The Critical Role of Measurements and Reliable Datasets for Building a Robust 6G

Nada Golmie

NIST | COMMUNICATIONS TECHNOLOGY LABORATORY

Communications Technology Laboratory @ NIST

Multidisciplinary R&D

Test and Evaluations

Traceable Measurements

Validated, Reproducible Data

Trusted Neutral Partner

Standards Development

Facilities and Testbeds

Precision Instrumentation

Public Safety and Mission Critical Communications

Requirements and Solutions

Metrology Span: Chip-scale devices to national-scale communications systems

Enabling secure, interoperable, and forward-looking Next G communications systems.

NIST COMMUNICATIONS TECHNOLOGY LABORATORY

Building a Robust 6G

Drivers

Resilient 6G

-> Robust, adaptive, and efficient systems

High Demands

-> High-bandwidth, ubiquitous, and smart

Measurements Needed:
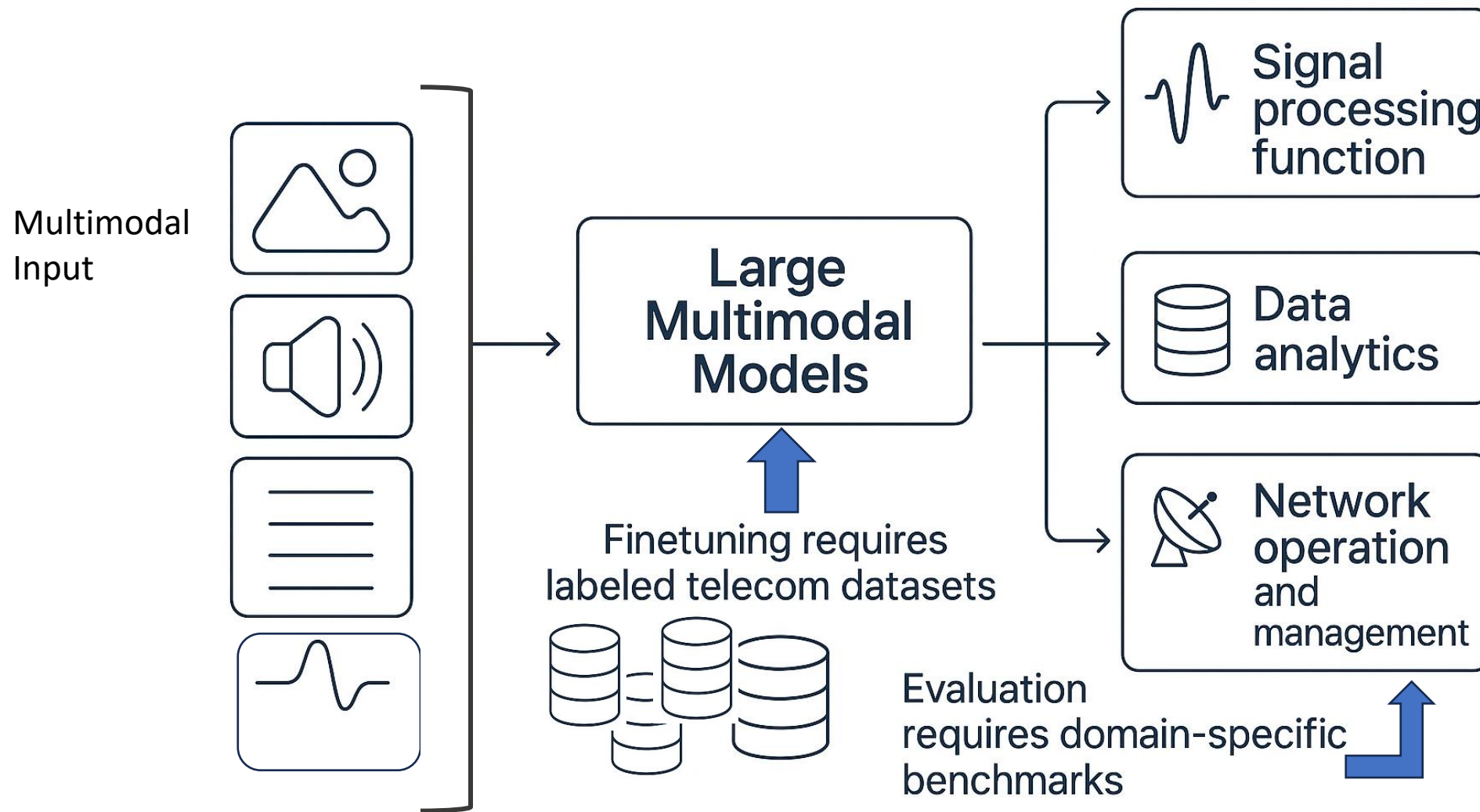
✓ Ground-truth for modeling diverse environments

