



AERP AW

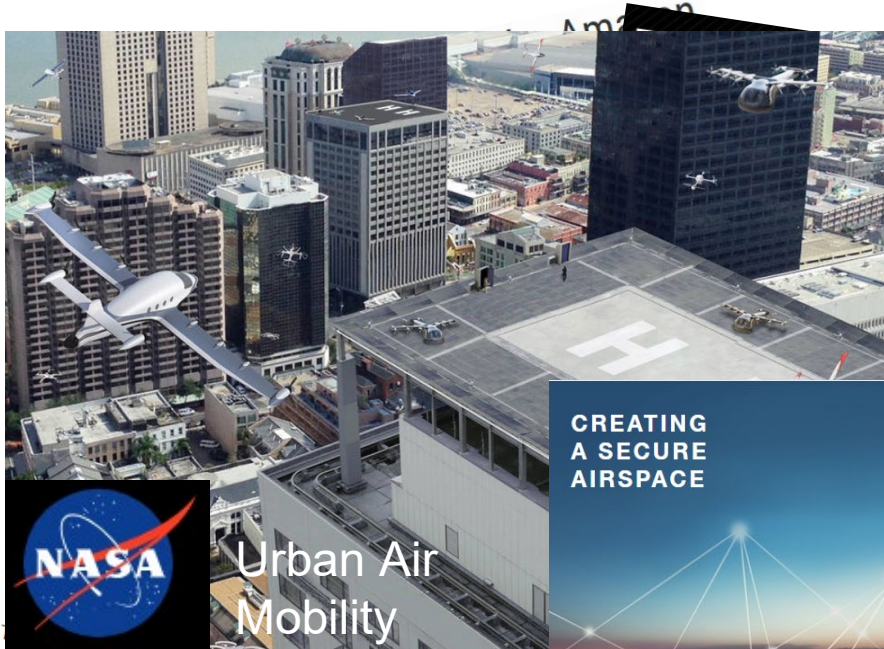
<https://aerpaw.org>

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

Vuk Marojevic, Ismail Guvenc, Rudra Dutta, Mihail Sichitiu, Jeffrey Reed

aerpaw-contact@ncsu.edu

Unmanned Aerial Systems (UAS)



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fully delivered
BY MARCO MARG



UBER



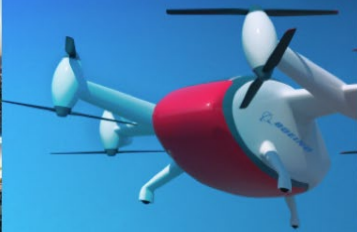
Urban Air
Mobility

... N.C. Department of Transportation's Division of Aviation
Matternet to conduct the first round of test flights for drones to carry
located across from WakeMed Raleigh Campus on Sunnybrook Road

CREATING
A SECURE
AIRSPACE



MOVING GOODS
AND CARGO



GIVING PEOPLE
MORE TIME



C:
Integration-



NA
Zipline is the
note areas of
from a central
deployed via
wing longer



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

AT&T's 'Flying COW' drone provides cell service to Puerto Rico

The mini-helicopter can provide voice, data and text services in a 40-square-mile radius.



Rob LeFebvre, @rob1ef
11.06.17 in Mobile

19
Comments

5789
Shares



Jammer Hunting with a UAV

May 4, 2015 - By GPS World Staff

6 Comments

Est. reading time:

A fully autonomous, unmanned aerial vehicle (UAV)-based system for locating GPS jammers, currently under development, seeks to localize a jammer to within 30 m in less than 15 minutes in an area comparable to that of an airport. Ultimately, the design team targets the ability to locate multiple, simultaneous jammers, and navigate in intermittent GPS and GPS-denied environments using a combination of GPS and alternate navigation aids. The system should be inexpensive and built from commercial available or open-source parts and software.

By James Spicer, Adrien Perkins, Louis Dressei, Mark James, Yu-Hsuan Chen, Sherman Lo, David S. De Lorenzo and Per Enge, Stanford University

September 27, 2016

Drones Help Stadium Networks Take Flight for Football Season

By Art Pregler

EDITOR'S PICK | 2,447 views | Dec 21, 2018, 10:32am

share



Ability To Stop Drone Attacks In U.S. Is Lacking, And It's The Legal Vision As Much As The Tech



Jonathan Rupprecht Contributor

Aerospace & Defense

I'm an aviation lawyer, commercial pilot, & flight instructor.



A passenger rolls away a sleeping aid as she sits with her luggage at London Gatwick Airport on Friday as flights started to resume following the closing of the airfield due to a drone incursion. (BEN STANSALL/AFP/Getty Images) GETTY

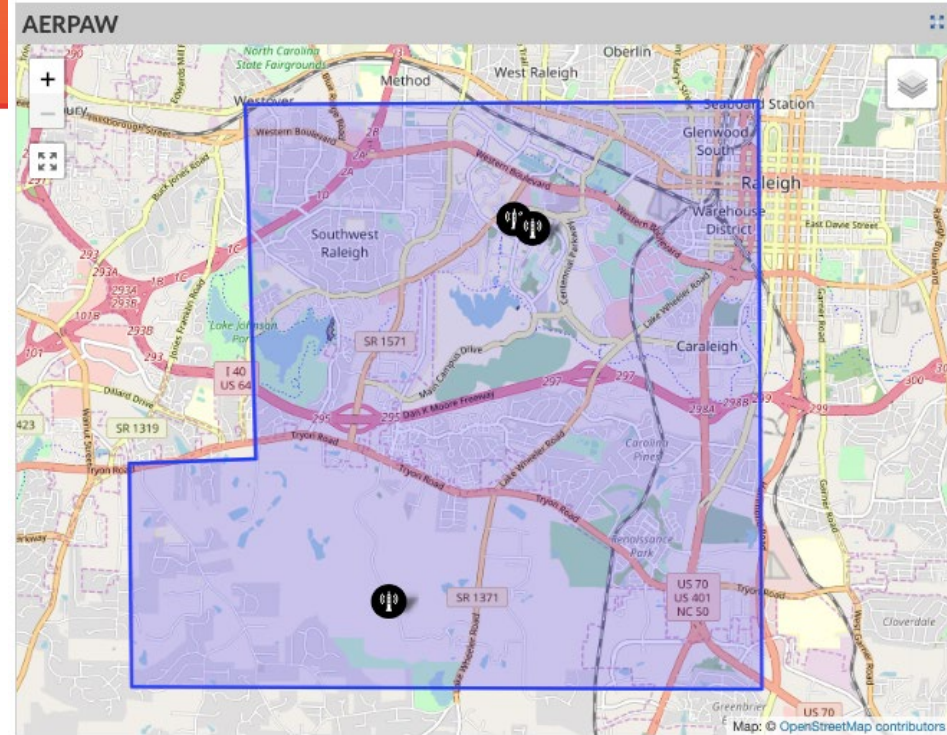
NSF Names Third PAWR Wireless Research Platform in North Carolina's Research Triangle

SEPTEMBER 18, 2019



PAWR Project Office

<https://advancedwireless.org/>



Outline

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




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The Aerial Experimentation and Research Platform for Advanced Wireless (AERPAW)—led by North Carolina State University—is in close partnership with the Wireless Research Center of North Carolina, Mississippi State University, the University of South Carolina, Purdue University, Renci, the Town of Cary, the City of Raleigh, the North Carolina Department of Transportation, and numerous industry partners—is the proposed PAVs platform.


