Aerial Experimentation and Research Platform for Advanced Wireless

AERPAW

https://aerpaw.org

UAS Testbed Architecture for 3D Mobility Research using Advanced Wireless Technology

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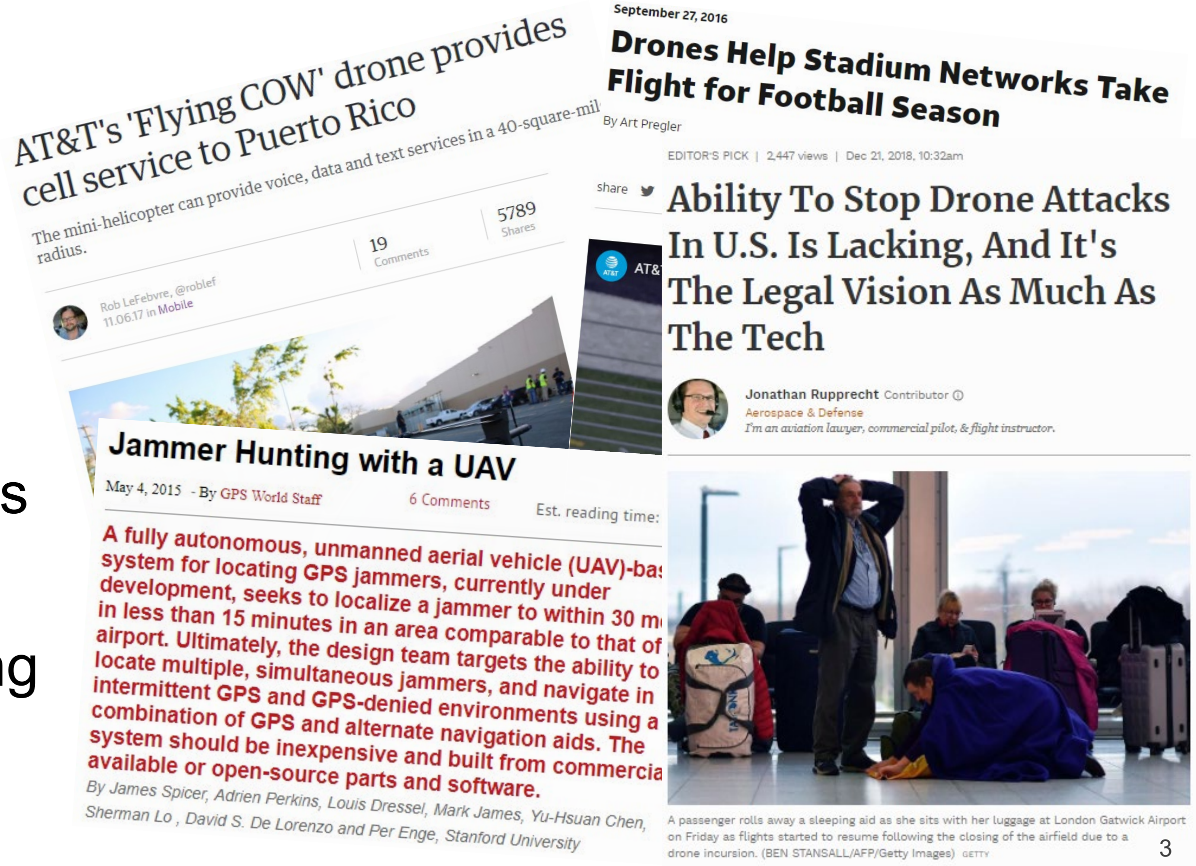
Unmanned Aerial Systems (UAS)

UAS Providing Advanced Wireless Service

- Hot-spot wireless access
- Post-disaster communications
- Search and rescue
- Situational awareness
- Jammer detection
- Detection and tracking of unauthorized UAS

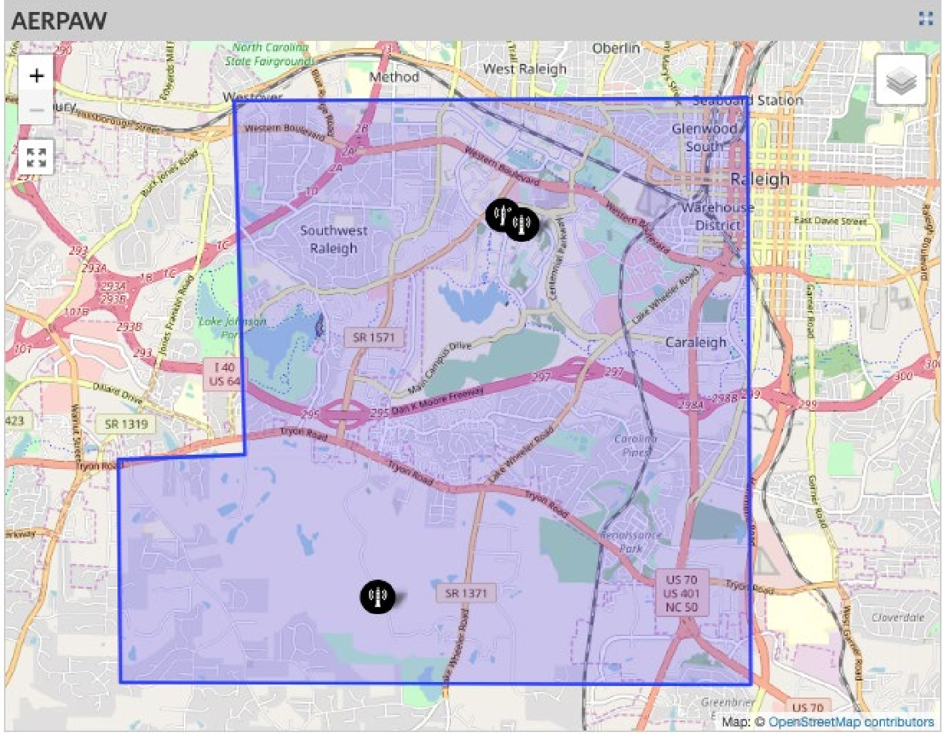


NSF Names Third PAWR Wireless Research Platform in North Carolina's Research Triangle

