRa Sensors

Compute: Intel NUC10



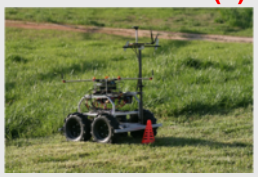
AERPAW Phase-1 Portable Nodes (3)

AERPAW Phase-1 Vehicles

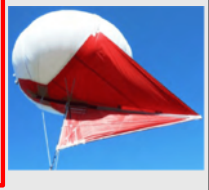
Carried By

AERPAW UAV (2)

AERPAW UGV (1)

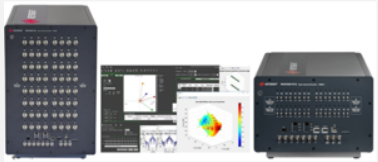


Helikite



Sandbox

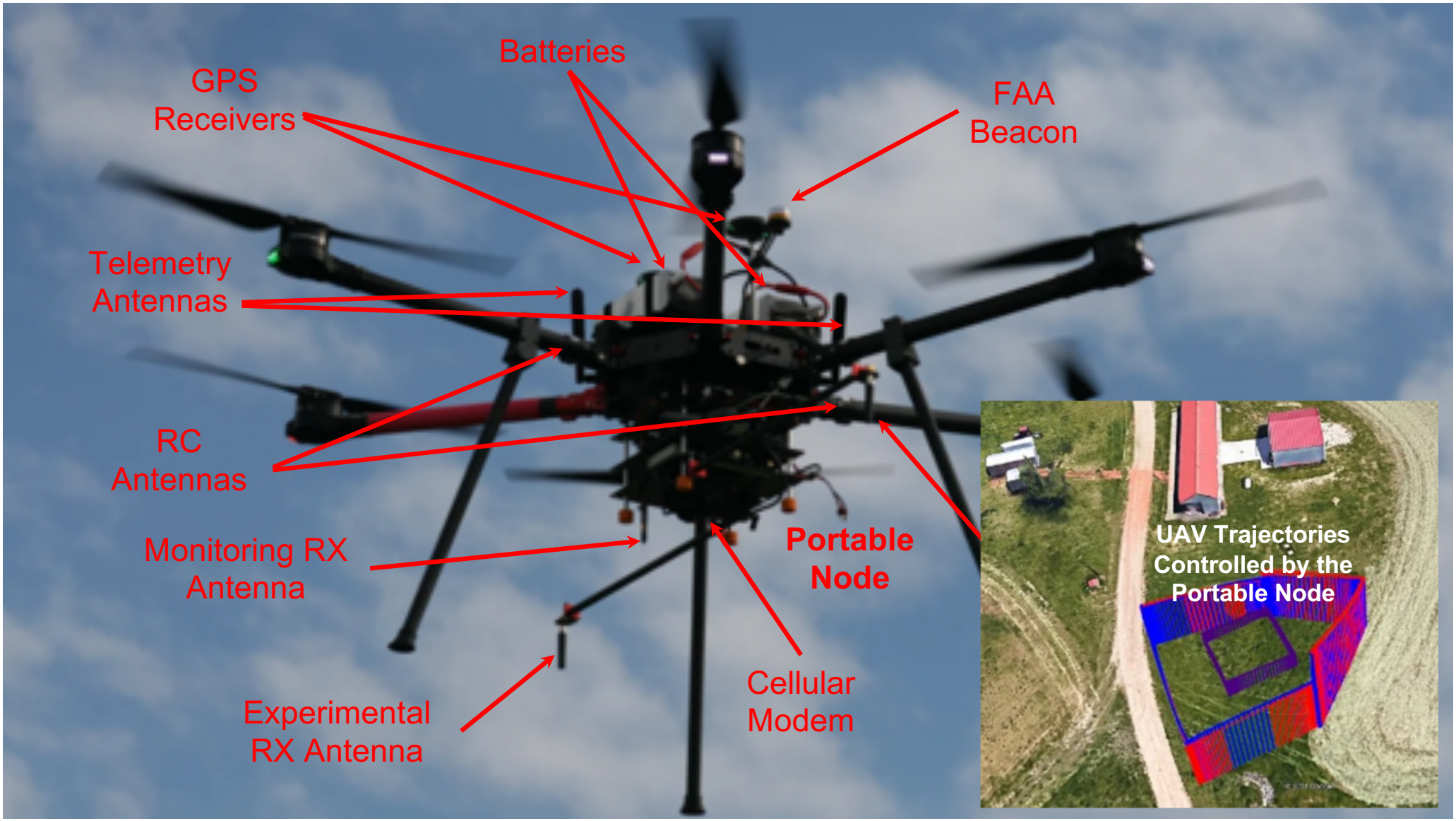
- Keysight Propsim Channel Emulator (32 Ports)
- **Wireless and drone emulation**
- Cabled testing

