PAWR Project Office

# Platforms for Advanced Wireless Research

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*https://www.advancedwireless.org/*

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# Today's Agenda

- PAWR Approach
- PAWR Awardees
  - COSMOS (http://cosmos-lab.org)
  - POWDER-RENEW (http://powderwireless.net)
- Technical Details
- Deployment Plan
- What's in it for You ?
- Looking Ahead
- Questions

# Platforms for Advanced Wireless Research

**Kick-Off April 2017**

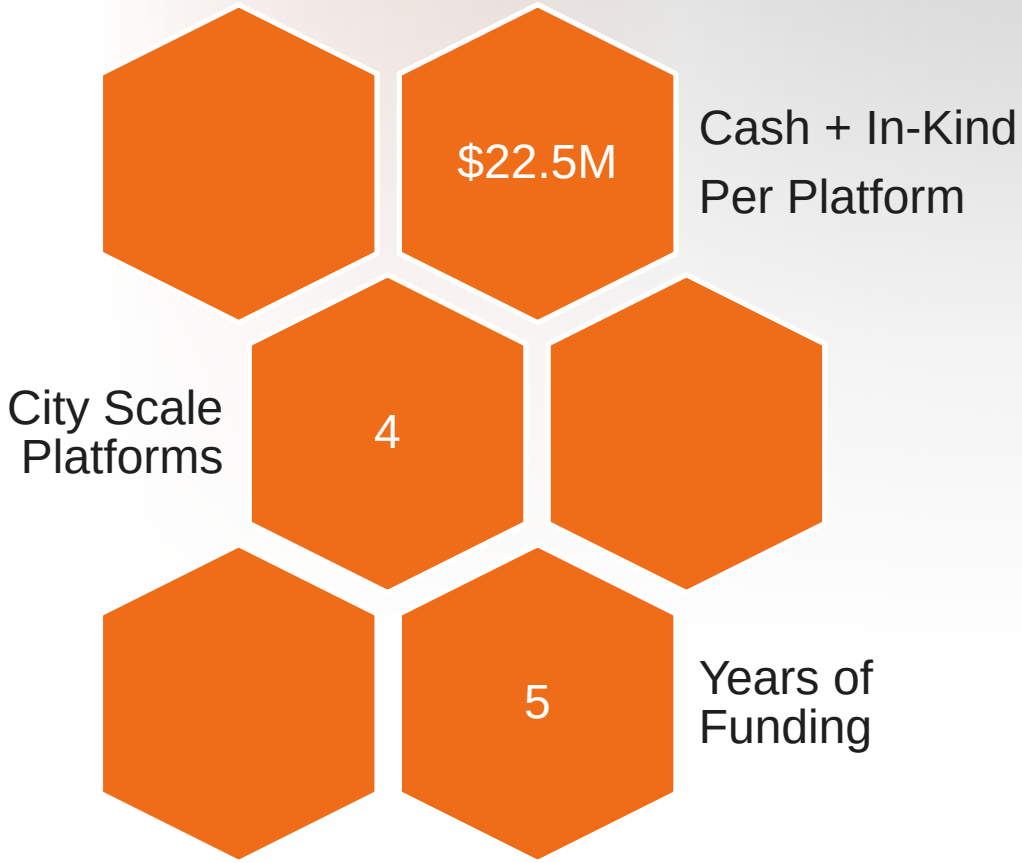

**Industry Consortium**
**<$ + In-Kind>**
**$50M**

**NSF**
**<$>**
**$50M**

# Level-Setting: PAWR Approach

| Attribute | Approach |
| --- | --- |
| Problem Definition | Enhanced efforts of ~400 university researchers who need mid-scale testing capabilities to ensure success |
| Early Industry Involvement | Multi-use research platforms with “pre-competitive” research topic areas selected bottom-up by university PIs, with industry input |
| Research Scope | Mid-sized areas within cities, experimental platforms, 10-20 antenna sites, backhaul, SDRs |
| Flexibility and Speed | 1 - 2 platforms per year in years 1 and 2 |
| Streamlined governance, deployment, and operation | One governance consortium focused on upfront research and policy; city/university teams propose how to streamline deployment and ops |

# Program Figures



# Charter Members


**PPO is Looking for more Industry Partners….**

# PAWR Guiding Principles

# Mapping System Elements to a Changing Landscape

- Programmable Wireless (RF, Baseband) Substrate
- Wireless and/or Transport X-Haul
- Software configurable edge infrastructure
- Modular Hardware; extensible; BYOD
- White-Box and Black-Box User Equipment