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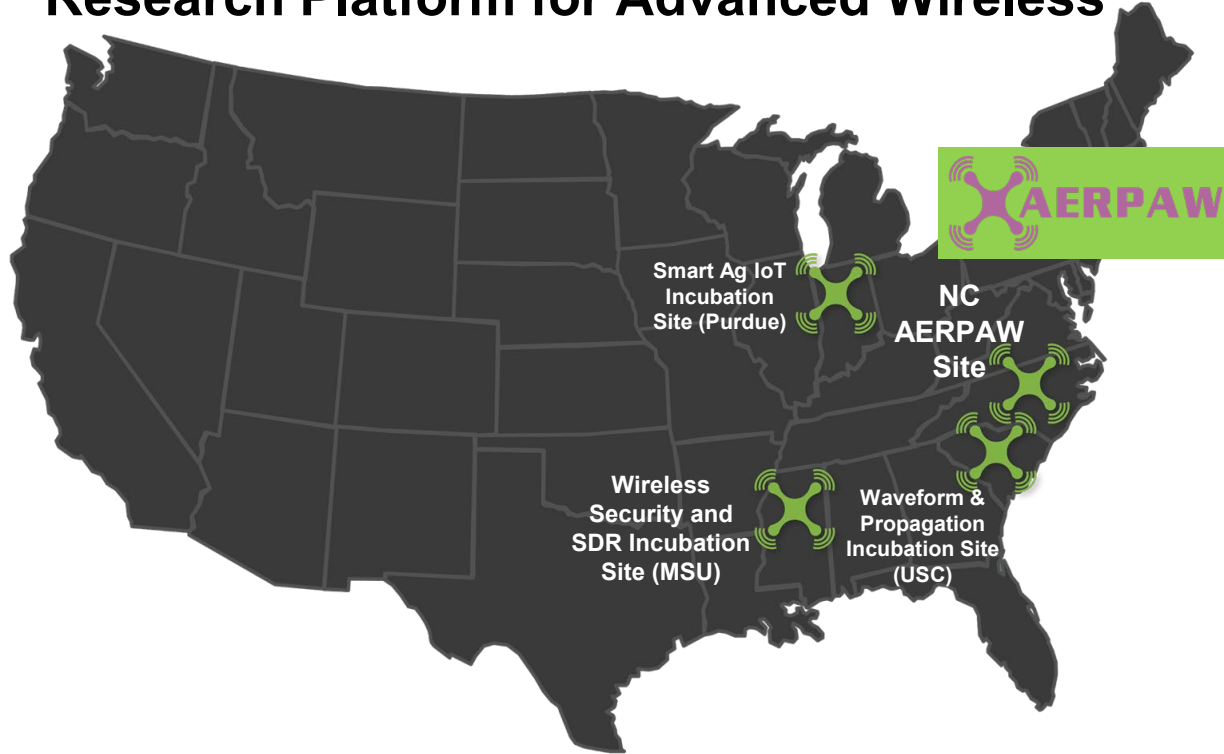




Mission

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



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 Sichertiu

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)



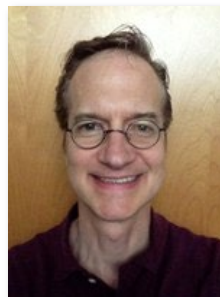
Robert Moorhead

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



TOWN of CARY



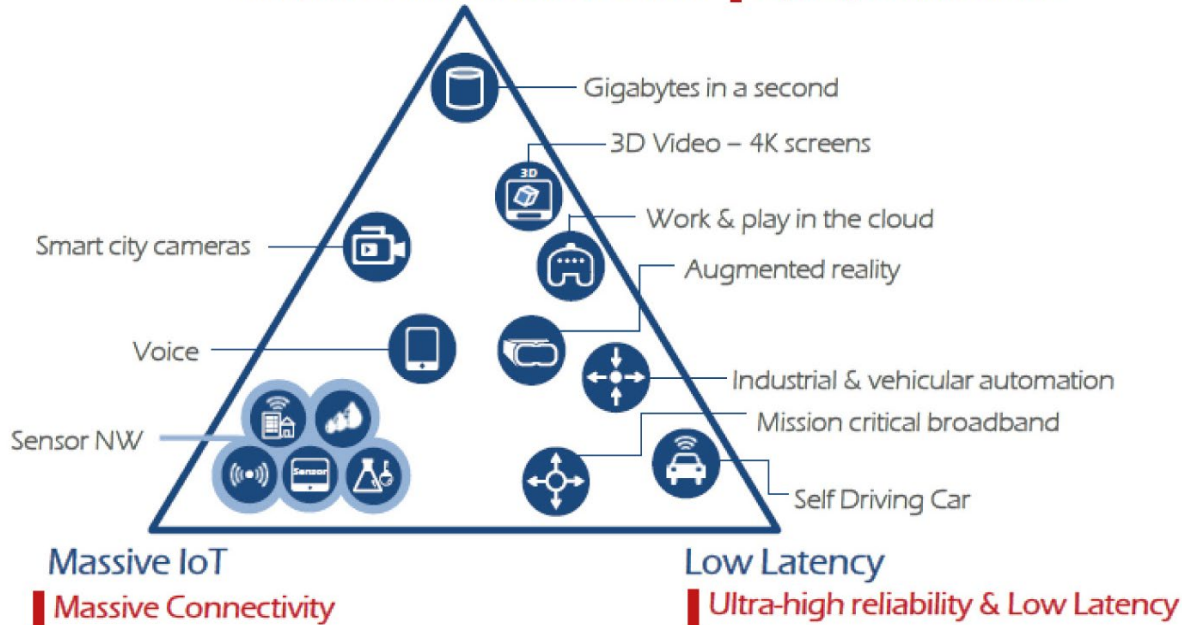
USERS





AERPAW: At the Crossroad of Advanced Wireless and UAS Research

Enhanced Mobile Broadband | Capacity Enhancement



5G is unleashing new, transformative applications and services:

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

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



Advanced Wireless for Autonomous and BVLOS UAS Operations



Beyond visual line of sight (**BVLOS**)

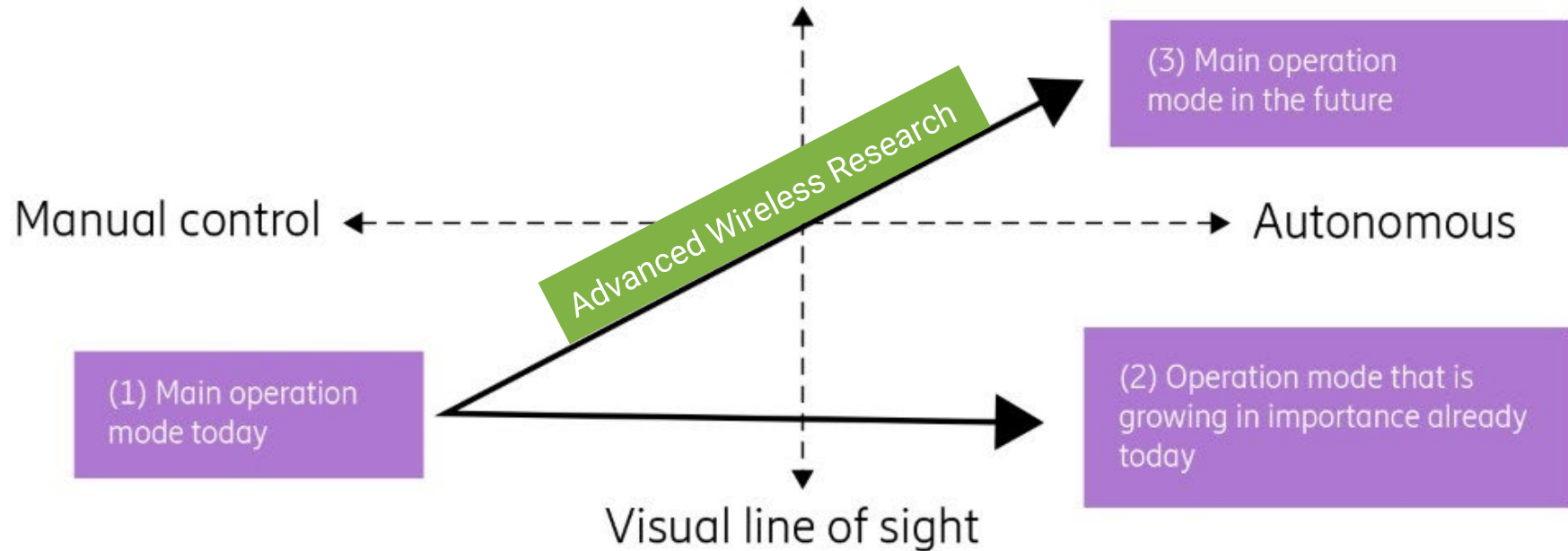
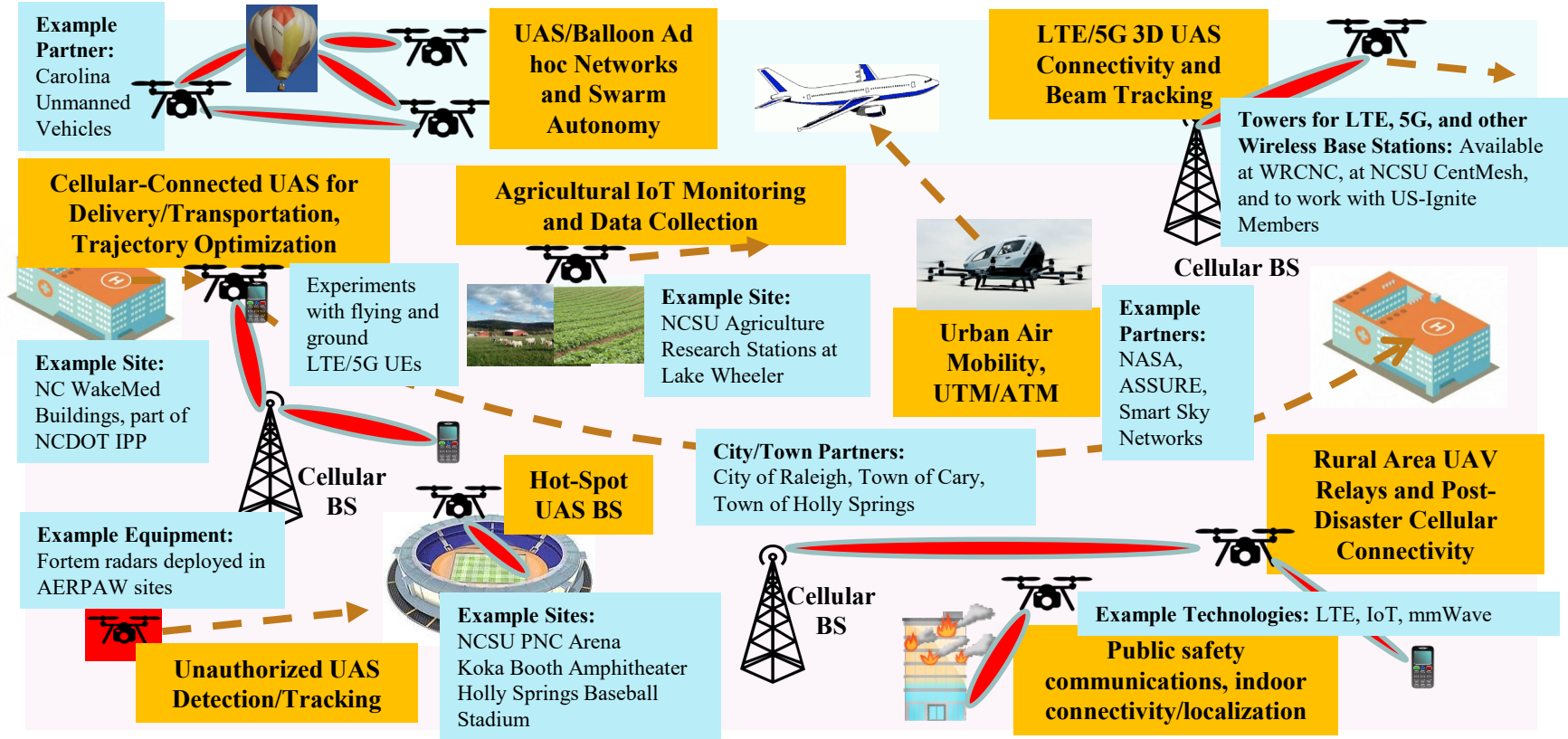