✓ Basis for optimization and standardization

✓ Accelerate the use of AI/ML

✓ Ensure reproducibility and benchmarking

Example Highlight:

NIST Measurements and Modeling for 6G Standard Development
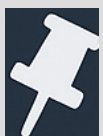
Enabling Wireless Intelligence

The need for multimodal datasets

State of Wireless Communications Curated Datasets

- Lack of standards
- Annotation and labeling issues
- Limited public access
- High dimensionality
- Privacy and regulatory concerns
- Environment and hardware variability

Key Desired Features for Telecom Datasets

NIST

High fidelity and realism

Multimodal and multi-layered

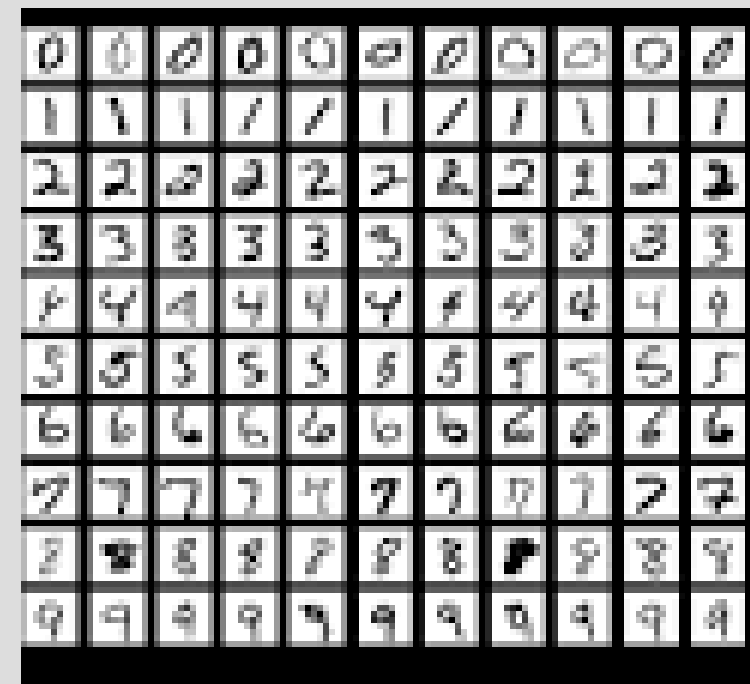Spatiotemporal ground truth

Labeling and annotation

Diversity and coverage

Reproducibility and traceability

Standardized formats and metadata

Scalability and size

Compliance and anonymization

The MNIST dataset published in 1990 is a widely used benchmark dataset in computer vision and machine learning, specifically for image classification.

CURATED CHANNEL PROPAGATION DATASETS

NextG Channel Model Alliance

- Established user community for the development of wireless signal propagation measurements and modeling.

- Serve as a focal point for consumers and producers of channel propagation measurements and data.

- Develop curated channel propagation measurement datasets.

- Disseminate measurements and models through an online repository
  https://nextg.nist.gov/

- Monthly seminars and sponsored workshops and panels.

- Over 300 participants representing over 180 organizations.

Industry (35%)
35%
20%
Government (20%)
45%
Academia (45%)
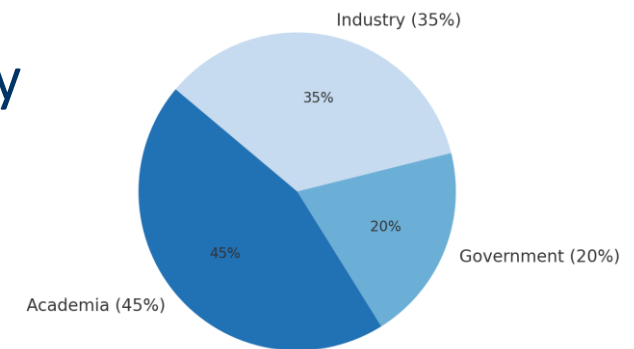
NextG Channel Model Alliance
Participant Breakdown

How to join: Email Nada Golmie (nada.golmie@nist.gov) and Marc Leh (mleh@corneralliance.com) to get started.