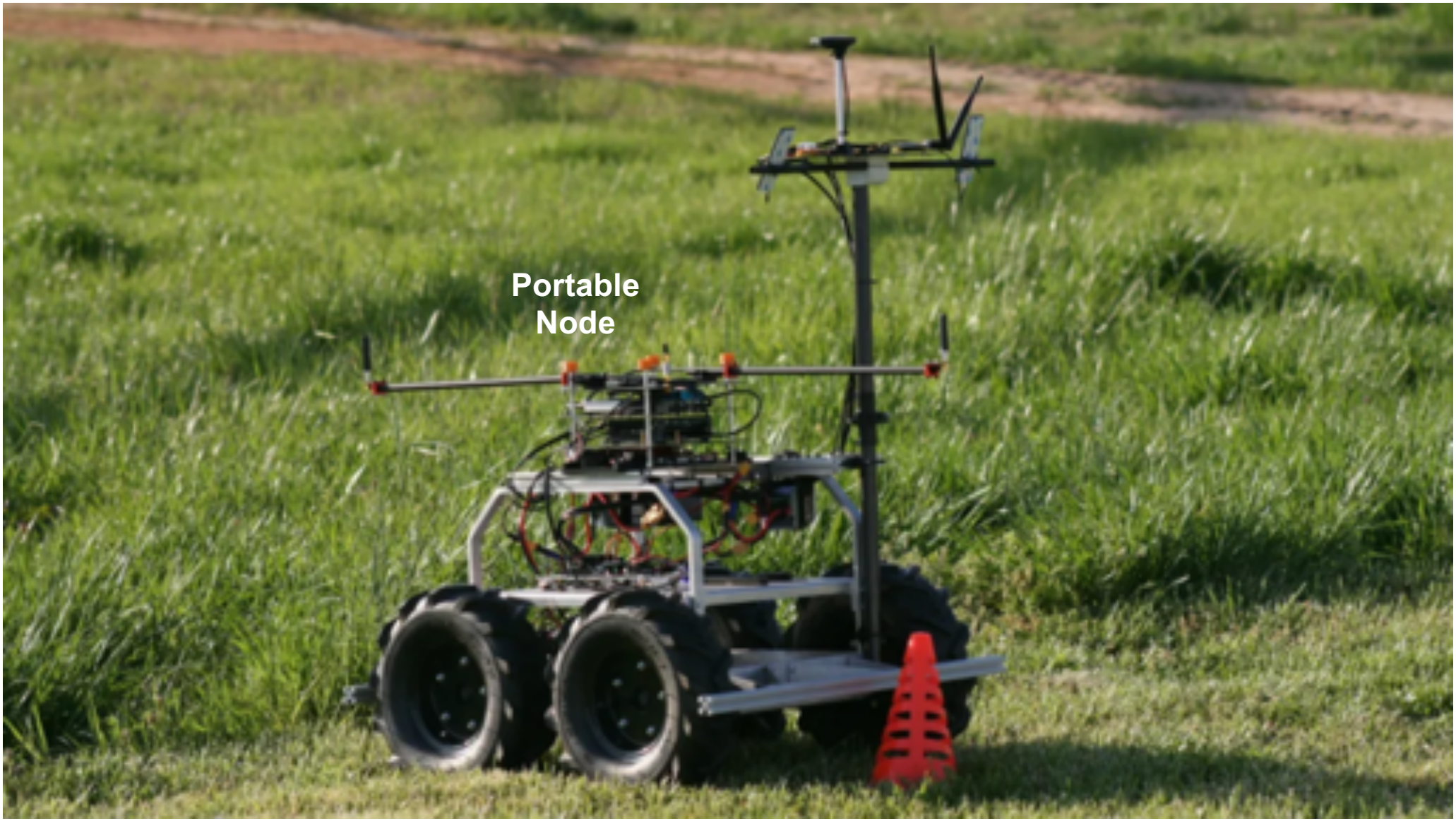


Experimentation Software

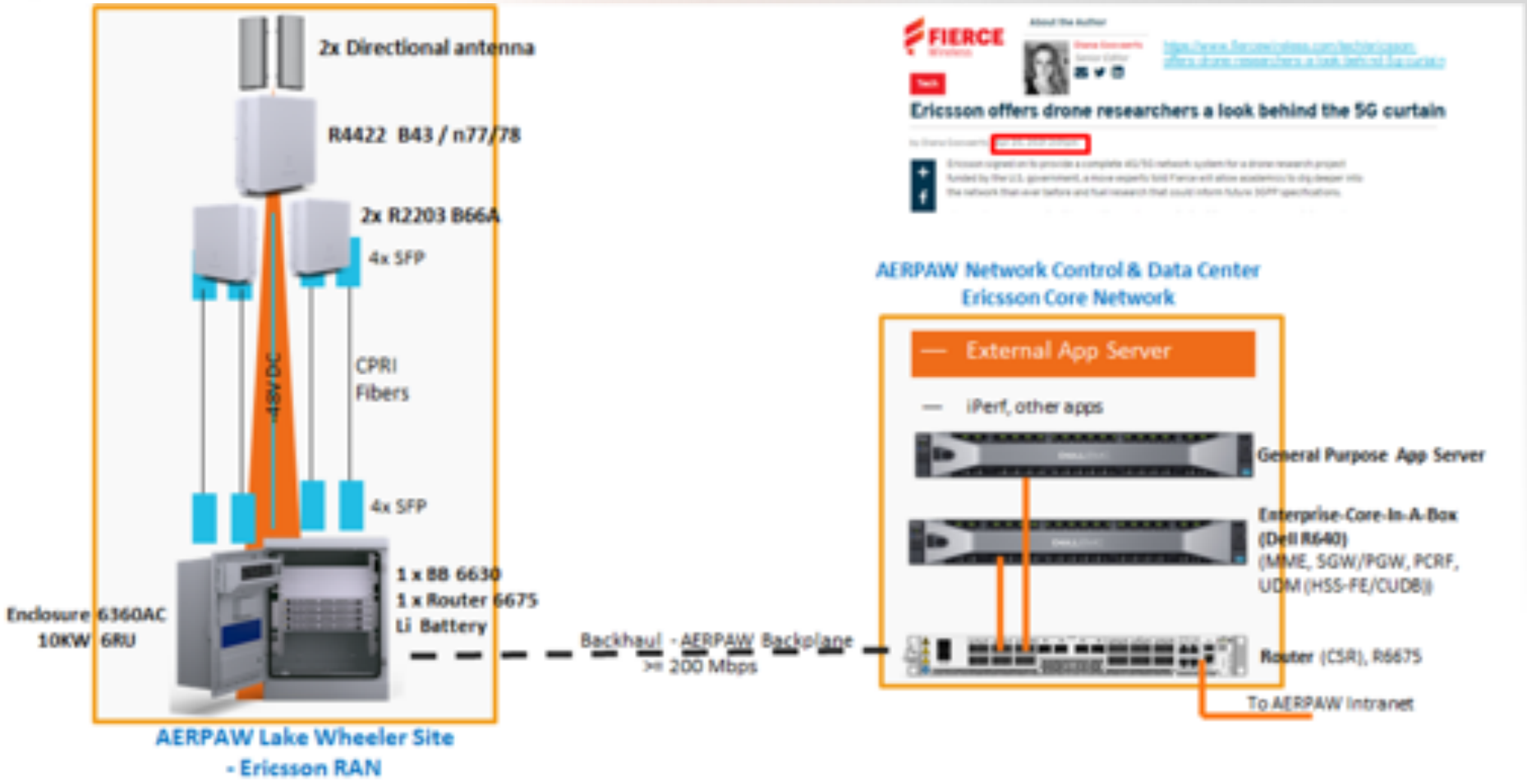
- USRPs: **OpenAirInterface, srsLTE, GNU Radio** Matlab
- Other software by Keysight, Facebook, Ericsson, Facebook, LoRa
- Experiments run on containers at fixed/portable nodes, both in **development and testbed experiment modes**