* Functional Disaggregation

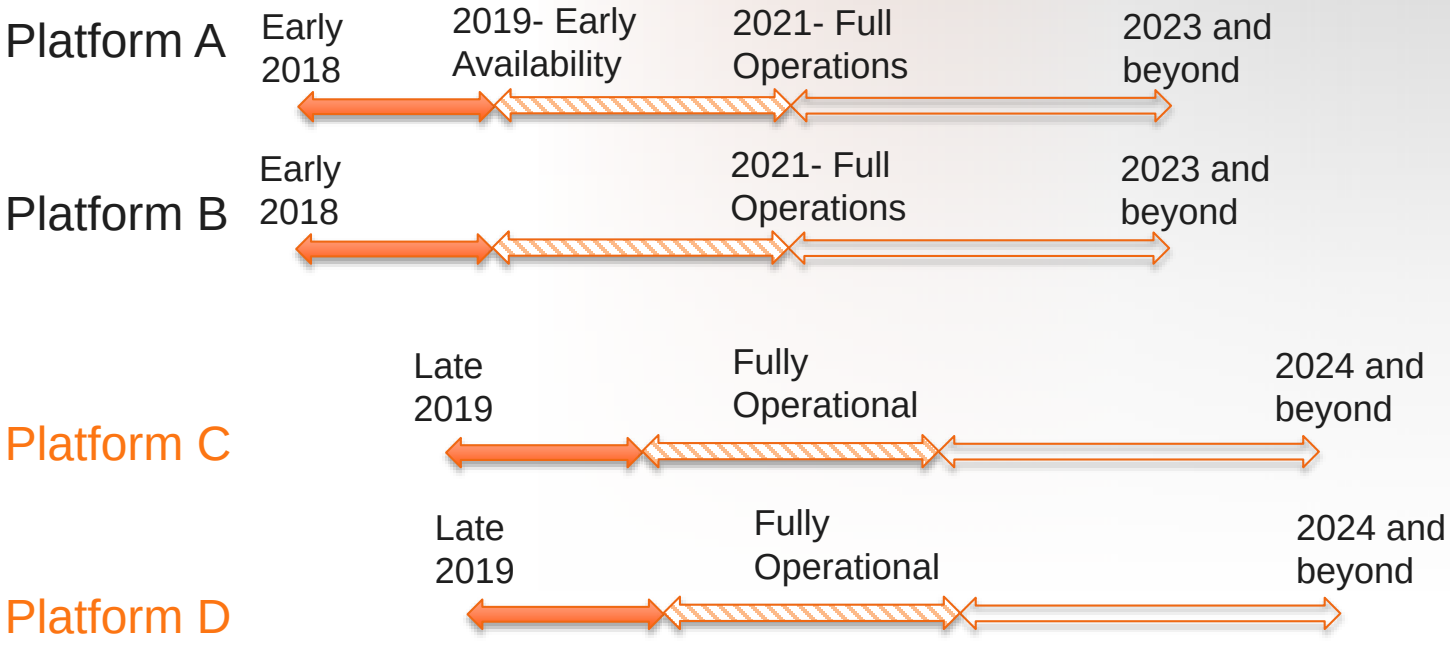
* Move Processing closer to the edge

* SDN+NFV to accelerate service deployment

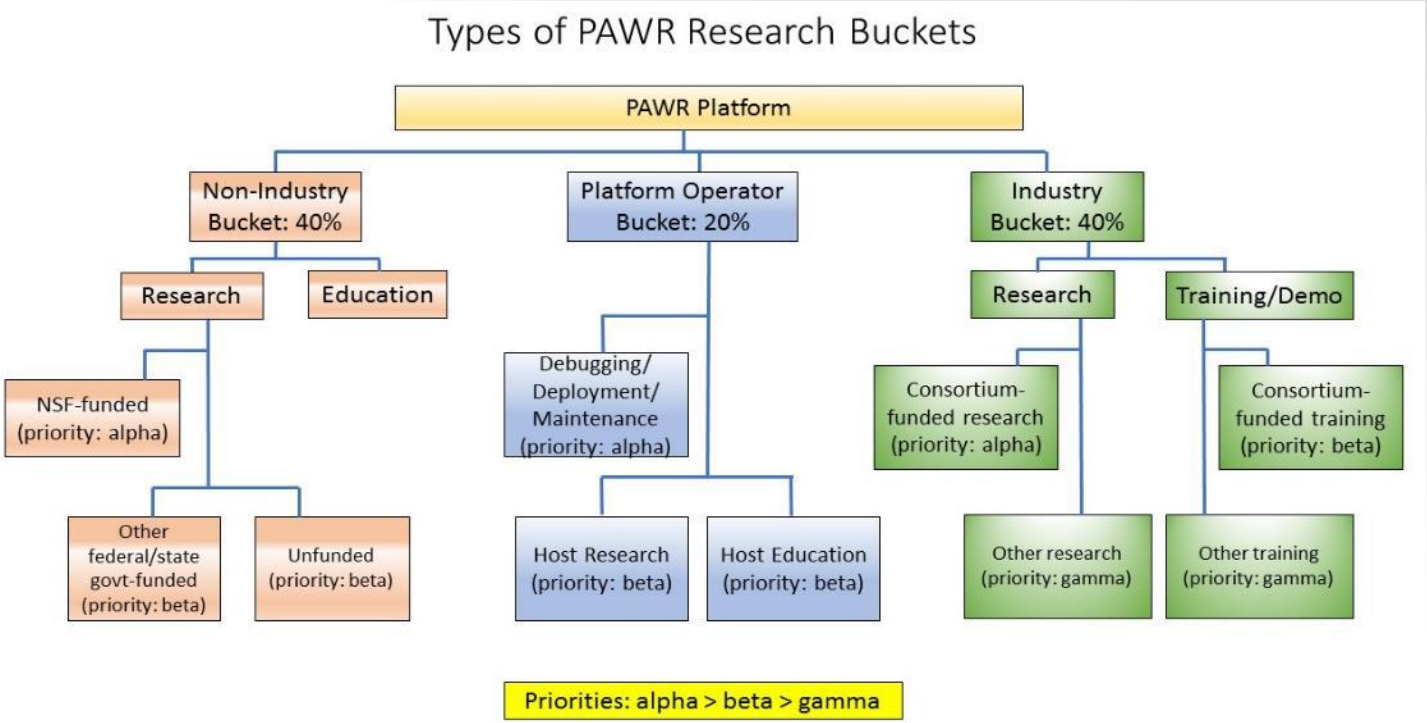
* Bringing Services closer to the user

* Devops + Closed Loop Network Automation

# Platform(s) Go-Live Timeline



# Time on Platforms



# PAWR Awardees

**Announced April 9 2018**

## Round I Platforms

Salt Lake City

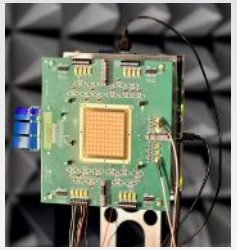
New York City

http://powderwireless.net

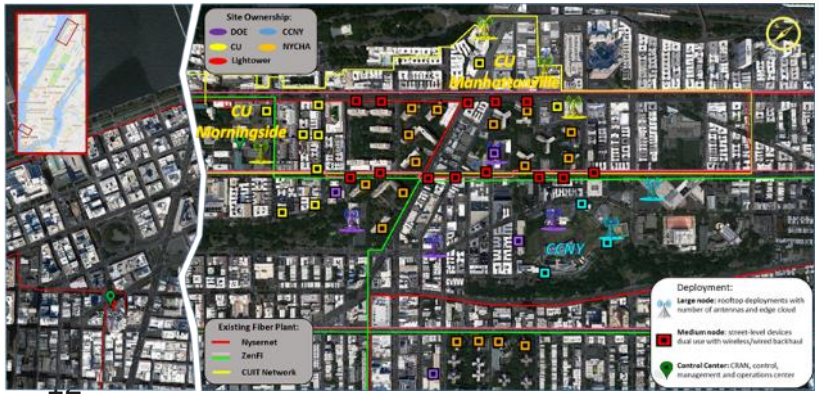
http://cosmos-lab.org

# COSMOS:Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment

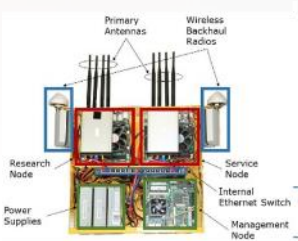
- A multi-layered computing system with an RF thin client; flexible signal processing; network function virtualization (NFV) between a local SDR (with FPGA assist) and a remote cloud radio access network (CRAN) with massive CPU/GPU and FPGA assist
- Deployed in New York City, one of the country's most populated urban centers
- Wideband radio signal processing (with bandwidths of ~500 MHz or more)