SEPTEMBER 18, 2019

PAWR Project Office

https://advancedwireless.org/



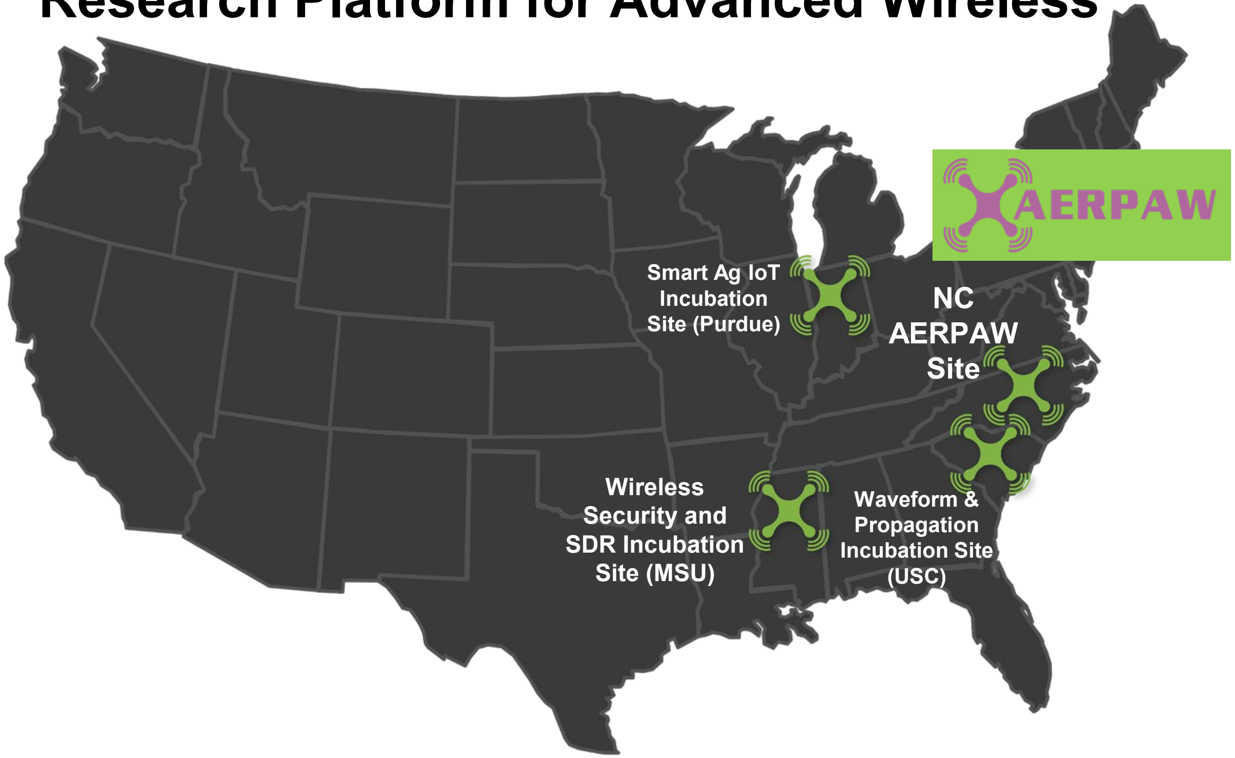
Outline

- AERPAW Team and Objective
- AERPAW Radios and Platforms
- Experiment Flow
- Research Examples

Mission

Serve as a unique technological enabler for research in advanced wireless with UAS

AERPAW: Aerial Experimentation and Research Platform for Advanced Wireless



Incubation site: develop unique testbed capabilities subsequently deployed at main sites to support corresponding experiments

AERPAW Team

NC STATE UNIVERSITY

wireless research center

MISSISSIPPI STATE UNIVERSITY

UNIVERSITY OF SOUTH CAROLINA

PURDUE UNIVERSITY

renci

AERPAW Investigator Team & Academic Partners

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

Rudra Dutta
NC State (SDN, architecture)

Mihail Sichitiu
NC State (drones, architecture)

Brian Floyd
NC State (mmW circuits, arrays)

Tom Zajkowski
NC State (UAS, FAA permitting)

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

Robert Moorhead
MSU (drones, FAA ASSURE, visualization)

Gerard Hayes
NC State, WRC (wireless and testing)

David Matolak
USC (propagation, waveforms)

David Love
Purdue (MIMO, SDRs, agriculture)

Jeffrey Reed
VT (lead user, SDRs, 5G)

...

Partnerships and Users

PARTNERS

NC STATE UNIVERSITY

wireless research center

MISSISSIPPI STATE UNIVERSITY

UNIVERSITY OF SOUTH CAROLINA

PURDUE UNIVERSITY

renci

Town of Cary

Raleigh

HOLLY SPRINGS North Carolina

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

USERS

AT&T

cisco

NTT docomo

IBM

KEYSIGHT TECHNOLOGIES

NATIONAL INSTRUMENTS

NOKIA

MITSUBISHI ELECTRIC

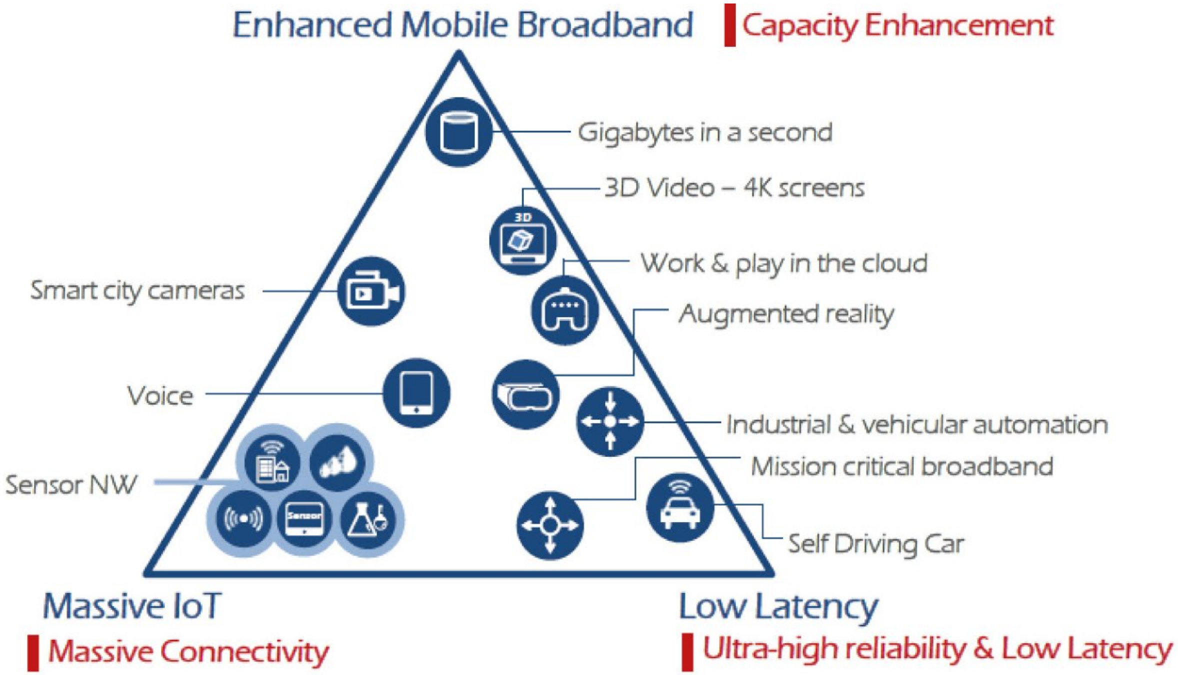
Qualcomm

The FAA's Center of Excellence for UAS Research ASSURE Alliance for System Safety of UAS through Research Excellence

INL Idaho National Laboratory

NC DIT

AERPAW: At the Crossroad of Advanced Wireless and UAS Research



(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

5G is unleashing new, transformative applications and services:

- Driverless cars
- Virtual/augmented reality (VR/AR)
- Internet of things (IoT)
- **Unmanned aerial systems (UAS)**