Indicates Phase-1 General Availability


GPS
Receivers
Batteries
FAA
Beacon
Telemetry
Antennas
RC
Antennas
Monitoring RX
Antenna
Portable
Node
Cellular
Modem
Experimental
RX Antenna
UAV Trajectories
Controlled by the
Portable Node


Portable
Node

AERPAW Ericsson Equipment



AERPAW Ericsson Equipment

4G LTE Network

- 2-sectors, each sector with 2x2 MIMO in Band 43 (3.6-3.8 GHz) and B66A (1.7/2.1 GHz)
- 3GPP Release 13 compliant
- Different bandwidths – 5, 10, 15, 20 MHz
- Different MIMO modes (TM2 Transmit Diversity, TM3 Open-loop 2x2 MIMO, TM4 Closed-loop 2x2 MIMO)
- Carrier aggregation
- Channel quality (CSI/PMI/RI) performance
- Link adaptation
- Various RRC procedures
- Cell-selection/Re-selection, Re-establishment, Handover

5G NR Non-Standalone (NSA) Network

- 2-sectors, each sector with 4G & 5G overlaid cells
- 4G in Band 66A & 5G in n77/78 (3.3-4.2 GHz), with 2x2 MIMO
- 3GPP Release 15
- LTE node for Control plane (+ Data plane)
- NR node for Data plane only
- All functionalities offered by LTE standalone node + Additional channel BW – 20, 40, 60, 100 MHz on NR
- Dual-connectivity operation
- 4x4 MIMO (with single sector setup)

Status:

- Deployed and tested 4G/5G NSA network in Phase-1 (see poster presentation)
- Phase-2 plans:
  - work towards making the network generally available to AERPAW users
  - scale up the number of base stations

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FCC Innovation Zone and Experimental Licenses

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

Phase-1 General Availability

- AERPAW focuses on 3.3-3.55 GHz band for Phase-1 USRP experiments
  - Have experimental licenses, will merge to innovation zone in the future
- We are also doing testing with commercial Ericsson (1.7/2.1 GHz and 3.7 GHz), LoRa (900 MHz), and Facebook (60 GHz) equipment at other bands, to be general available after Phase-2
- Additional SDR frequencies are being explored for Phase-2 airborne operations

FAA Constraints and Exemptions

- Baseline operation under Part 107
  - Line of sight, under 55 pounds, under 100 Mph, below 400 feet
- Currently collecting data for waivers under:
  - § 107.35 – Operation of Multiple Small UAS
  - § 107.39 – Operation over human beings.
- AERPAW Air Operations under ITRE-Aviation (Co-PI Tom Zajkowski)
  - Currently these as well as other exemptions in place, but for specific prior contexts
  - Need to be re-done for new aircraft type