- Support for mmWave communication (28 and 60 GHz)
- Optical switching technology (~1µs) provides passive WDM switch fabrics and
- radio over fiber interfaces for ultra-low latency connections



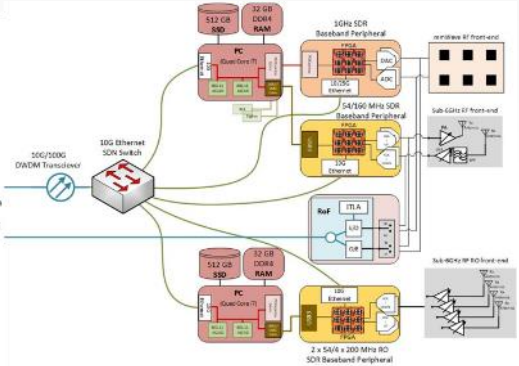
28GHz phased-array ICs and phased-array antenna modules (PAAM)




Deployment Area: West Manhattan/Harlem



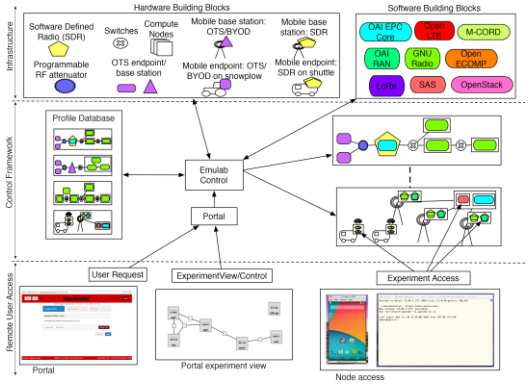

COSMOS Radio Site Design




All-Optical Network Design

# POWDER: Platform for Open Wireless Data-driven Experimental Research

- Next Generation Wireless Architecture
- Dynamic Spectrum Sharing
- Distinct environments: a dense urban downtown and a hilly campus environment.

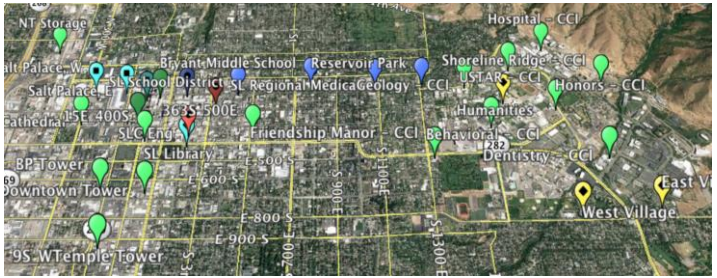


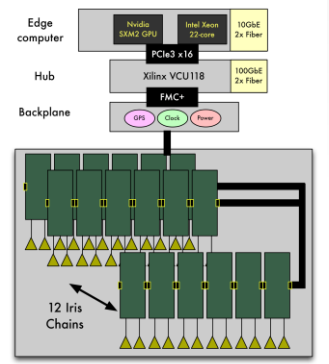

Control Framework with Hardware + Software Building Blocks

# RENEW: A Reconfigurable Eco-system for Next-generation End-to-end Wireless

- RENEW Massive MIMO base station
- End-to-End Programmable
- Diverse Spectrum Access 50 MHz-3.8GHz
- Hybrid Edge computer composed of FPGA and GPU/CPU-based processing,
- Hub Board aggregates/distributes streams of radio samples