Wireless Measurement and Modeling R&D @ NIST
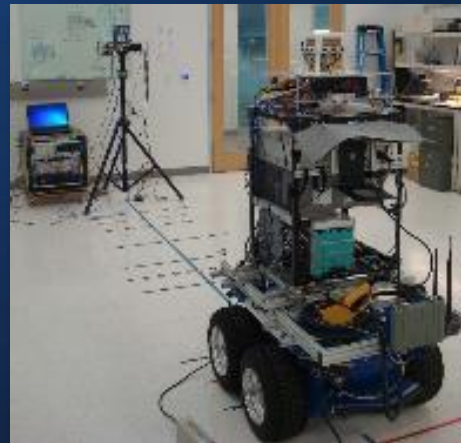

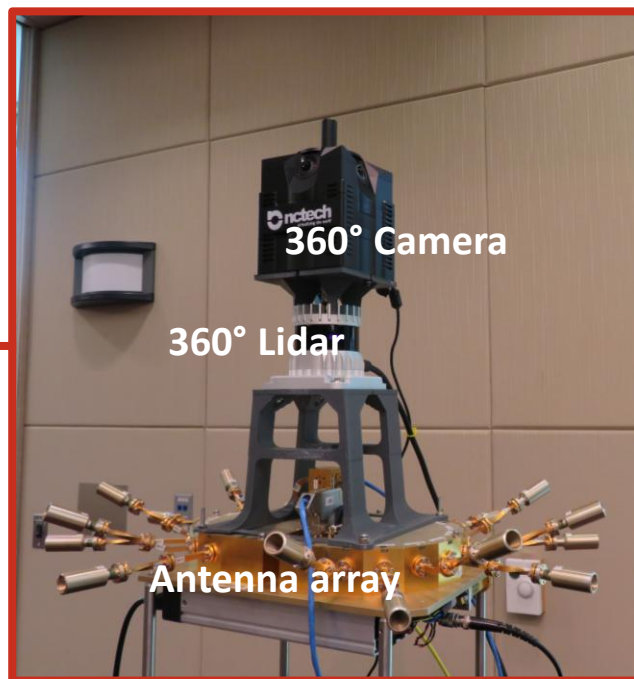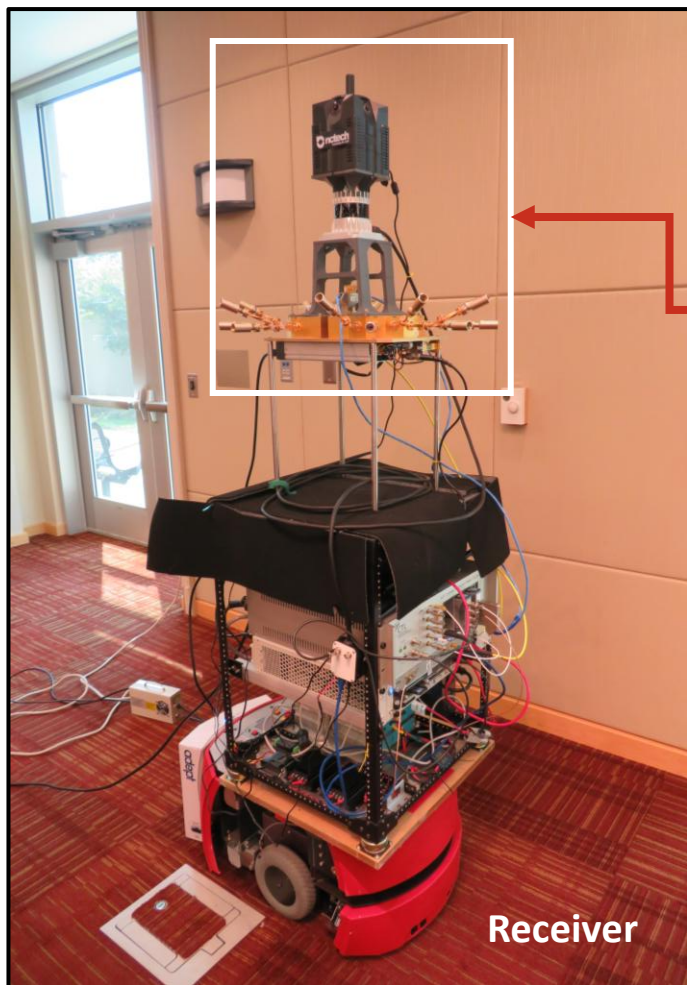Measurement and Instrumentation