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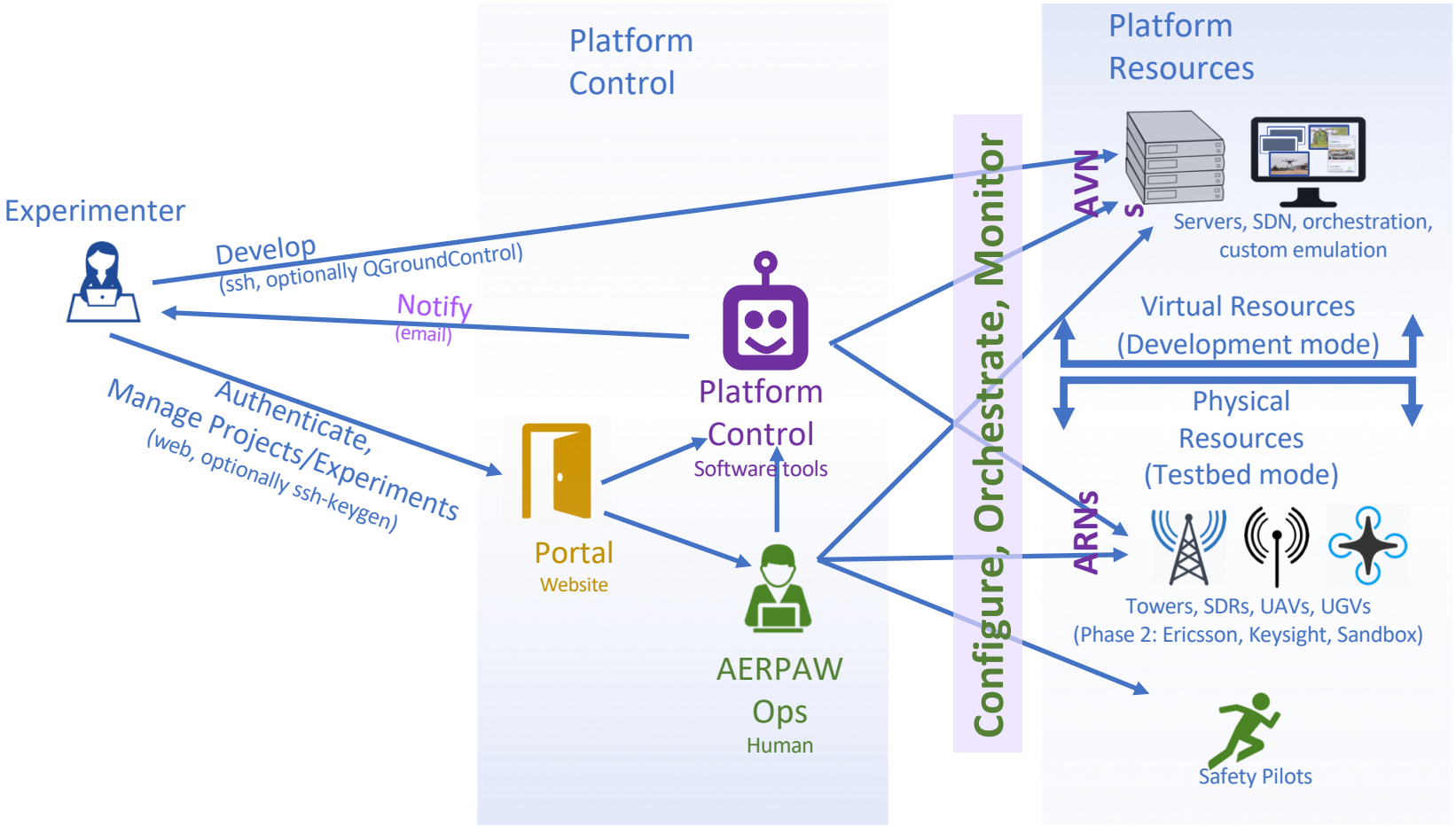
Main Entities and Interactions



Other Modes not Impossible, but not Norm

- Approach 1: Program-it-Yourself (PiY)
  - Main modalities – as on previous slide

- Experiment-as-a-Service (EaaS)
  - You explain your experimental intent to us, we develop and execute it
  - You get results