Deployment Area: UofU Campus +Downtown SLC + Connected Corridor



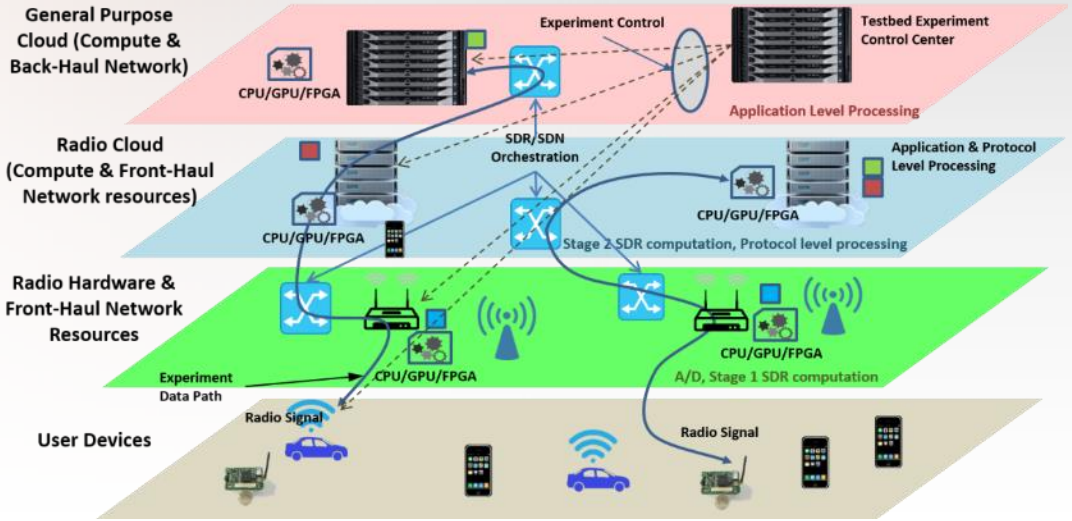

Architectural view of RENEW base station

IRIS software-defined radio modules

# System Architecture

COSMOS

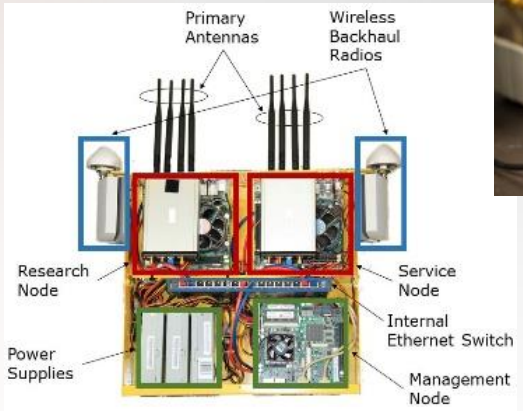
- Developed a fully programmable multi-layered (i.e. radio, network and cloud) system architecture for flexible experimentation
- COSMOS architecture has been developed to realize ultra-high BW, low latency and tightly coupled edge computing
- Key design challenge: Gbps performance + full programmability at the radio level



# Key Technologies - SDR

COSMOS

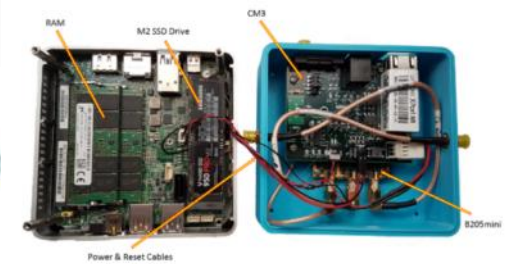
- All-software solution adopted for radio technology
- Advanced SDR Radio Nodes at various performance levels and form factors
- Design goal: 400 Mhz – 6 Ghz + 28 Ghz and 60 Ghz bands, ~500 Mhz BW, Gbps
- Signal processing can be spread between radio node & edge cloud RAN




WINLAB SDR circa 2010

Mobile SDR Node (Small)

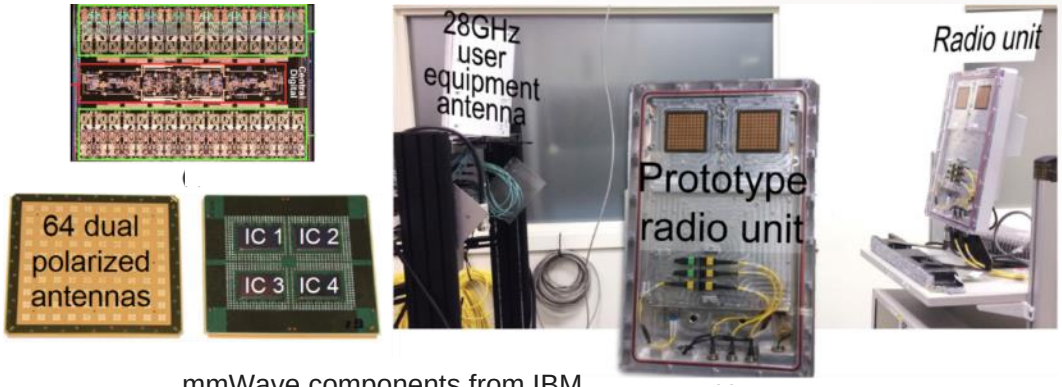
Prototype COSMOS SDR Node (Medium)



# Key Technologies -mmWave

COSMOS

- mmWave a key new technology for the testbed, with limited availability of components
- Leveraging ongoing CU collaboration with IBM to provide mmWave phased arrays (64 antennas, 8 beams) for both 28 Ghz and 60 Ghz
- Extensive mmWave systems expertise at NYU, including prototype systems and channel measurements




mmWave components from IBM

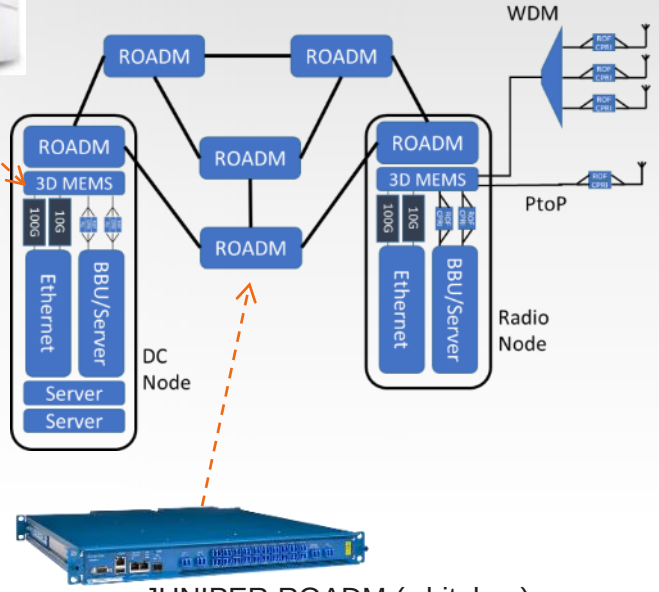
NYU Channel Measurements

# Key Technologies – Optical Net

COSMOS

- Fast and low latency optical x-haul network using 3D MEMS switch and WDM ROADM
  - Configure wide range of topologies
  - Experiment on converged fiber/wireless networks
- Enables fast front-haul/mid-haul/back-haul connectivity between radio nodes and edge cloud
- SDN control plane for both optical and Ethernet switching
- Leverages results from CIAN NSF ERC, EAGER dark fiber project at Columbia