Advanced Wireless for Autonomous and BVLOS UAS Operations

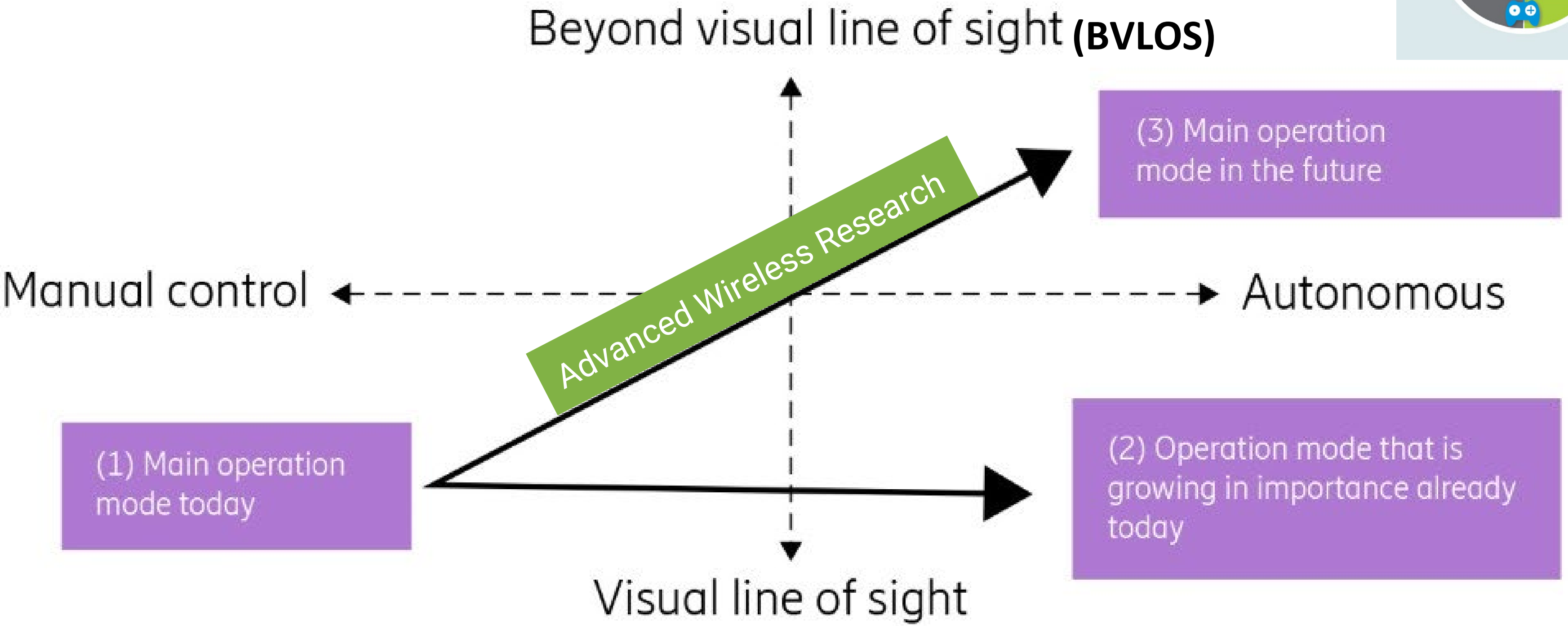
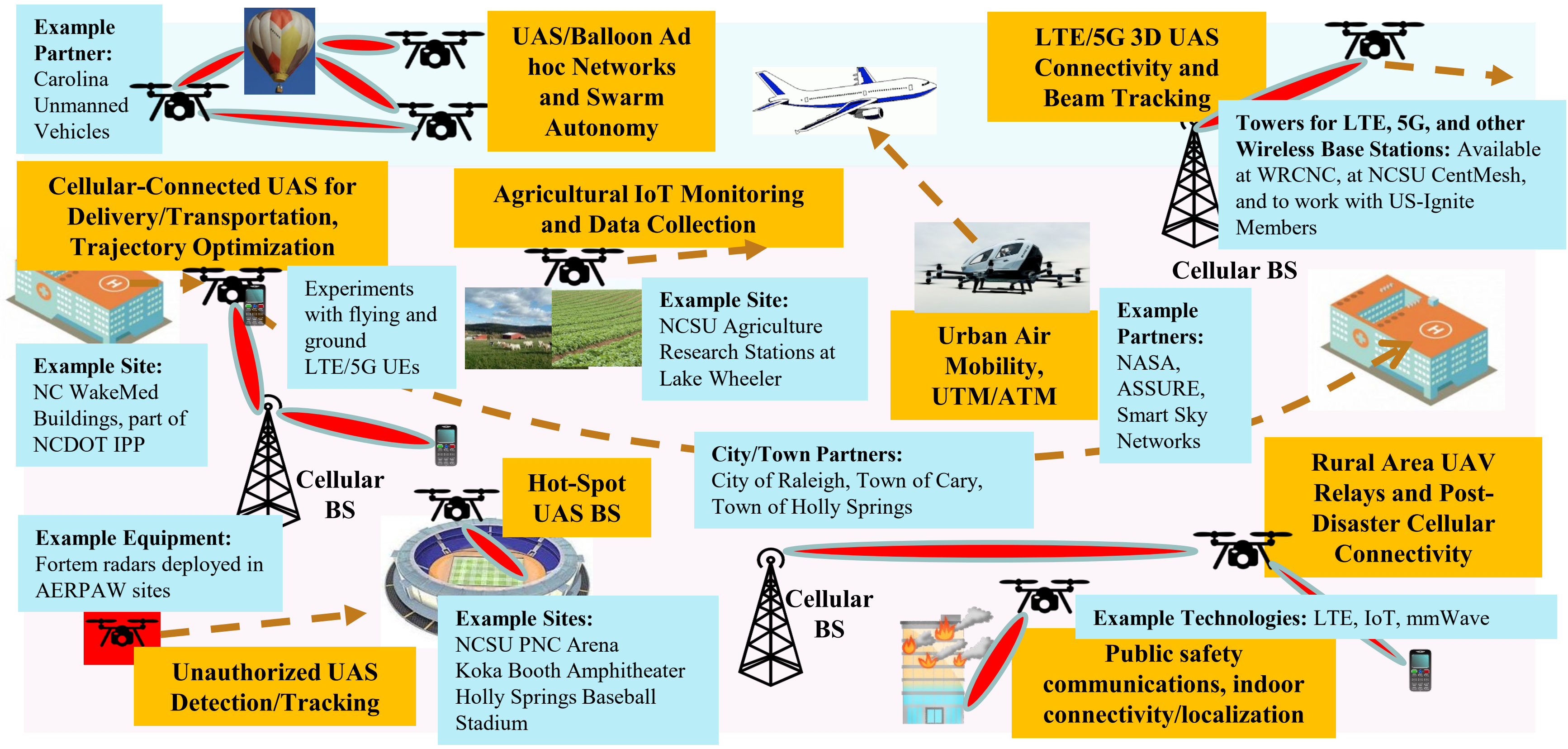


Image source: Ericsson

AERPAW: Applications and Use Cases



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Platform Equipment Options for Users

Equipment	Fixed Nodes (E.g., at Towers)	Mobile Nodes (E.g., at UAVs)
SDRs	NI USRP X310/N310/mmW	NI USRP B210/mmW
5G NR	Ericsson 5G gNBs	5G UEs
RF Sensors	Keysight N6841A RF Sensor	Keysight Nemo RF Sensors
IoT Devices	SigFox/LoRa Access Point	SigFox/Lora Sensor
UAS Radar	Fortem SkyDome	N/A
UWB	TimeDomain P410/P440 radios	TimeDomain P410/440 radios
WiFi Sniffers	WiFi Pineapple	WiFi Pineapple

Bring your own device (BYOD) experiments will also be supported if they satisfy criteria

AERPAW SDRs from National Instruments

USRP X310 (*fixed nodes*)

- ➔ Up to 160 MHz of bandwidth
- ➔ Frequency range: DC to 6 GHz (with daughterboards)
- ➔ 2 Channels
- ➔ Kintex-7 FPGA

USRP N310 (*fixed nodes*)

- ➔ Supports 4 channels for MIMO operation
- ➔ Up to 100 MHz of bandwidth/channel
- ➔ Frequency range: 10 MHz to 6 GHz
- ➔ Stand alone (embedded) or host-based (network streaming) operation
- ➔ Remote management capability

USRP 5G mmW (expected, *fixed & mobile nodes*)