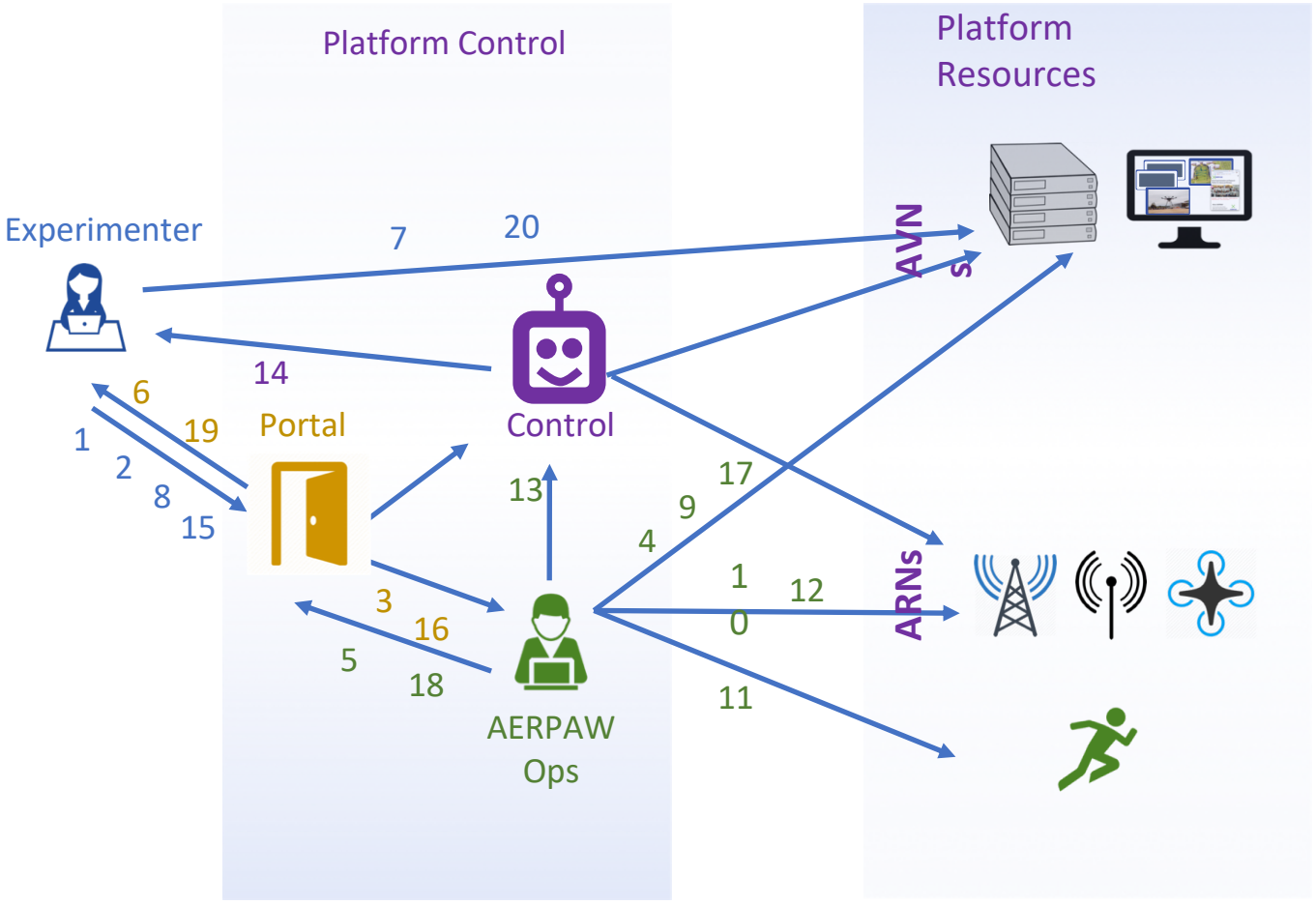
- Experiment-Development-as-a-Service (EDaaS)
  - You explain your experimental intent to us, we develop it
  - You get developed experiment, modify, follow PiY from there on

- Live Limited Access
  - For parts of the testbed facilities, for some clients with documented and verified expertise (and possible indemnification and liability assumption)

- Bring your own Device
  - Case-by-case basis; Initial plan submission → Review → Detailed plan submission → approval → agreement execution