Modeling Abstractions

Partnership, Collaboration, Standard Development
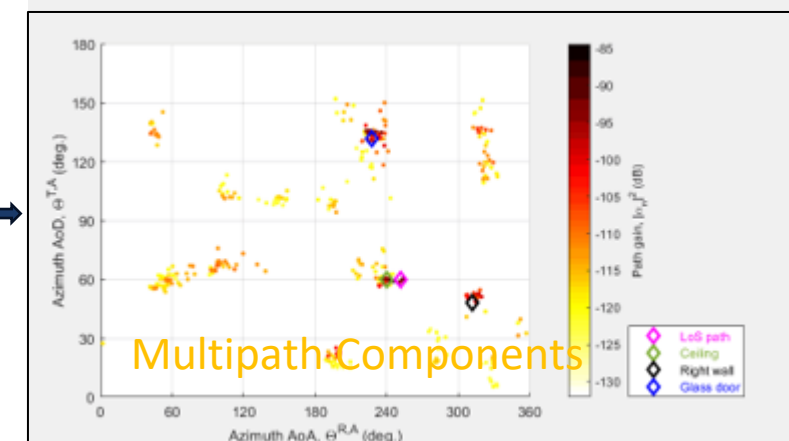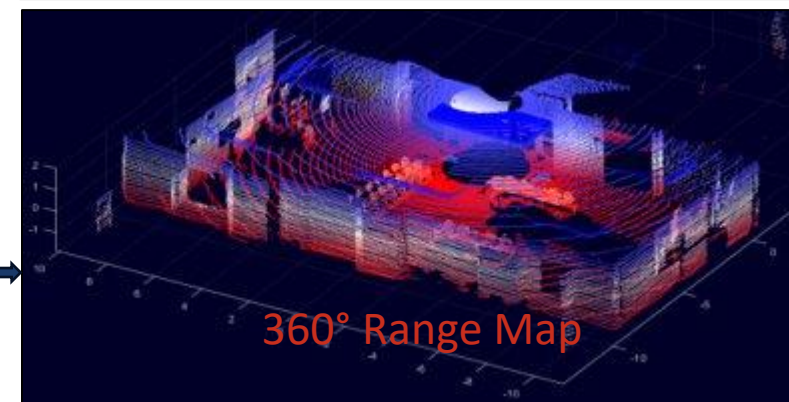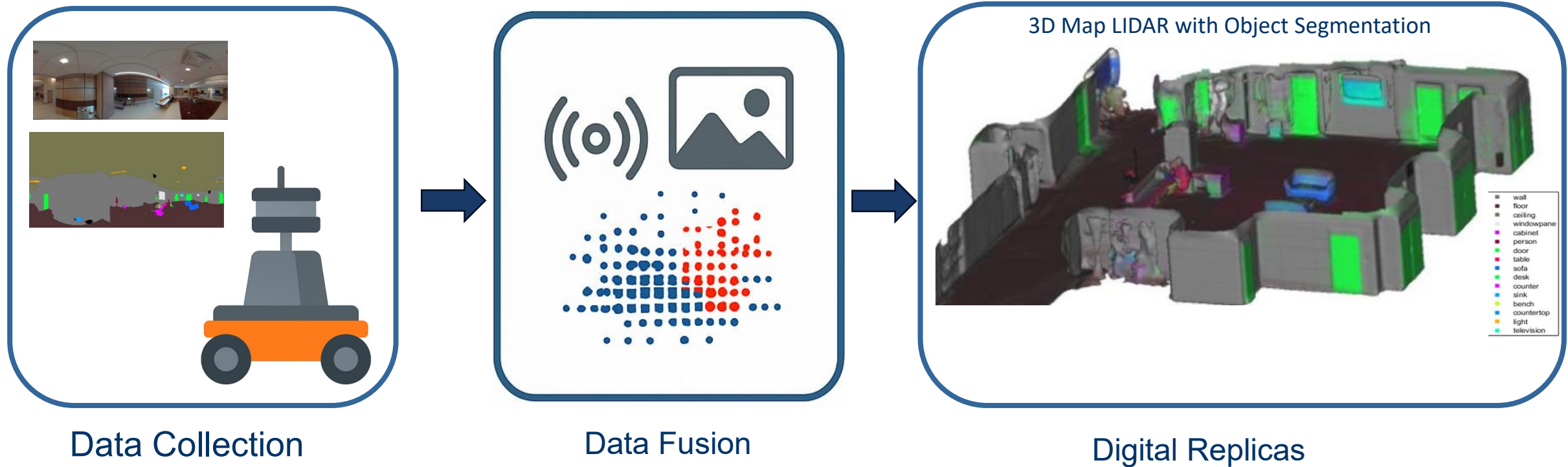