Calient MEMS Switch




JUNIPER ROADM (whitebox)

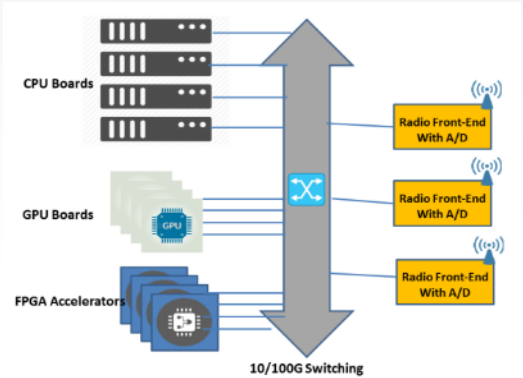
CIAN

# Key Technologies – SDN & Cloud

COSMOS

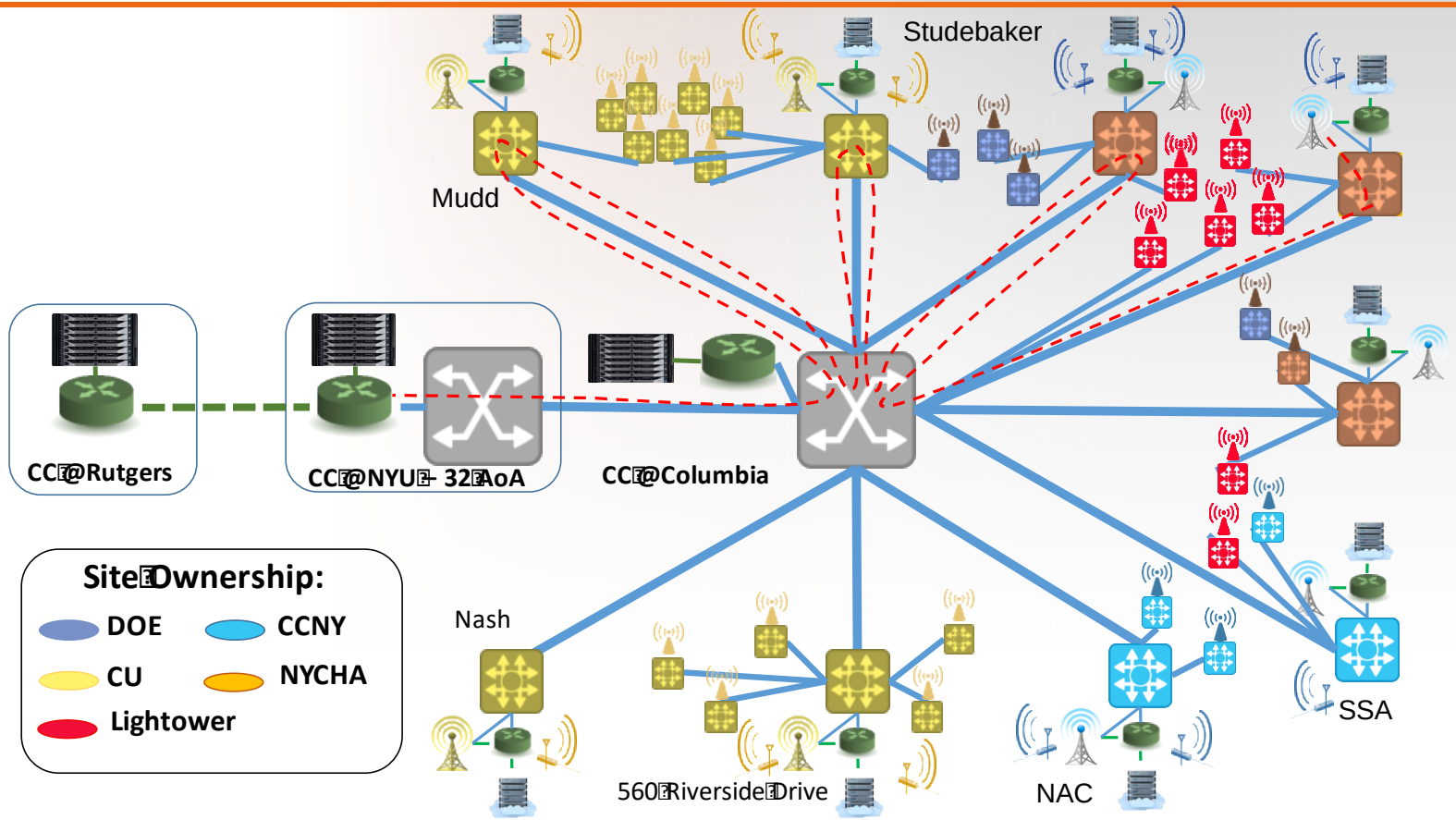
- SDN control plane used to control x-haul and cloud server connectivity
- Open Network Operating System (ONOS) with radio API extensions
- Compute clusters collocated with radio nodes (M,L) with choice of CPU, GPU and FPGA accelerators
- Also, users have access to regular cloud racks for L3→ applications (GENI & NSF-Cloud federated clusters)

SDN Switching Rack




COSMOS Deployment Map
Morningside Heights
Manhattanvil
Site Ownership:
DOE
CU
Lightower
CCNY
NYCHA
Existing Fiber Plant:
Nysernet
ZenFi
CUIT Network
Deployment:
Large node: rooftop deployments with number of antennas and edge cloud
Medium node: street-level devices dual use with wireless/wired backhaul
Control Center: CRAN, control, management and operations center

# Planned Deployment




City scale living lab, for novices through experts, to enable repeatable research and fundamental advances in wireless technologies, services and applications