- Mixed and Custom Approaches
  - Nothing is impossible, let's discuss

Main Entities and Interactions

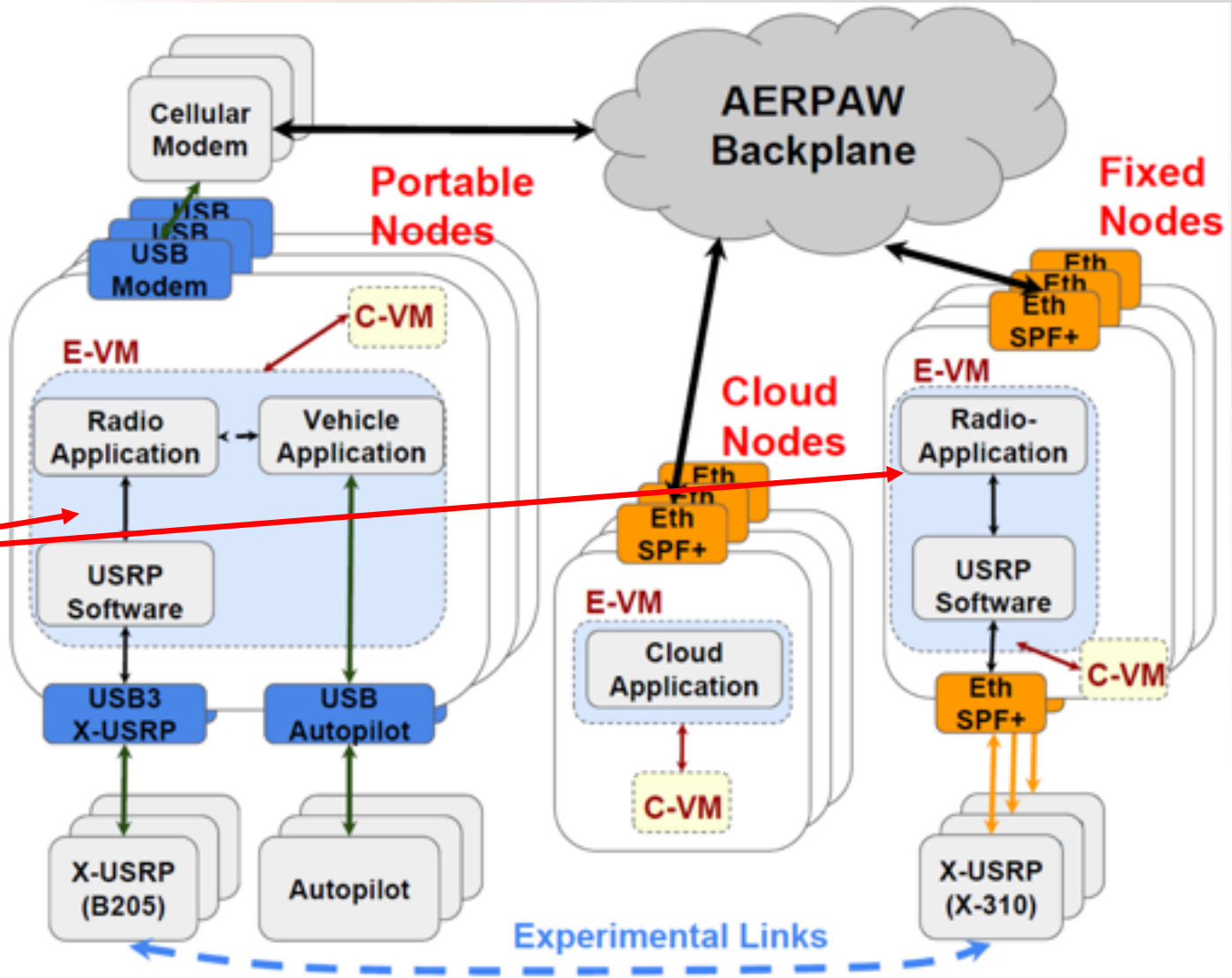


1 Register, supply credentials
2 Create experiment, request develop
3 Pass virtual request info
4 Instantiate virtual experiment
5 Pass virtual manifest, change status
6 Pass virtual manifest info
7 Login to virtual nodes, code, test
8 Submit experiment for testbed
9 Retrieve experimenter code
10 Install experimenter code
11 Handover to pilots/operators
12 Retrieve experimenter data
13 Inform completion
14 Inform experimenter
15 Request develop returned expmt.
16 Pass request info
17 Re-instantiate virtual experiment
18 Change status
19 Notify changed status
20 Login to virtual nodes, view