Dataset Dissemination

Context-Aware Channel Sounding

360° Image

360° Range Map

Multipath Components

Receiver

Receiver Data Collection:
- 360° Image (Camera)
- 360° Range Map (LIDAR)
- RF Data (Antenna array)

360° Camera

360° Lidar

Antenna array

Multimodal Data Fusion for Digital Replicas

Data Collection

Data Fusion

3D Map LIDAR with Object Segmentation

Digital Replicas

A. Bodi, S. Berweger, R. Caromi, J. Bang, J. Senic, C. Gentile "AI-Based Environment Segmentation Using a Context-Aware Channel Sounder," European Conference on Antennas and Propagation (EuCAP 2024).

RF Measurements for Sensing Targets

Gesture

Walking

Vitals Sensor

Humans

Vehicles

L = 1.1 m

W_arm = 0.85 m

W = 1.2 m
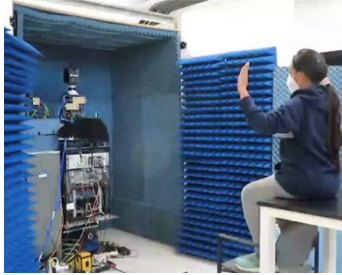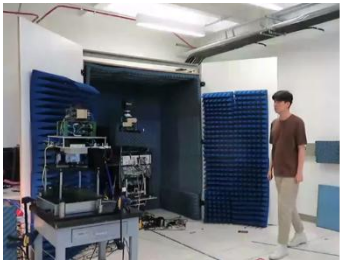
Robotic Arm
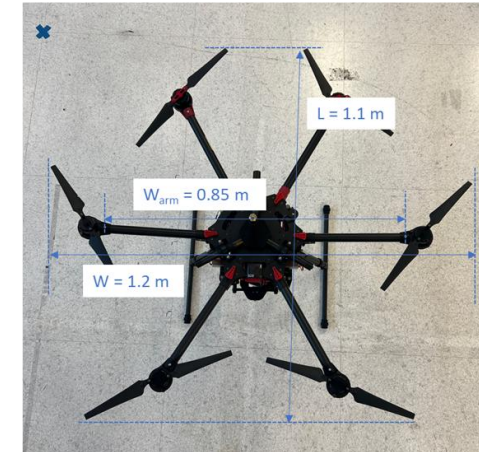
Drone

Automatic Mobile Robot (AMR)

C. Gentile, J. Chuang, S. Blandino, J. Senic, J. Bang and S. Berweger, "Measuring the RCS of Multipoint-Scattering Targets in JCAS Channel Sounding," 2025 19th European Conference on Antennas and Propagation (EuCAP)
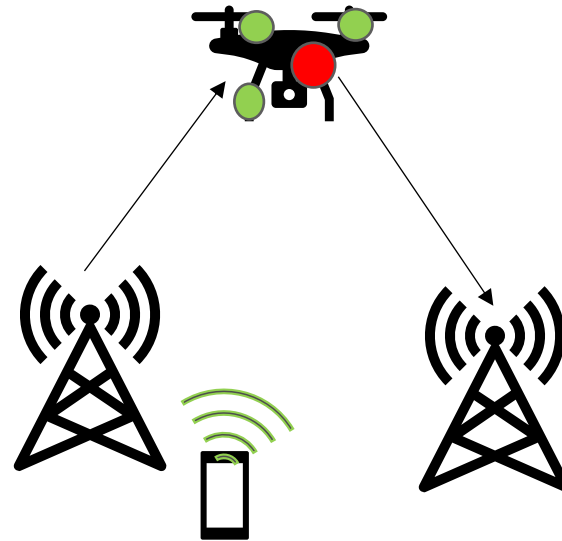
Target Modeling: Varying Complexity Levels