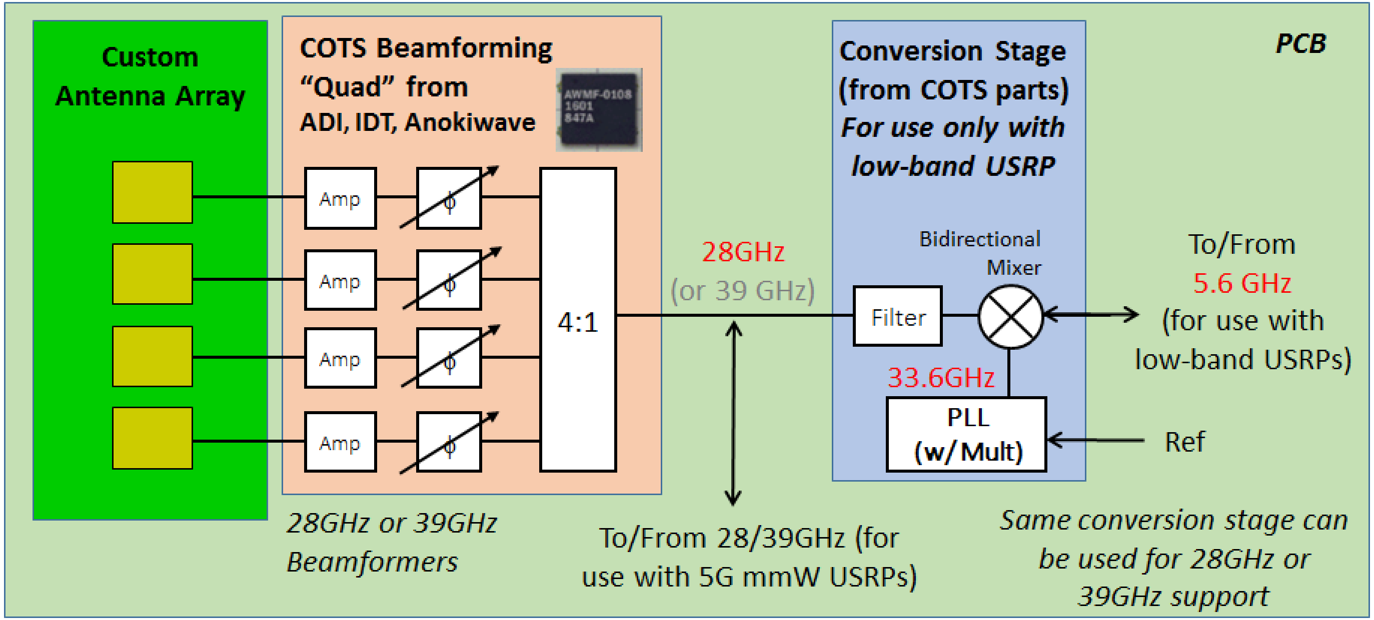
- ➔ Up to 400 MHz bandwidth
- ➔ Expected center frequency: 28 GHz
- ➔ We anticipate payload will be similar to USRP X310 series
- ➔ Considered for both at towers and drones

USRP B205mini / B210 (*mobile nodes*)

- ➔ Up to 56 MHz of bandwidth
- ➔ Frequency range: 70 MHz to 6 GHz
- ➔ B210 supports 2 Channels for MIMO
- ➔ Spartan-6 FPGA

Custom Millimeter-Wave Extenders for USRPs

- ➔ mmW beamforming for UAS is critical; however, low-cost beamforming solutions which easily interface with USRP are still being brought to market.
- ➔ We plan to develop custom beamforming modules suitable for UAS using a mixture of commercial off-the-shelf (COTS) parts.



Co-PI Brian Floyd, NCSU, bafloyd@ncsu.edu

Communications Experiment Software

Software we will integrate and provision to experimenters

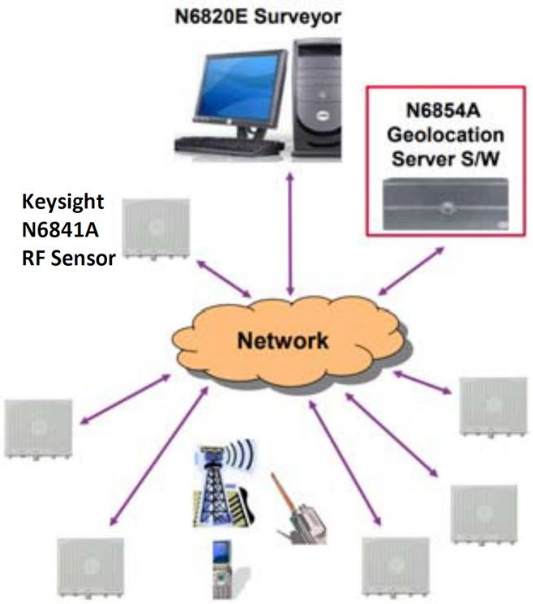
➔ srsLTE, 4G now, 5G in the future
➔ Open air interface (OAI), 4G and 5G software suites
➔ GNU Radio

Experiment support software we will develop

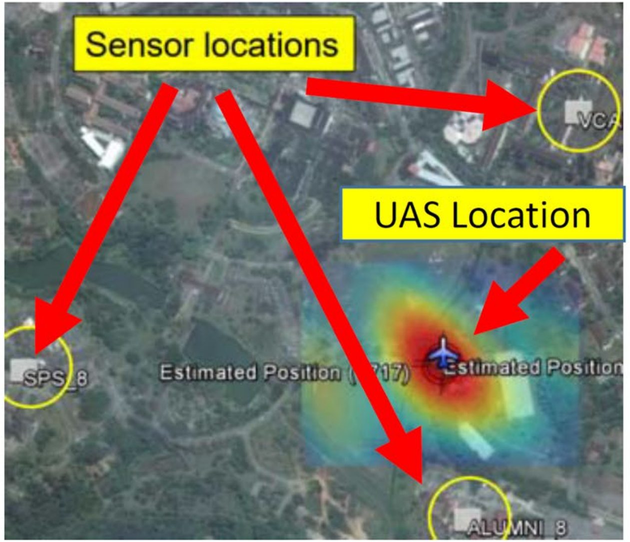
➔ Waveforms
➔ Adapted protocols for supporting research and standardization

Software developed by users

Keysight RF Sensors at Ground/Aerial Nodes



(a)



(b)

(a) Drone tracking RF N6820E sensor from Keysight, (b) Example use for UAS localization/tracking. Can be used to sense any other fixed/mobile RF source, e.g. for interference localization.

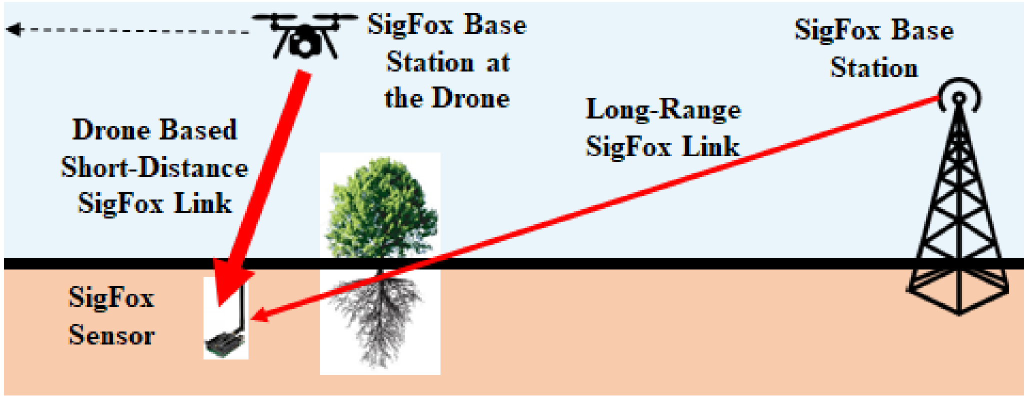
Keysight 4G/5G network measurement solutions for commercial BS coverage experiments at aerial platforms

SigFox IoT and Fortem Radar

SigFox: Major applications in agriculture (Purdue, NCSU), Signals in the Soil, and broadly in UAS based monitoring