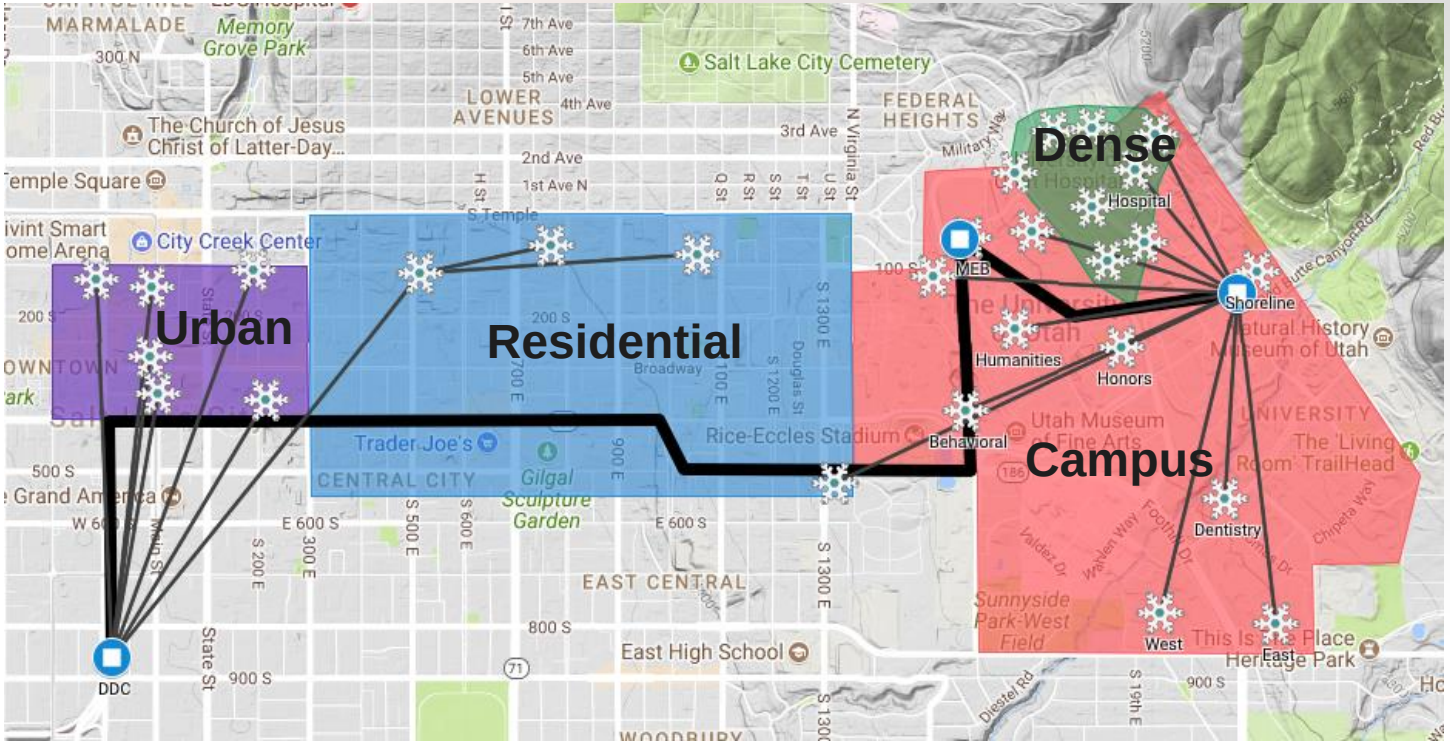
# Accelerating “World’s Firsts”

**GOAL: Enable unforeseen community-driven “world’s firsts”**

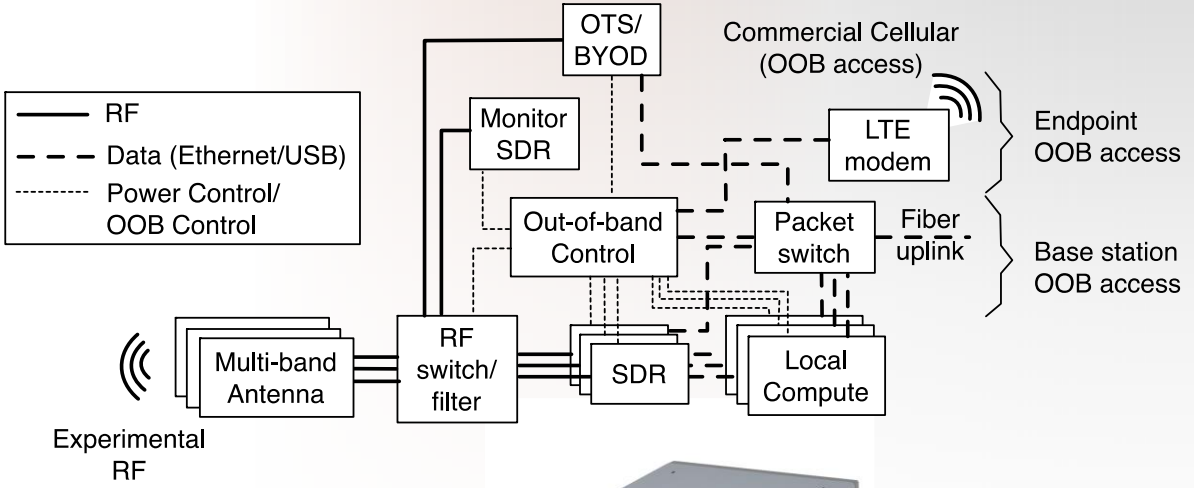
- World’s first fully programmable & observable Massive MIMO network platform
- Base-station class 3.5GHz (key 5G band), low-latency design
- Capable of 50MHz – 3.8GHz

- World’s first open-access complete networks stacks
- Support cellular and WiFi standards as baseline
- Foster next-generation ideas
- Support end-to-end applications