Image source: Ericsson

AERPAW: Applications and Use Cases



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NC STATE
UNIVERSITY

TOWN of CARY

 Raleigh

renci



 wireless
research center

 UNIVERSITY OF
SOUTH CAROLINA

PURDUE
UNIVERSITY

 MISSISSIPPI STATE
UNIVERSITY

aerpaw.org

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



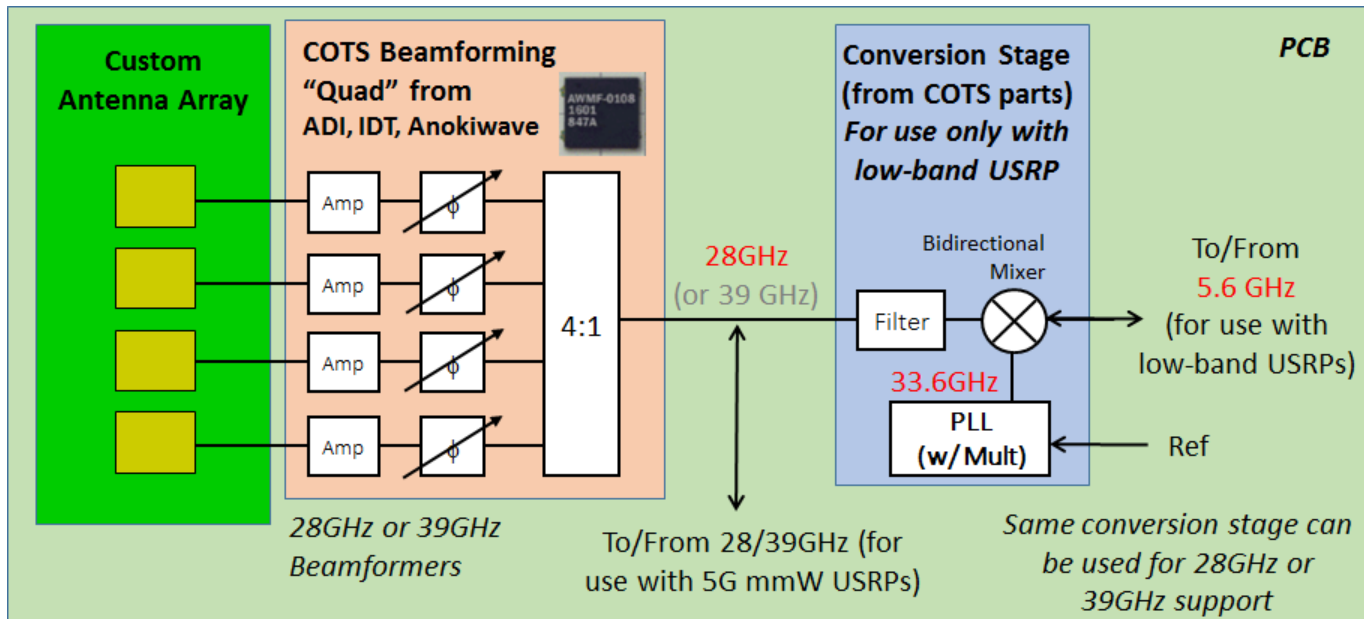
USRP B205mini / B210 (*mobile nodes*)

- 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

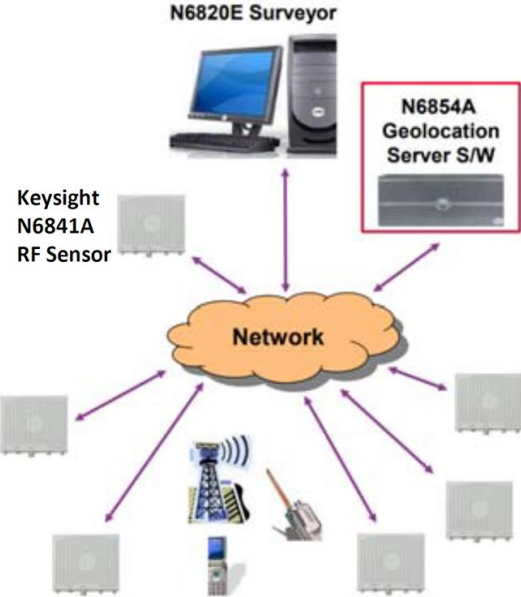
- srsLTE, 4G now, 5G in the future
- Open air interface (OAI), 4G and 5G software suites
- GNU Radio

Experiment support software we will develop

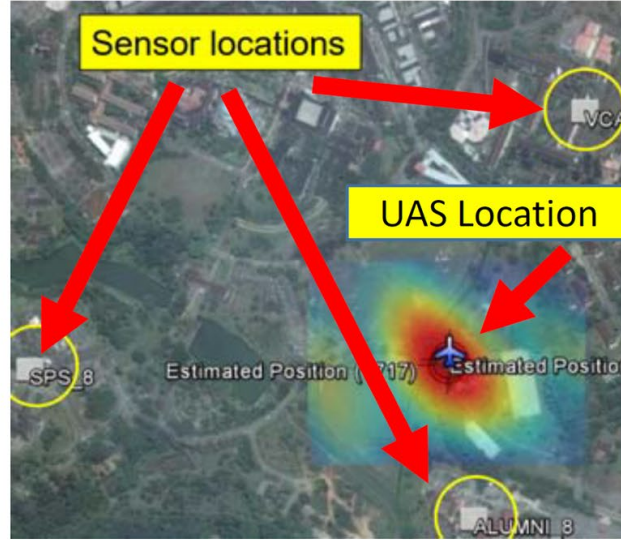
- Waveforms
- Adapted protocols for supporting research and standardization

Software developed by users

Keysight RF Sensors at Ground/Aerial Nodes



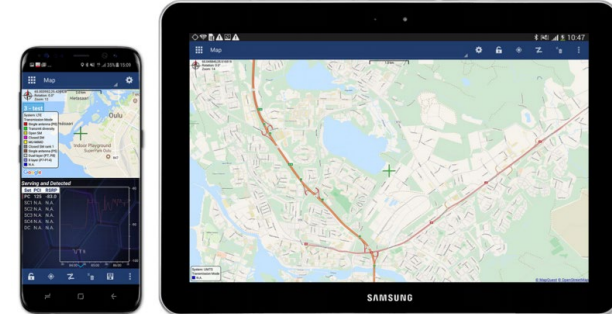
(a)



(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 Technologies
Nemo Handy
Fast, Efficient, On-the-Go Network
Measurement and Troubleshooting