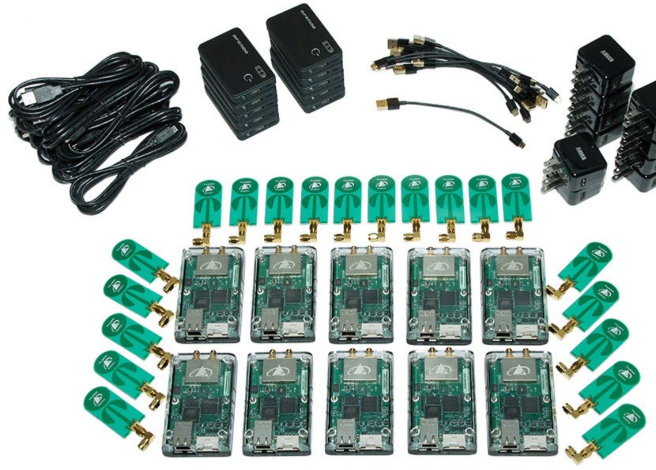
Fortem: A NCDOT IPP partner, detection of unauthorized or non-cooperating UAS

- **Powerful Sensor**
  - Effective 3D radar sensor that detects and monitors with precision, day or night and in all weather conditions
  - Simple intuitive interface and U/I
  - Built for air and ground application
- **Integrated and Compact**
  - Integrated high-resolution electronically-steered patch antenna array
  - Integrated inertial navigation system (INS) enables clutter rejection in airborne applications
- **Simple Connectivity**
  - Ethernet output (JSON) for streaming detection & track data to other systems
  - Graphical User Interface (GUI) for radar operation and configuration
  - APIs for programmatic radar control
  - Ethernet provides up to 1 Gbps data transfer rates



Skydome

UWB Transceivers and WiFi Sniffers



WiFi Pineapple

- ➔ Frequency: 2.4 GHz and 5 GHz WiFi
- ➔ Can capture probe requests from all WiFi-equipped mobile devices
- ➔ Applications in search and rescue, occupancy monitoring

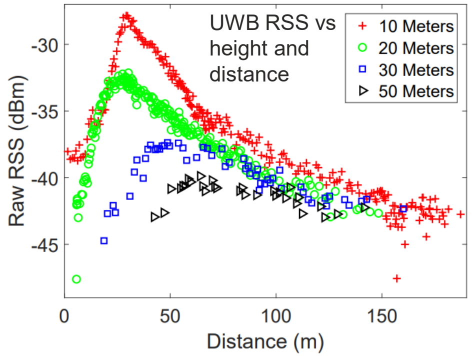


Image Source: Guvenc et al., 2018

Time Domain P440 radios

- ➔ Frequency: 3.1 GHz - 4.9 GHz
- ➔ 2 GHz of instantaneous bandwidth
- ➔ 2 cm ranging precision over 100