# Geographical Coverage

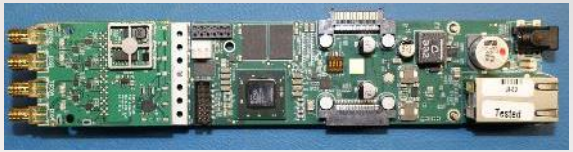


# Off-the-shelf RF equipment

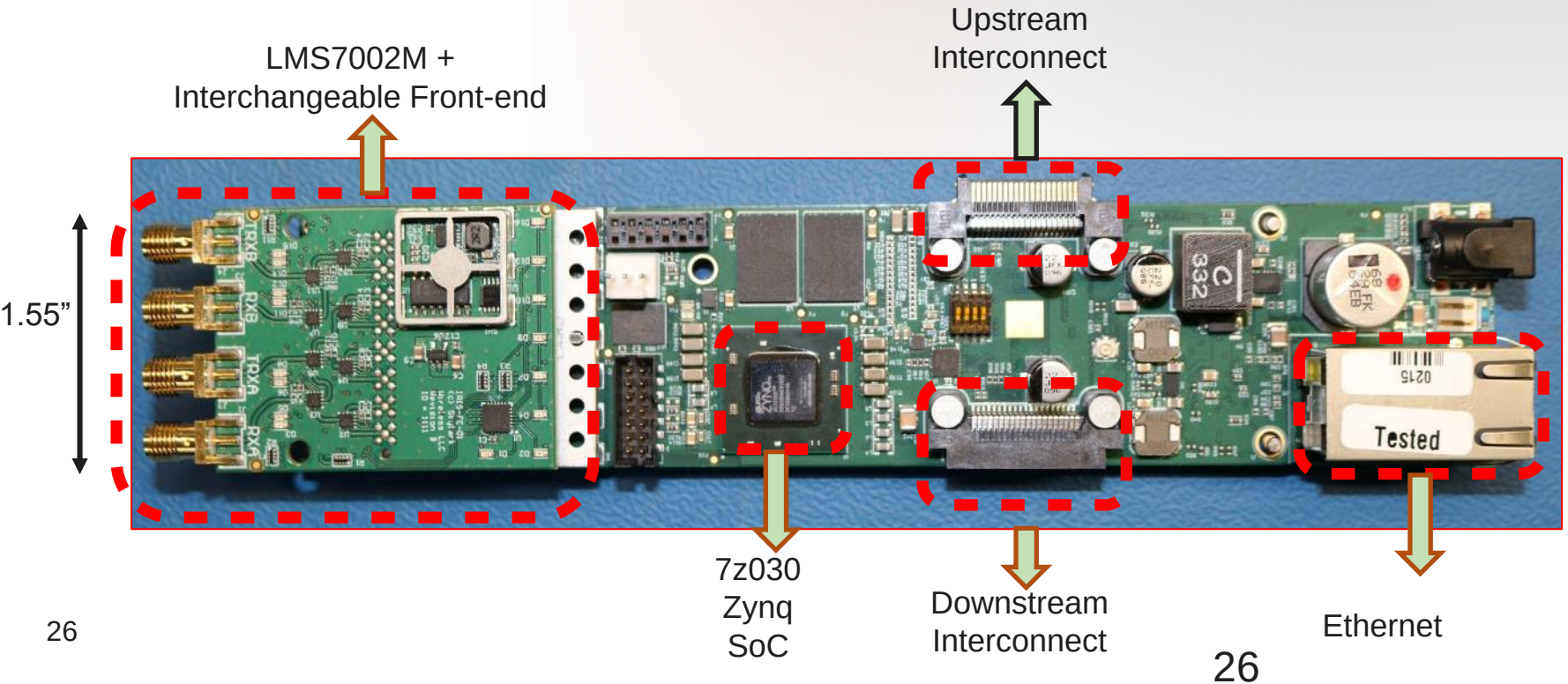



# RENEW Massive-MIMO Base Stations

- Iris SDR is the building block
- 64-128 antenna configs
  - Next gen design targets 256-antennas
- 40 Gbps Ethernet backhaul through fiber
  - Next gen design targets 100Gbps link
- HW Built-in Clock Sync
  - Support for SyncE/PTP underway
- Software initiated triggers for time synchronization



# Building Block: Skylark Iris Module



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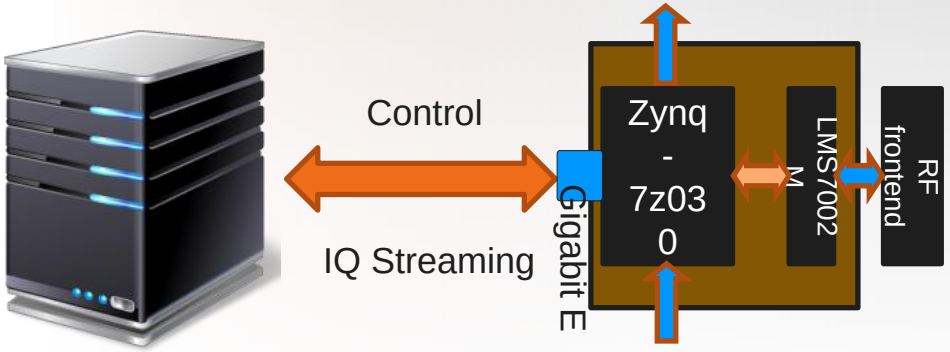
# Software Flow: GPP-Centric Model




- Iris supports IQ streaming to PC for host-processing style applications
  - Similar to other existing platforms such as USRP.
- It can still do processing in the FPGA for latency-sensitive operations