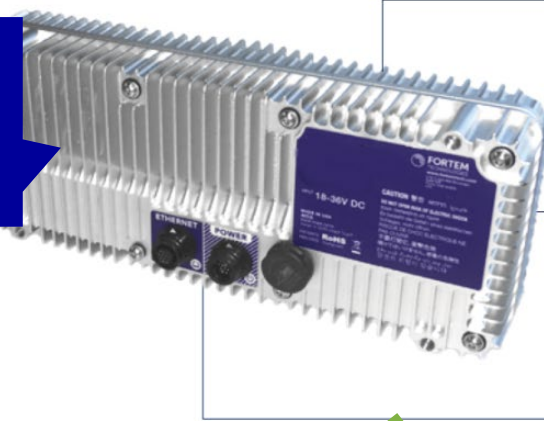
NEMO

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

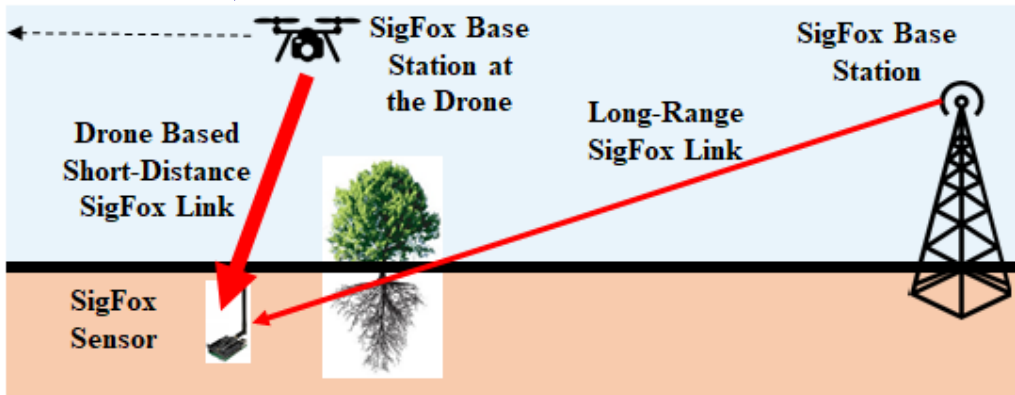
- Effective 3D radar sensor that detects and monitors with precision, day or night and in all weather conditions
- Simple intuitive interface and UI
- Built for air and ground application

• 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

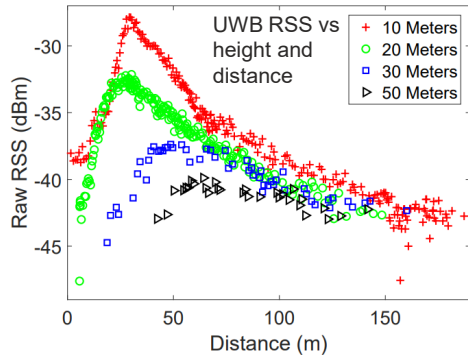


UWB Transceivers and WiFi Sniffers



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



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

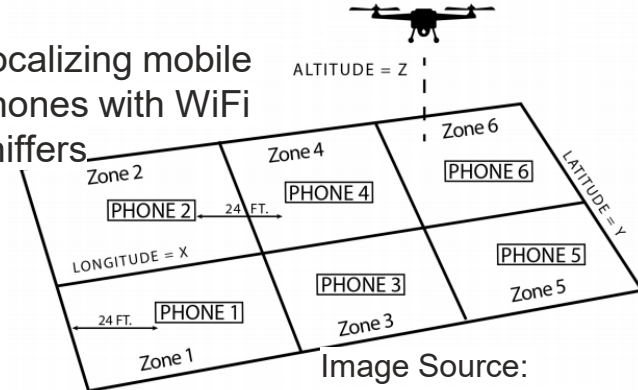
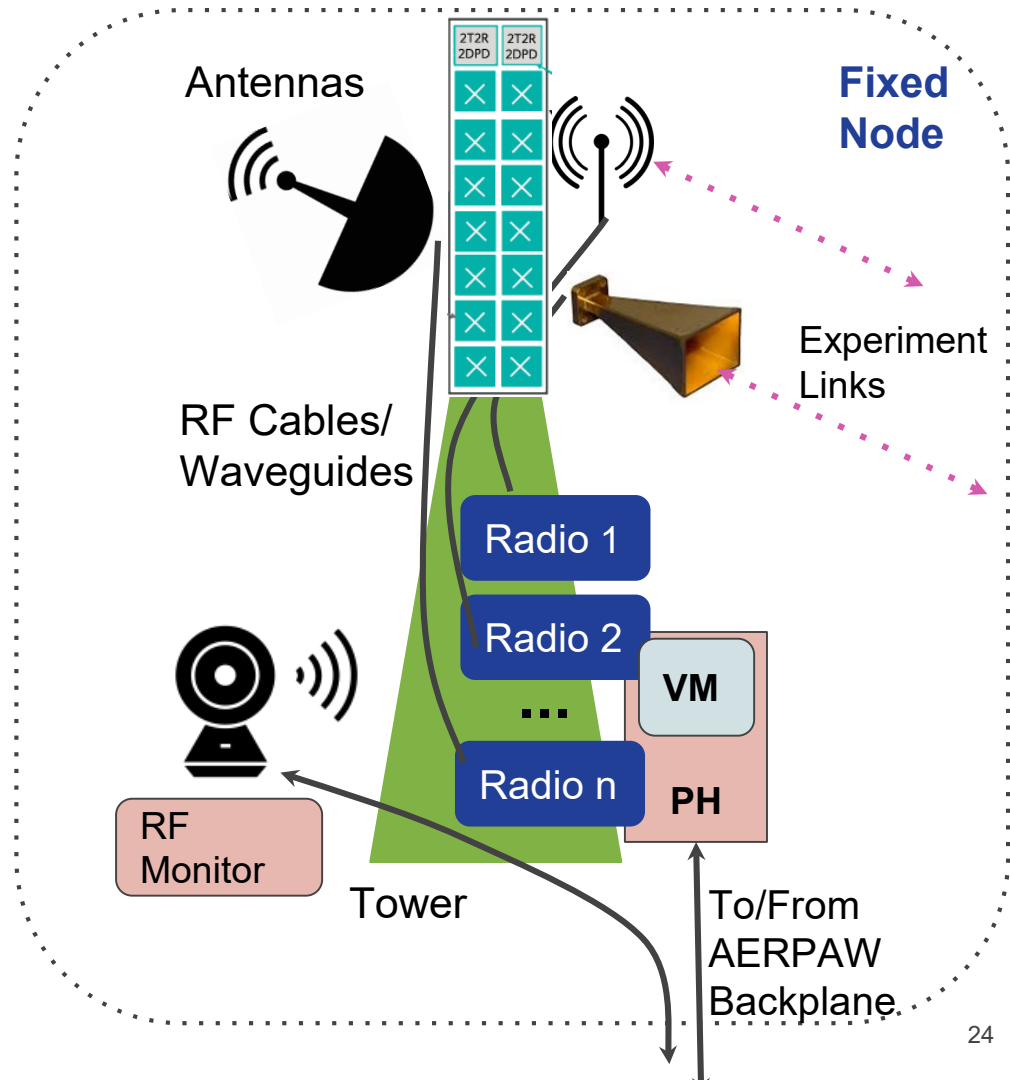