Localizing mobile phones with WiFi sniffers

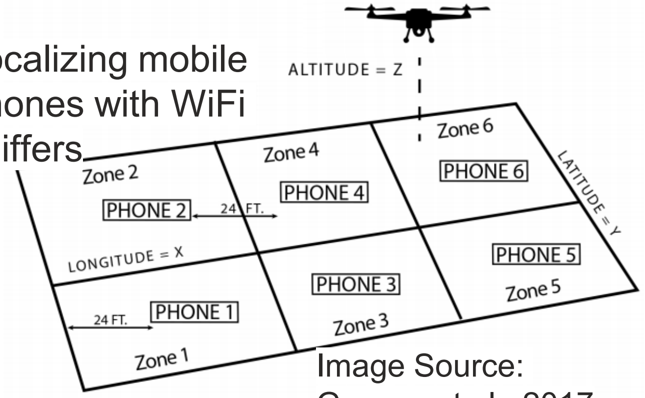


Image Source: Guvenc et al., 2017

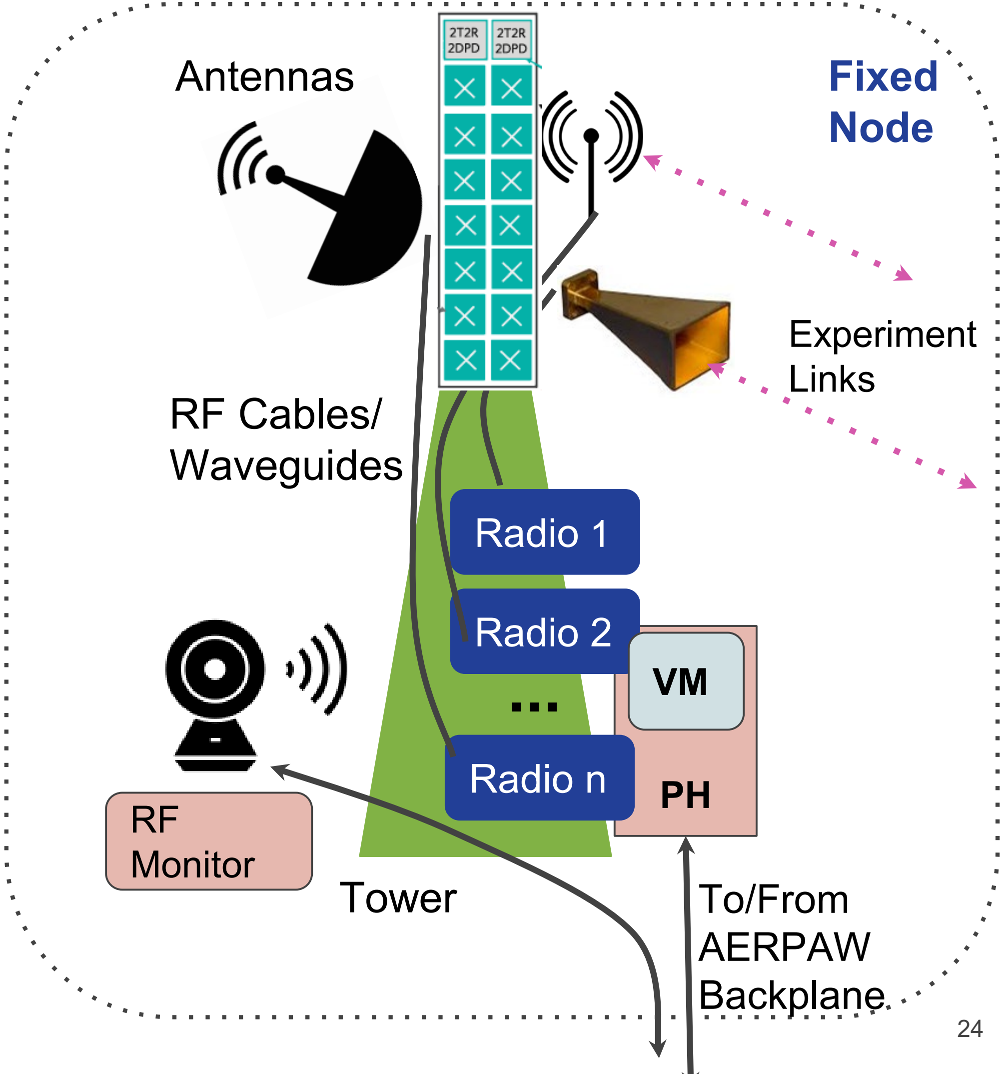
Fixed Nodes

➔ Provides the users a programmable fixed node

➔ Consists of:
  - Physical Host (workstation)
  - Radios
  - Antennas
  - Tower

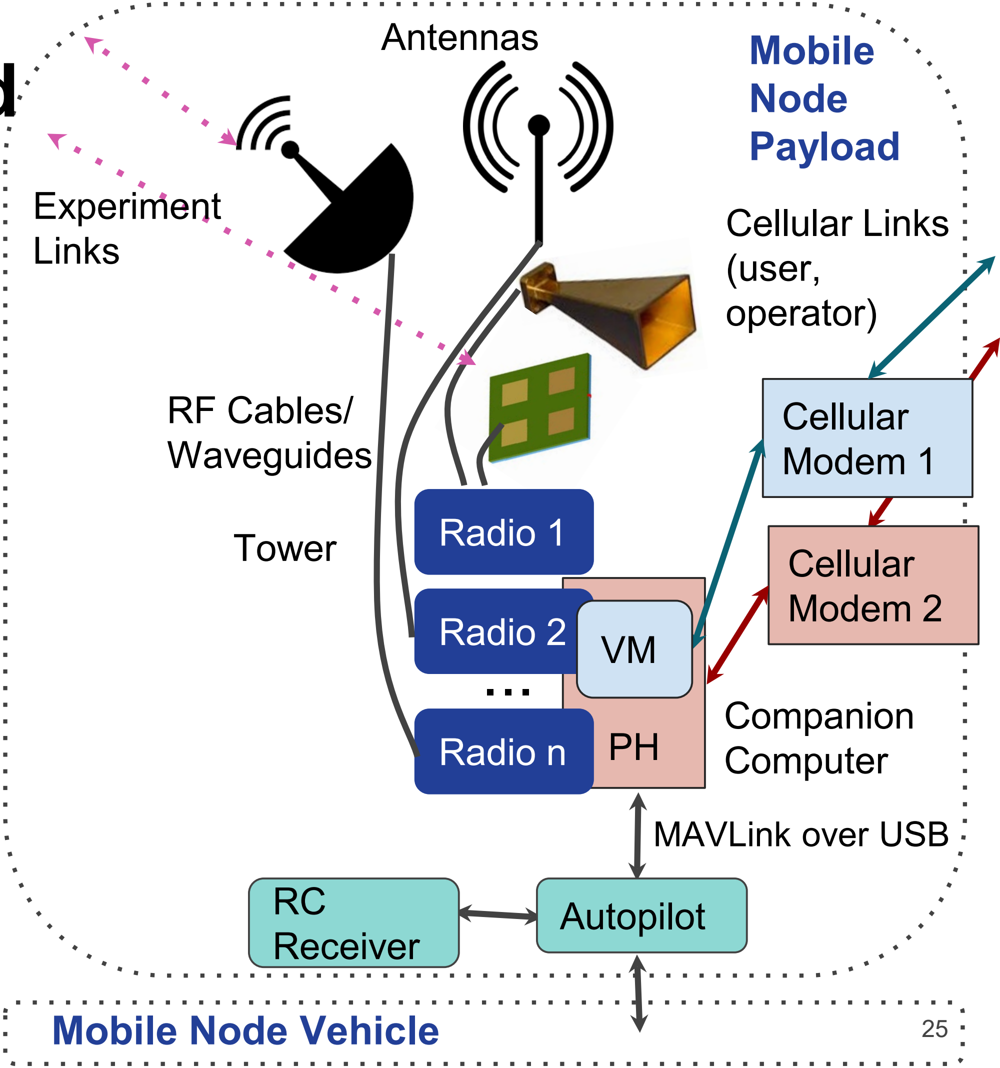
➔ Optionally, steerable directional antennas

➔ The operator loads VM Image to the fixed node physical host through Testbed Backplane



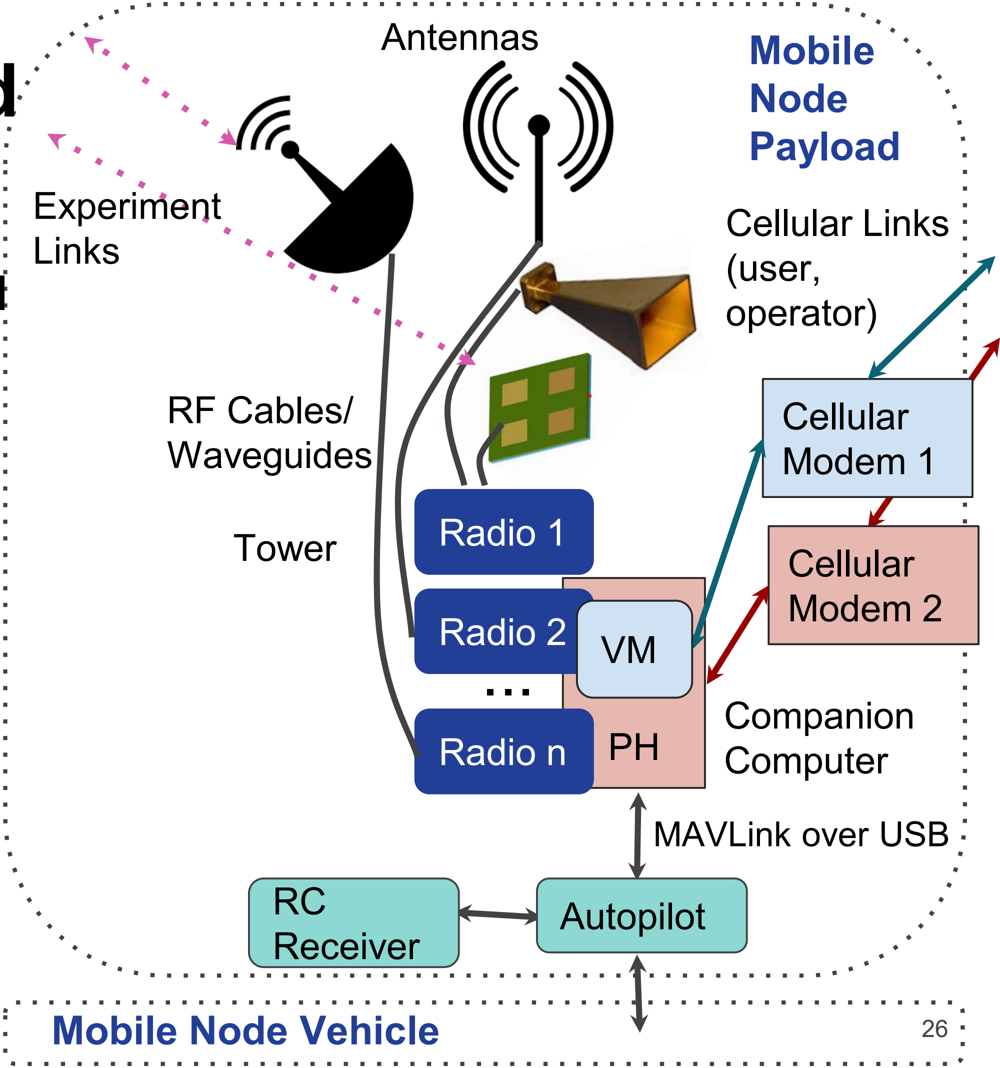
Mobile Nodes Payload

- ➔ Provides the users a programmable mobile node
- ➔ Consists of:
  - Companion Computer + VMs
  - Radios
  - Antennas
  - Autopilot
- ➔ Optionally, steerable directional antennas
- ➔ The operator loads VM Image to the mobile node physical host through Testbed Backplane