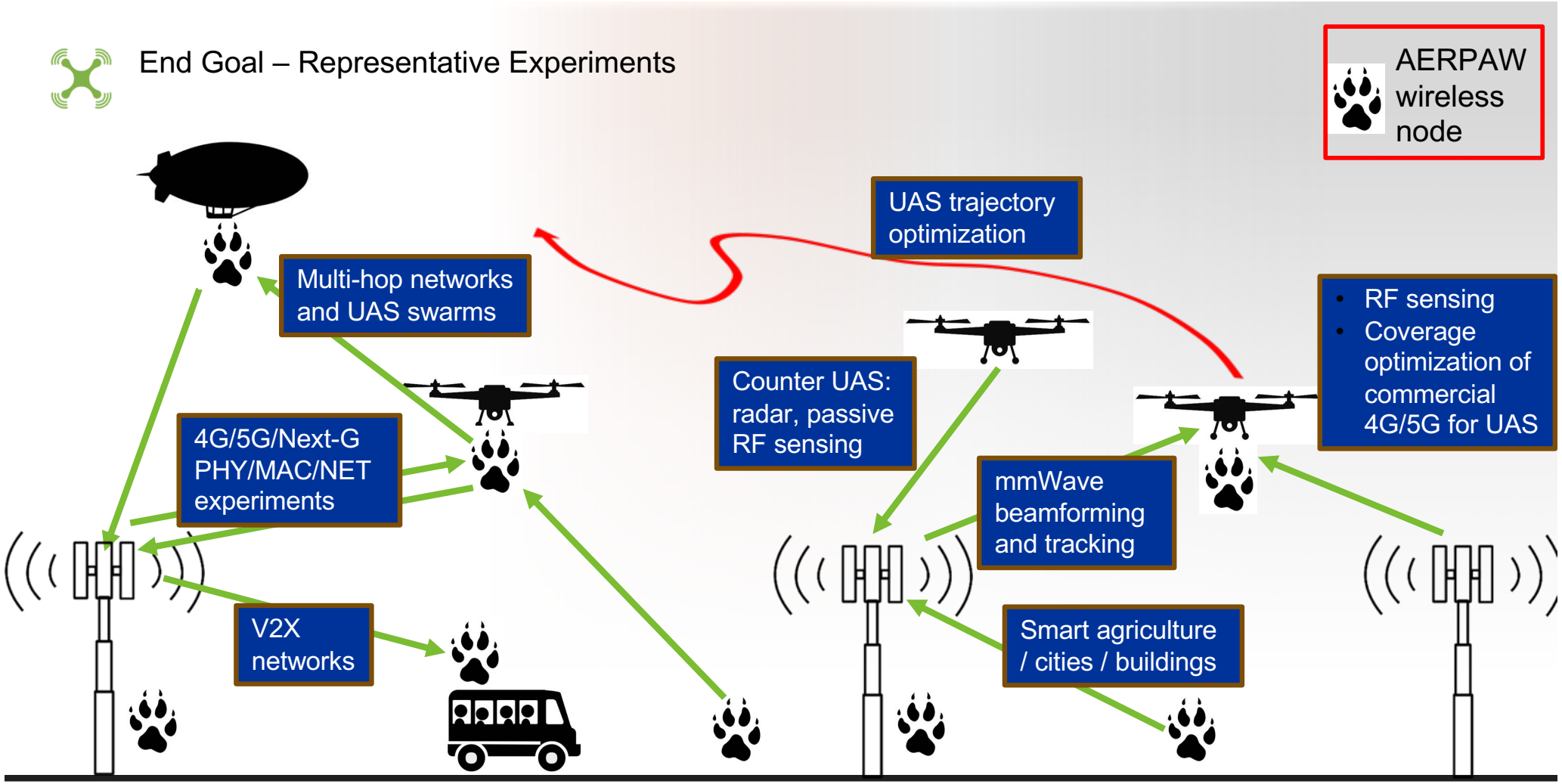
AERPAW E-VM and C-VM Architecture

Programmable SDR-based nodes

E-VM software is what the experimenter develops



End Goal – Representative Experiments



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Questions?

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