Target Detection:
Single Ray Model
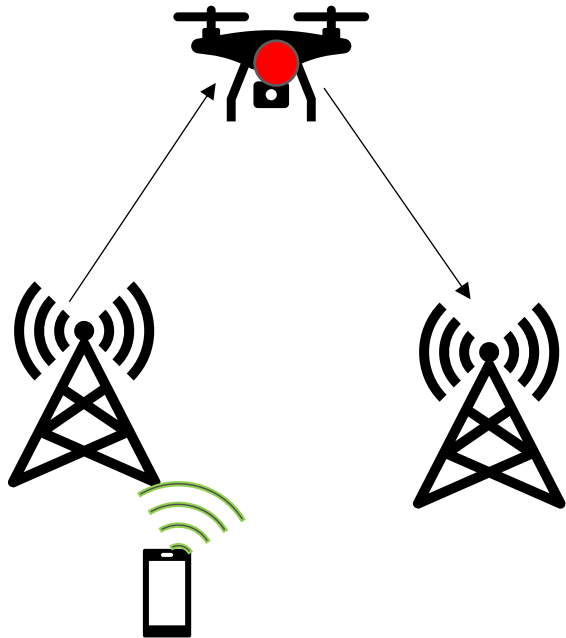
Target Classification:
Stochastic Cluster Target Model

Target Motion:
Quasi-deterministic Cluster Model

Intruder detection

UAV/AGV detection
Immersive experience
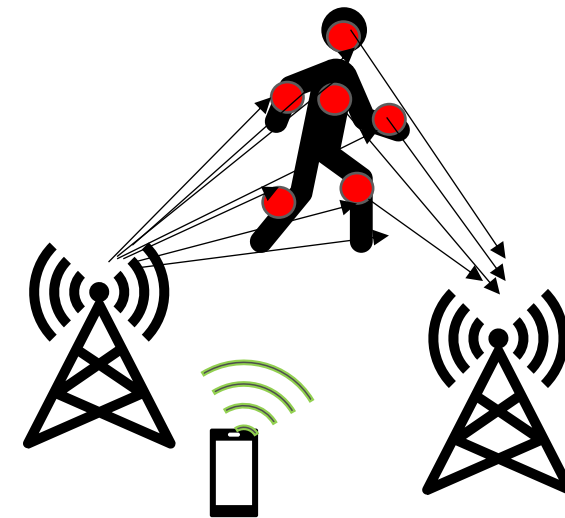
Gesture recognition
Sports monitoring
Public safety search and rescue

Advancing Standards for Integrated Sensing and Communications

NIST

IEEE 802.11bf (Wi-Fi Sensing)

Contributed measurements to the development of a channel model and to MAC/PHY enhancements.
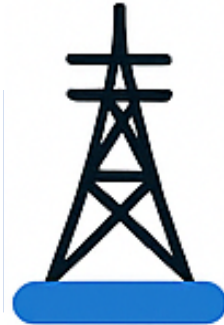
ATIS Next G Alliance (NGA)

Partnered with NGA members to provide channel measurements and modeling techniques for integrated sensing and communications.