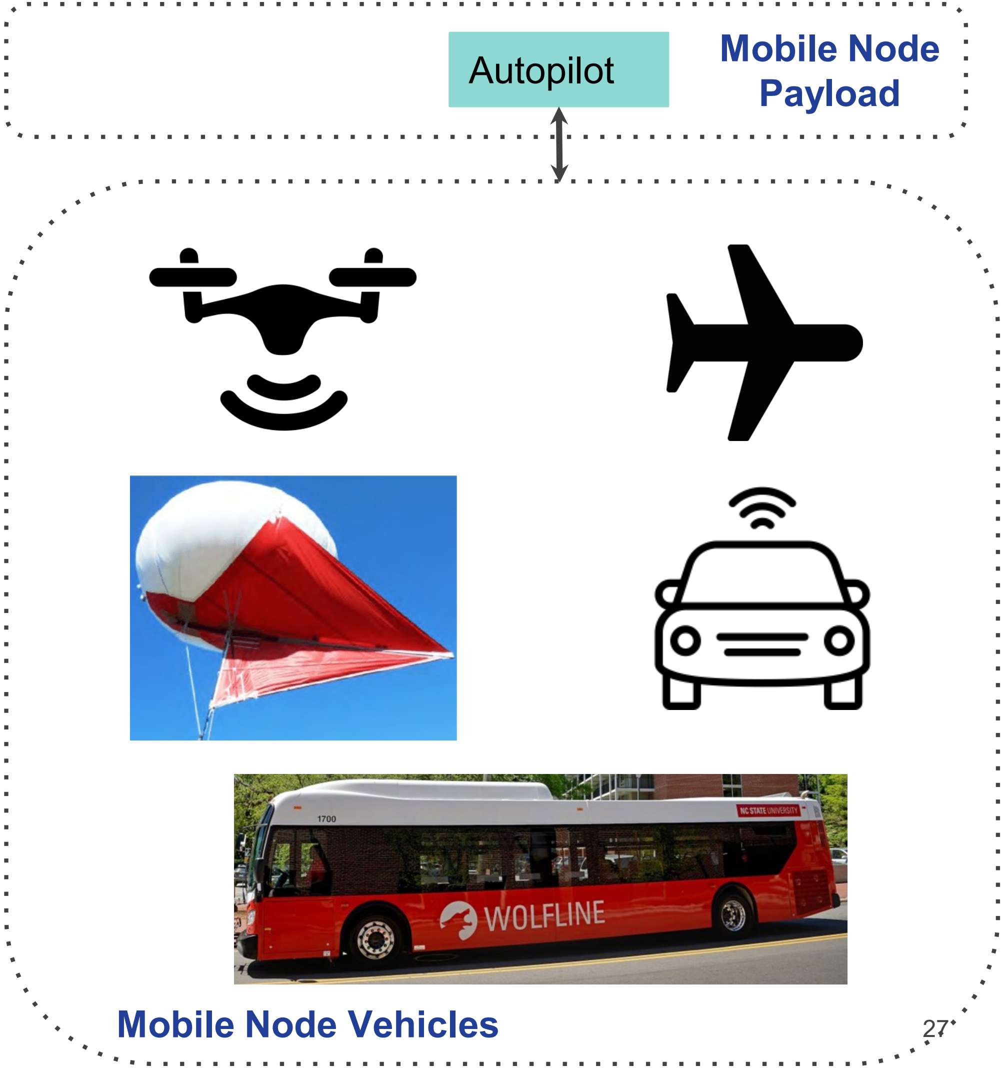
Mobile Nodes Payload

- ➔ Cellular Link 1 under **user** control
- ➔ Cellular Link 2 under **operator** control
  - Start the experiment
  - Normal termination of experiment
  - Abort the experiment
- ➔ RC Receiver under **operator** control
  - Abort experiment



Mobile Nodes Vehicle

- Multicopters
- Fixed wing
- Helikite
- Rover
- Bus



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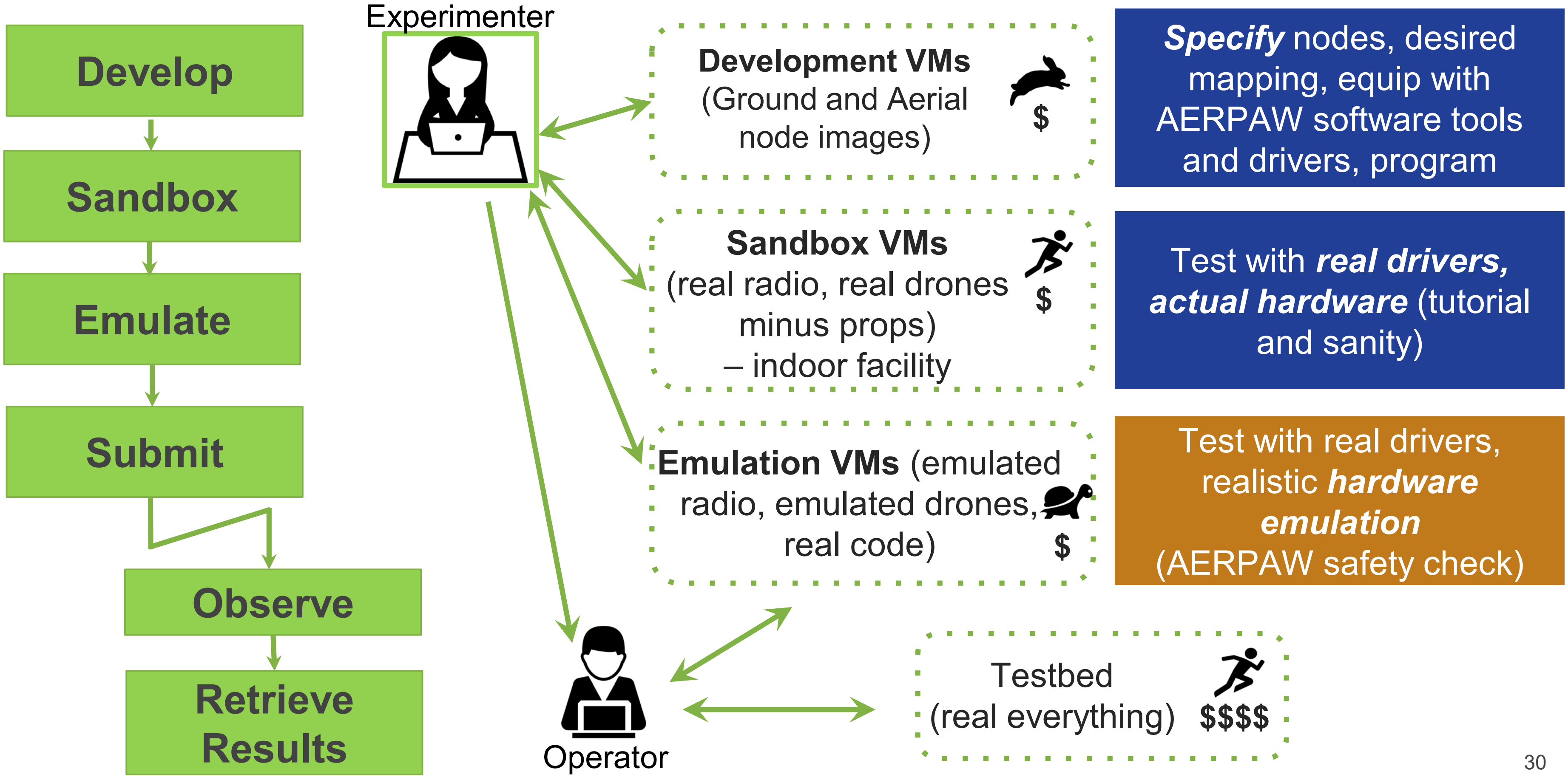
Experiment Preparation to Execution