Image Source:
Guvenc et al., 2017

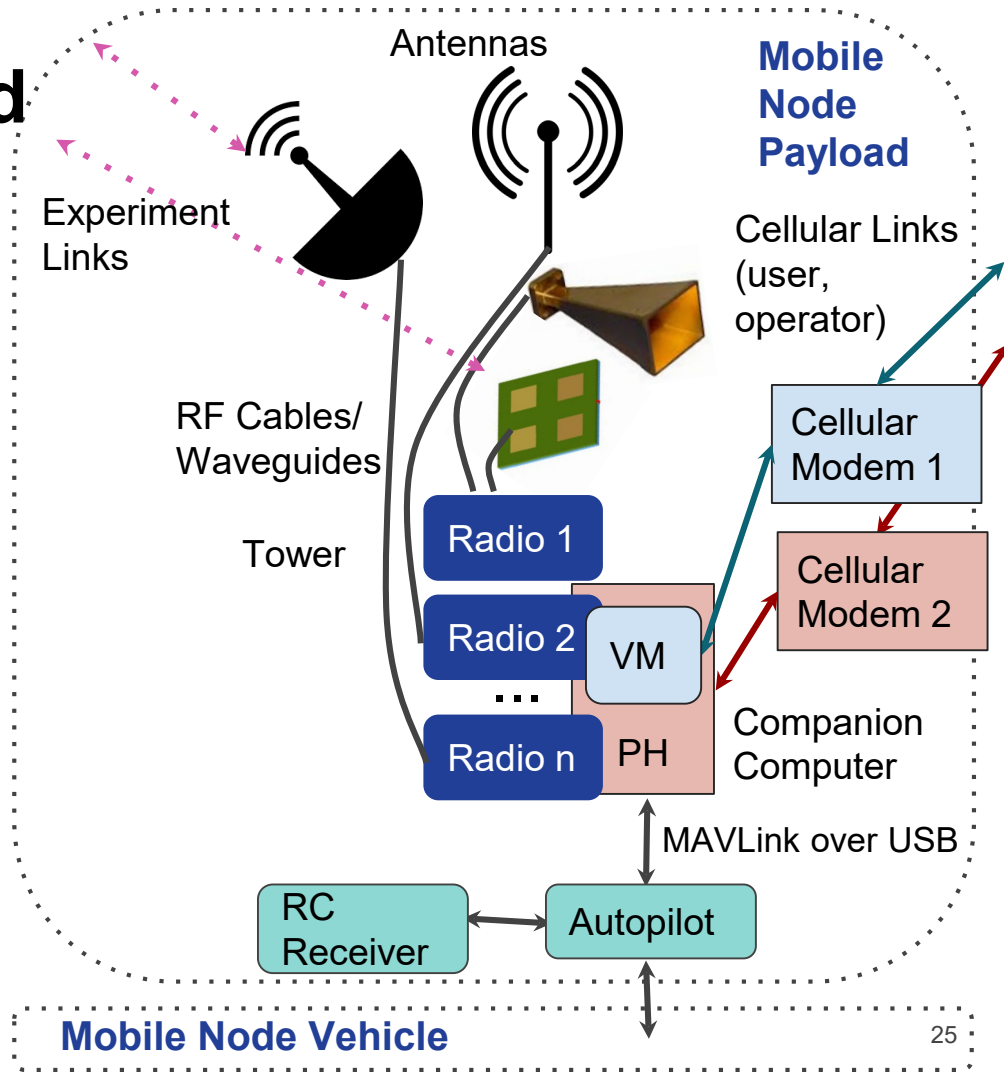
Fixed Nodes

- 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



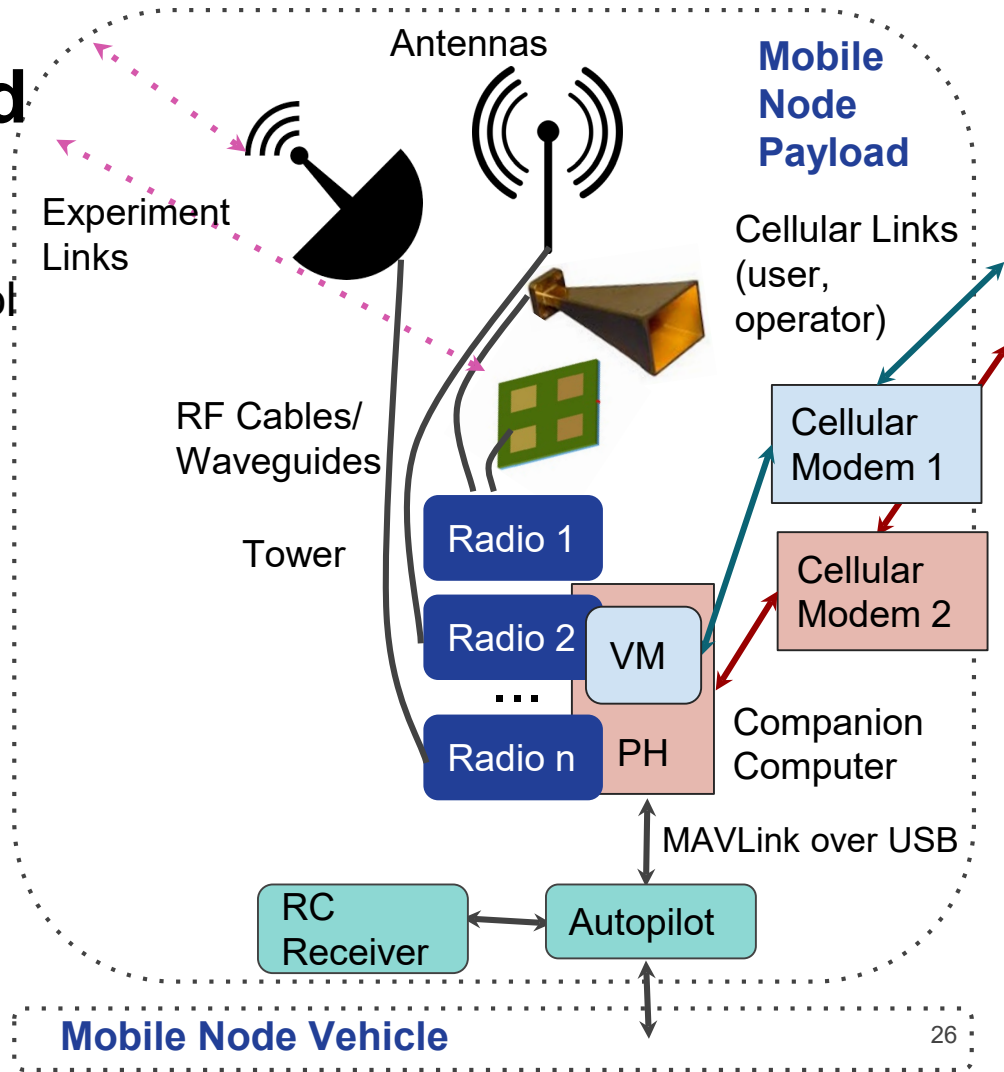
Mobile Nodes Payload

- 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



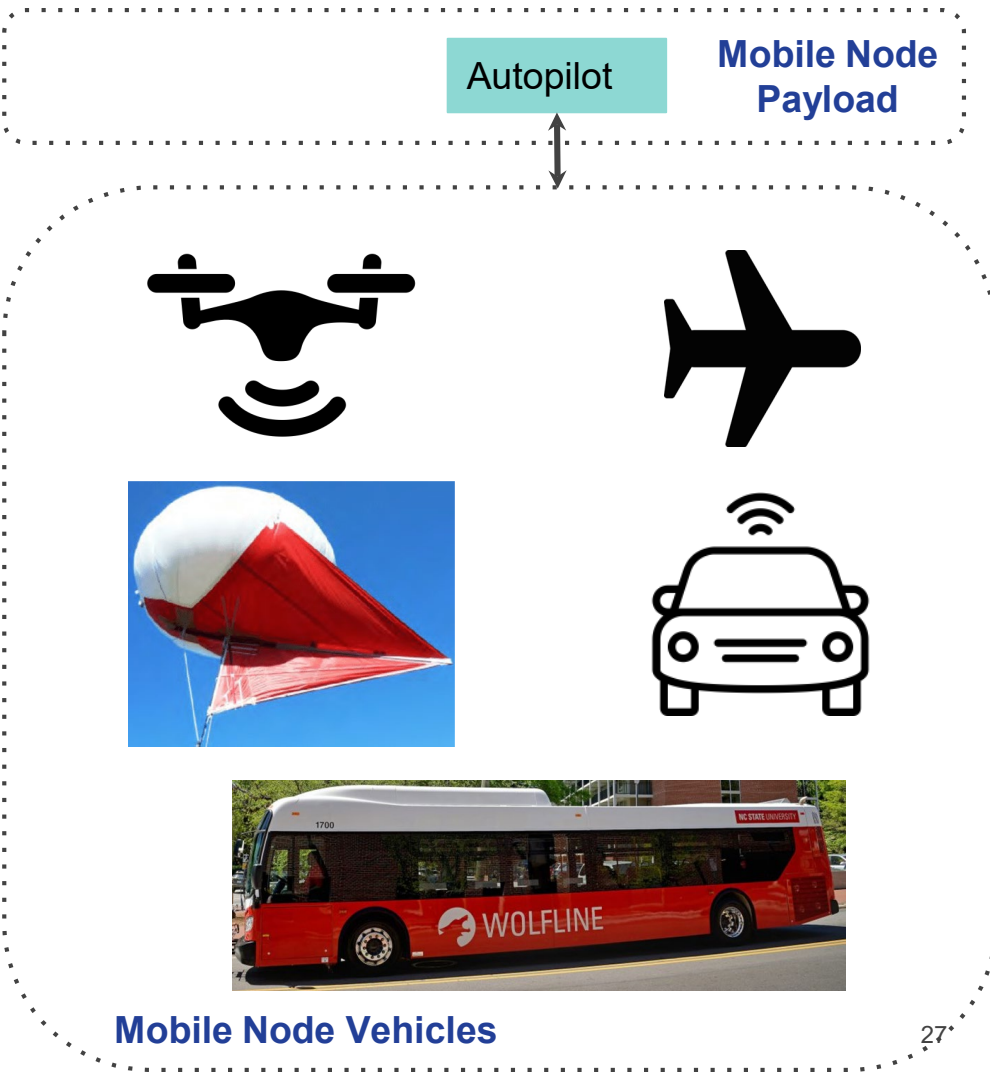
Mobile Nodes Payload

- 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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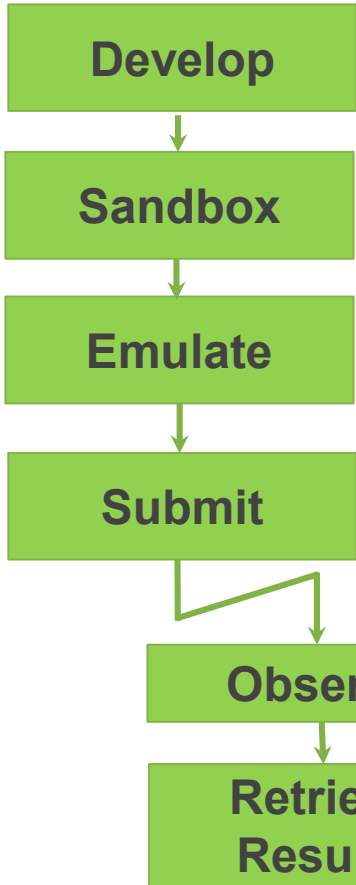

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Experiment Preparation to Execution




Experimenter




Development VMs
(Ground and Aerial node images)  \$

Sandbox VMs
(real radio, real drones minus props) – indoor facility  \$

Emulation VMs (emulated radio, emulated drones, real code)  \$



Operator

Testbed
(real everything)  \$\$\$\$

Specify nodes, desired mapping, equip with AERPAW software tools and drivers, program

Test with **real drivers**, **actual hardware** (tutorial and sanity)

Test with real drivers, realistic **hardware emulation** (AERPAW safety check)