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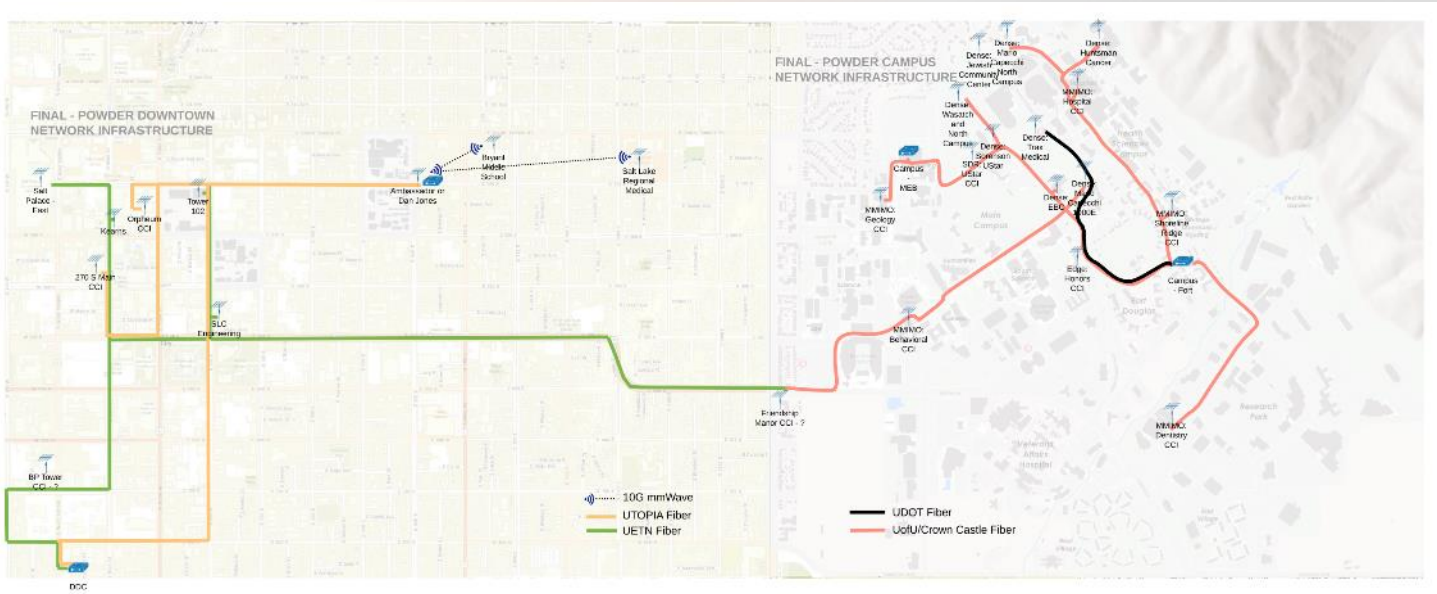
# Backhaul Network and Near Edge




- 100 Gbps private Metro Scale Fiber network
- Synchronous Ethernet (SyncE), Precision Time Protocol (PTP) for full path support
- Embedded Router Synchronization

# Spectrum

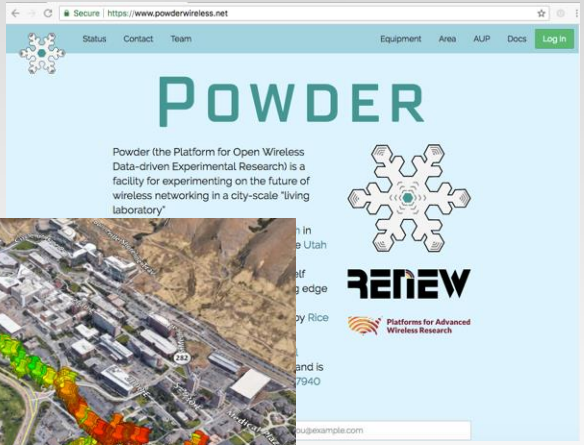
| Range (MHz) | |
|---|---|
| 698-806 | Commercial/Public Safety |
| 902-928 | Industrial, scientific and medical (ISM) |
| 1710-1755 | Extended Advanced Wireless Services (EAWS) uplink |
| 2110-2155 | Extended Advanced Wireless Services (EAWS) downlink |
| 3550-3650 | Citizens Broadband Service |
| 5150-5925 | Unlicensed National Information Infrastructure (U-NII) |

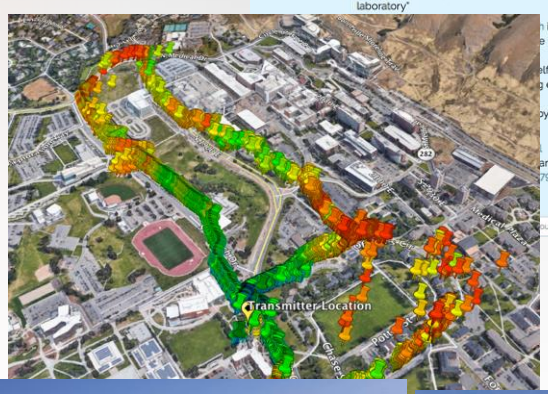
- Broad range of frequencies
- Program license/Innovation zone
- Dynamic spectrum access system: federated wireless

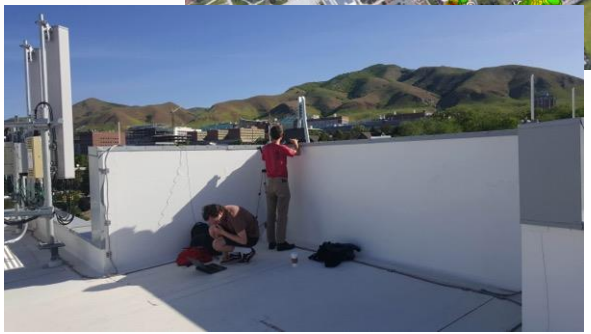
# Status

**powderwireless.net**

- Technology preview available:
  - Small number of SDR nodes with OAI profile
  - Try out POWDER portal/workflow
  - Looking for feedback…
- More information
  - Technology/timeline/team
- Busy with site surveys/RF measurements



# What’s in it for You?

| | |
|---|---|
| Research at-scale | Using Highly instrumented end-to-end Platforms to explore wireless, edge and cloud research topics independently or together |
| Industry Opportunity | Critical gap between demand pattern and supply; move away from legacy infrastructure; rapid development, inter-operability |
| International Scope | Federation between US,EU,Asia platforms, shared learning, data and operational best practices |

# Looking Ahead: Shift in Focus

**Applications drive Technical Requirements**

- Open-ended for emerging and frontier ideas; focus on what is new and cutting-edge
- Partner with Industry Vertical Experts to explore state of the what and the how;
- Provide solutions and specifications as well as relevant trade-offs and implications;
- Looking for various possible solutions to particular challenges

# Round II RFP


Research Community
Industry Partners
Round I Respondees
May 2018
RFP July 2018
Round II Award
Q3 2019

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