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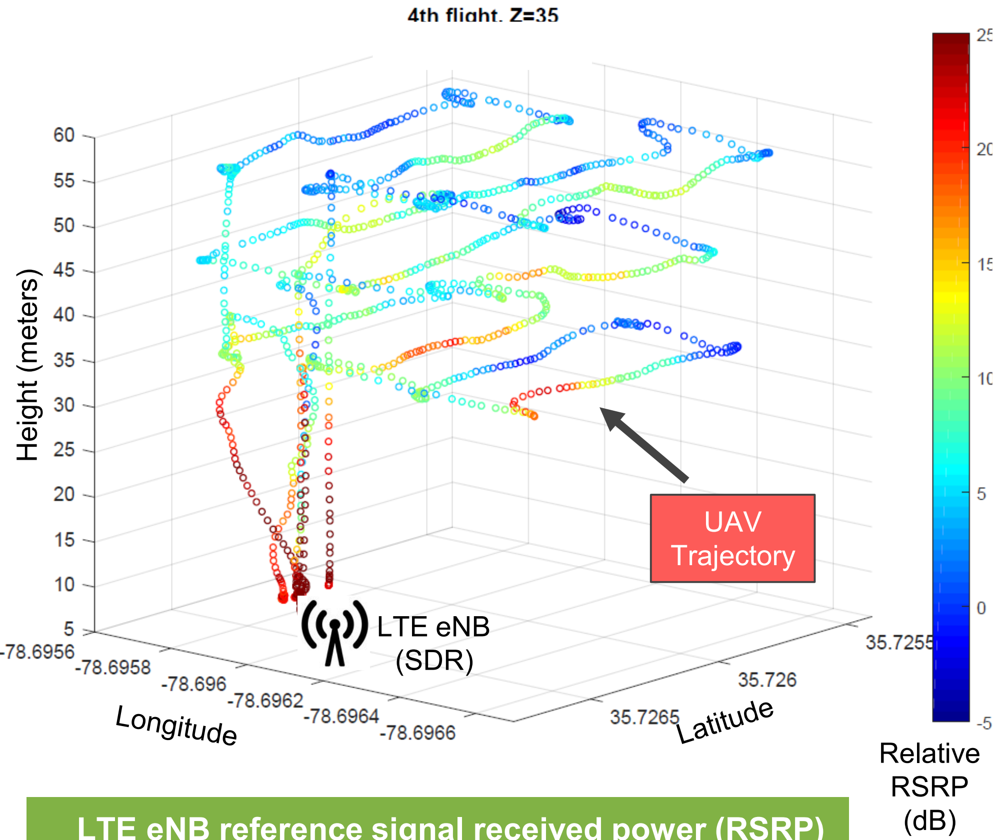
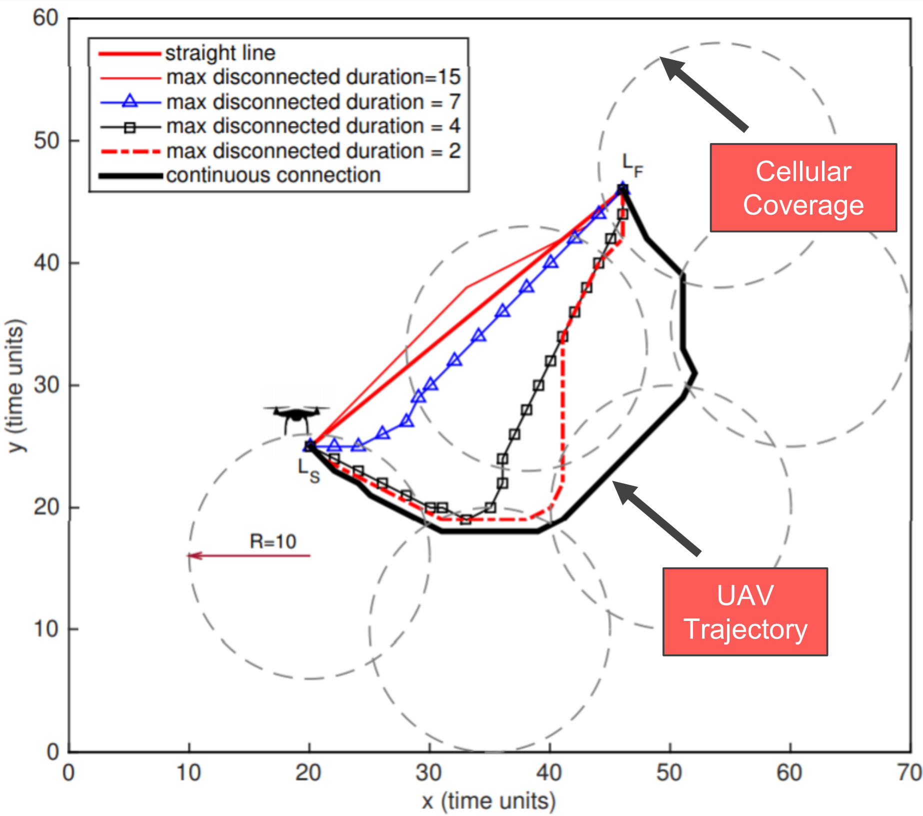
AERPAW Short & Long Term Research Examples



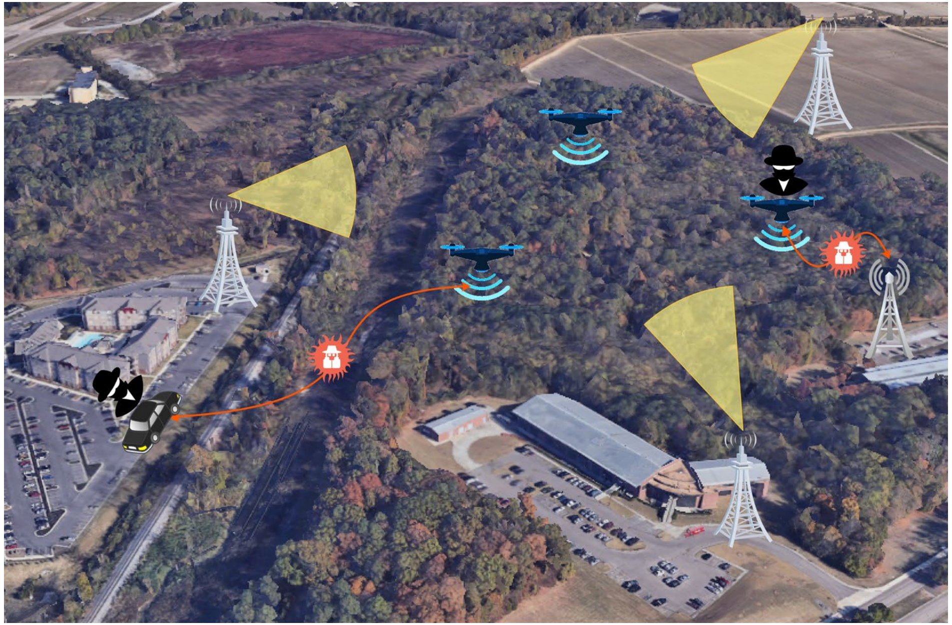
LTE eNB reference signal received power (RSRP) measurements at UAS [Sichitiu/Guvenc, 2019]



UAS autonomy and trajectory optimization [Bulut/Guvenc 2018]

Wireless Security Incubation Site @ MSU

- UAS communications security
  - PHY layer and protocol security
  - Link and system reliability in harsh signaling environment
  - Counter UAS systems
  - Standardization
- Air interface & protocol design
  - Parameter exposure, incl. perform. measurement counters and KPIs
  - Adaptive waveforms and protocols
  - Smart interferers



Research Park, Mississippi Sate/City of Starkville, MS

Timeline

- AERPAW design being finalized end of 2019
  - Radios, network, UAVs, location of fixed nodes, …
- Deployment starts end in 2020
- First fixed and mobile nodes available in summer 2020
  - Workshop and summer school
- Testbed fully developed end on year 3

We want to work with you!

- Understand/continuously refine research needs
  - Capabilities, usability needs
- Expand our user groups
- Define research projects
- Collaborate on platform design, deployment, evolution
- Collaborate on data collection and standardization
- ...

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