3GPP 6G Standardization

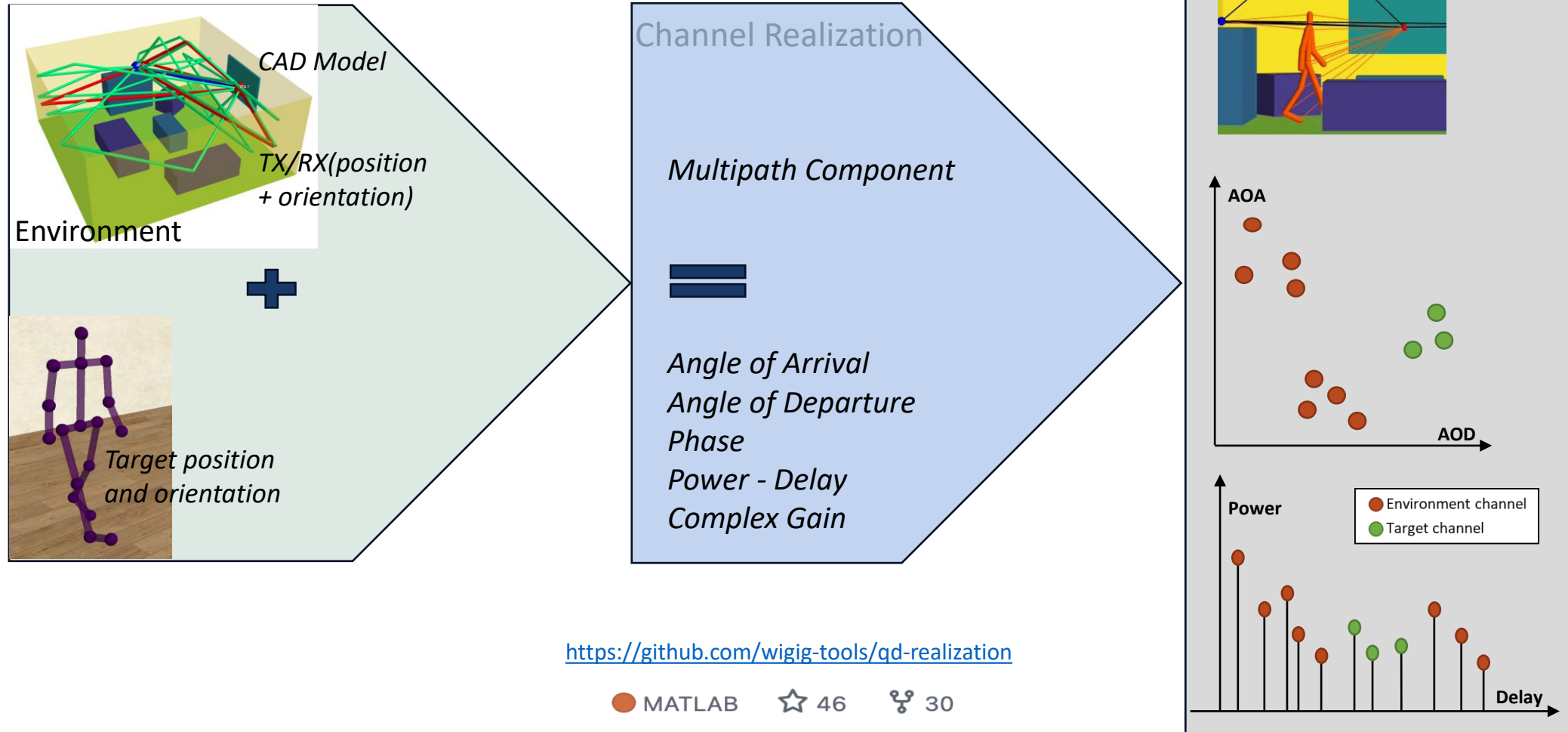Delivered measurement-based findings to 3GPP RAN1 and contributed to the development of channel models for sensing

Real-world channel measurements to accelerate wireless standard development

Modeling Abstractions: Tools and Open-Source Code

RF Measurements

nextg.nist.gov

Measurement to Model Abstraction

System-level (ns-3)

PHY + Sensing (MATLAB)

Channel Realization (MATLAB)