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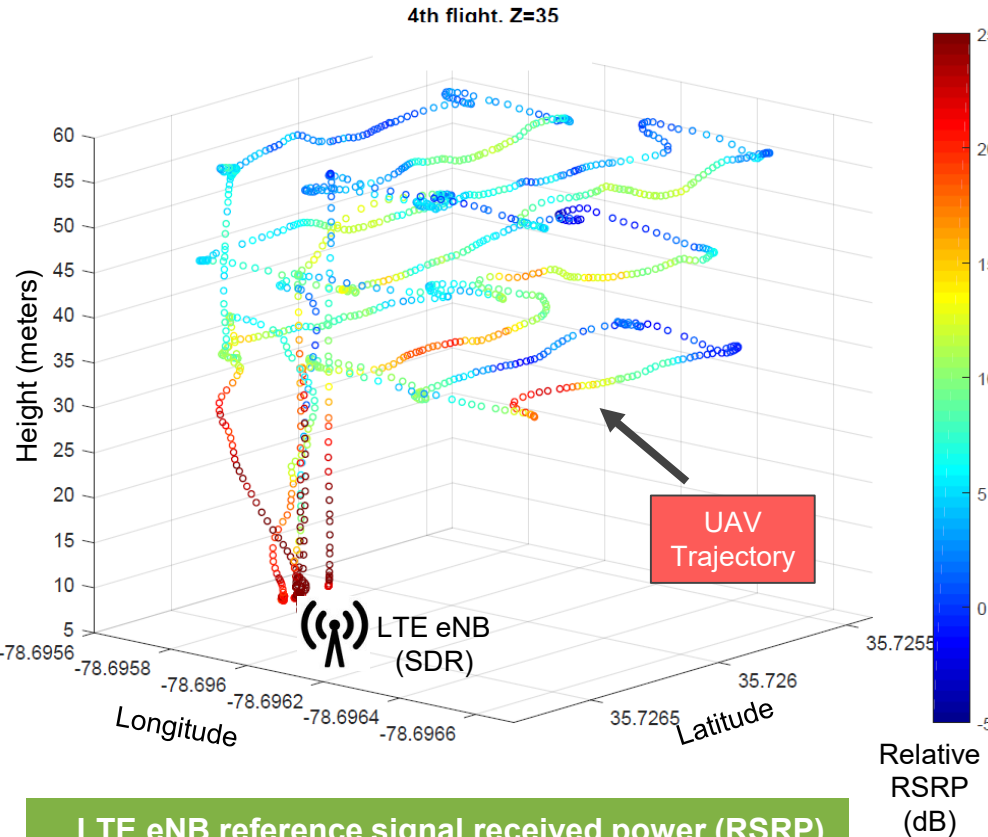


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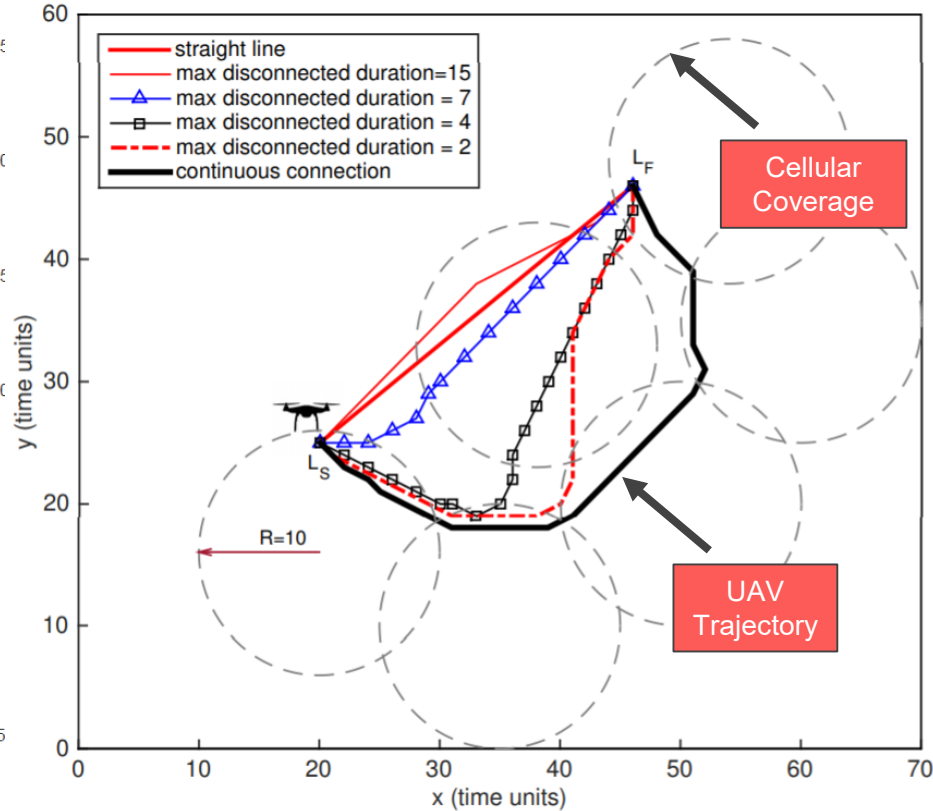




AERPAW Short & Long Term Research Examples



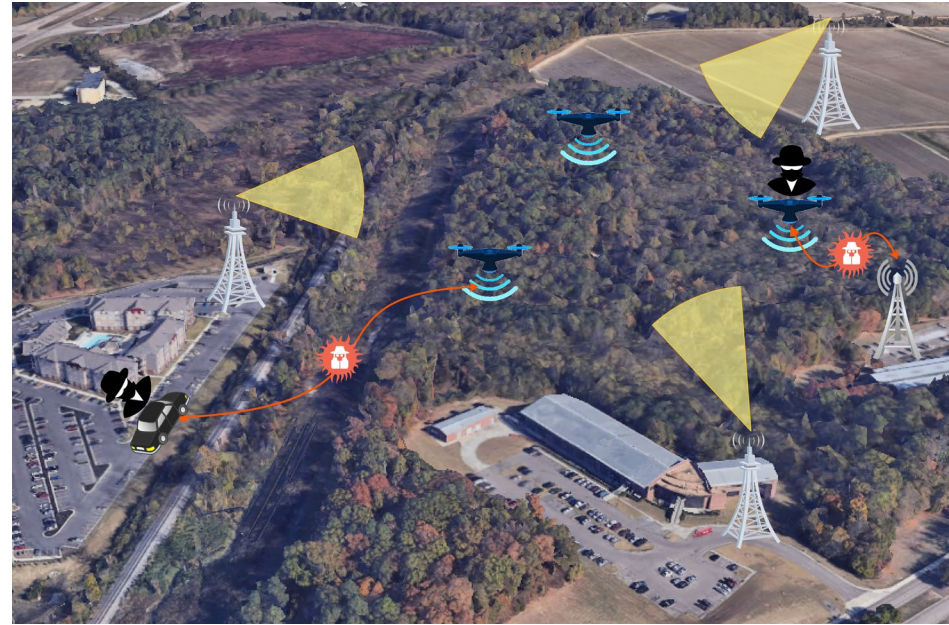
LTE eNB reference signal received power (RSRP) measurements at UAS [Sichitiu/Guvenc, 2019]



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 State/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
- ...

vuk.marojevic@msstate.edu

aerpaw-contact@ncsu.edu