Open-source code on GitHub
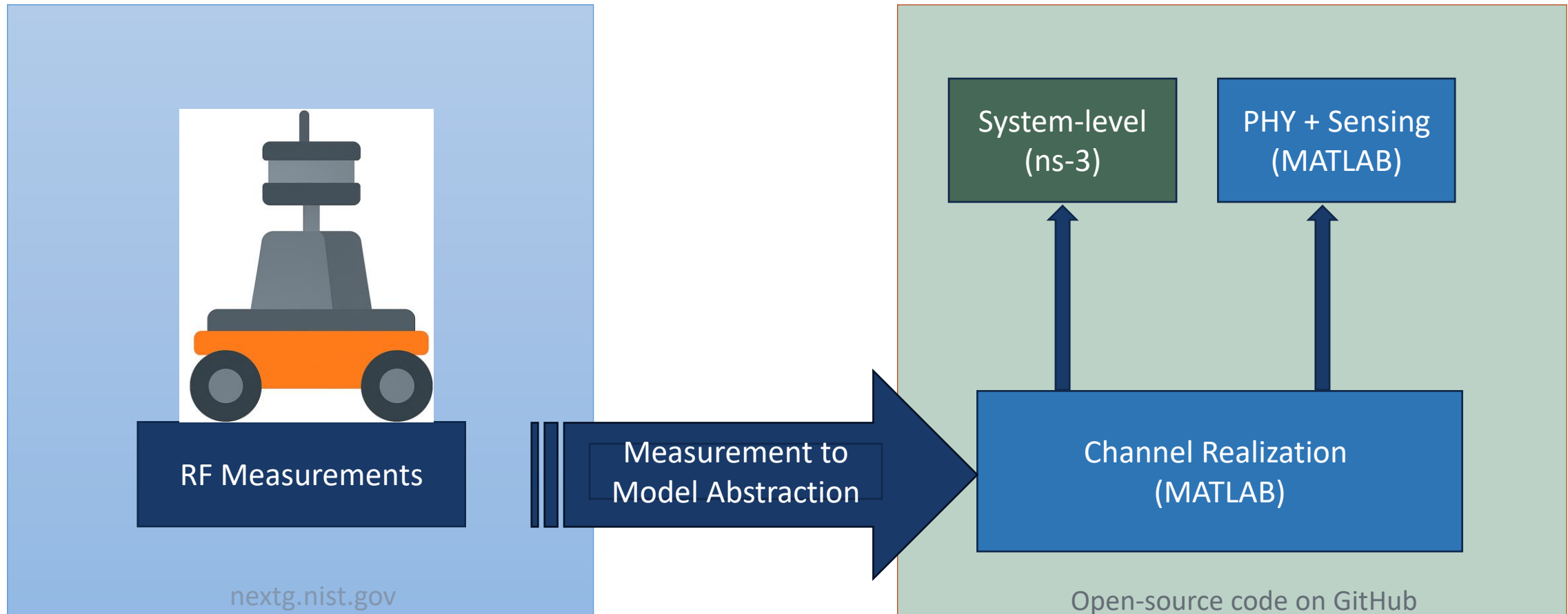
Channel Realization Software: WiFi Example

CAD Model

TX/RX(position + orientation)

Environment

Target position and orientation

Channel Realization

Multipath Component

=

Angle of Arrival
Angle of Departure
Phase
Power - Delay
Complex Gain

AOA

AOD

Power

● Environment channel
● Target channel

Delay

https://github.com/wigig-tools/qd-realization

● MATLAB   ☆ 46   ⅄ 30

Wi-Fi Sensing: ISAC-Physical Layer Model (ISAC-PLM)

Channel Model

Channel measurements

Channel Model/Measurements
MPCs (AOA, AOD, phase, delay, complex gain)

PHY Input
WLAN transmission scheme: SC vs OFDM, SU-MU/MIMO, MCS, precoding scheme, equalizer method

Sensing Input
Pulse Repetition interval, number of pulses, microdoppler processing ..

ISAC-PLM

Communication performance *BER, PER, EVM, Data Rate*

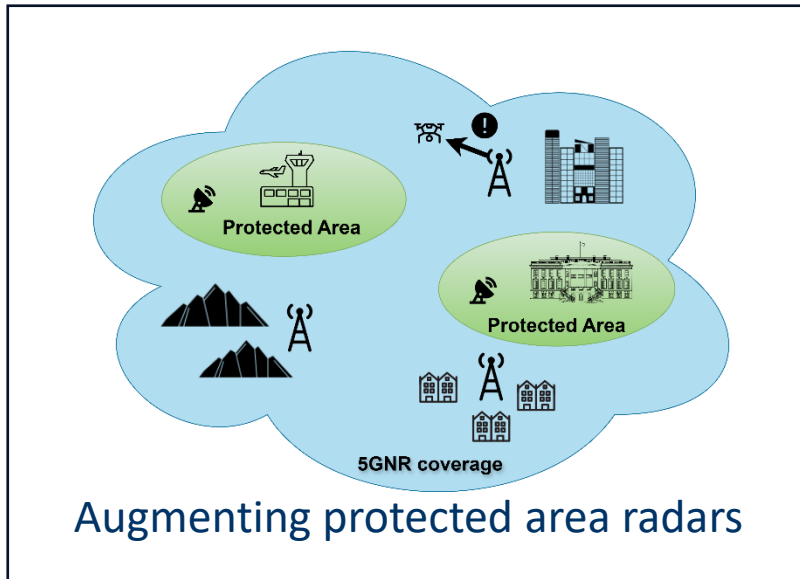| Sensing accuracy: *MSE/NMSE range/velocity* |
| --- |

Micro-Doppler Analysis
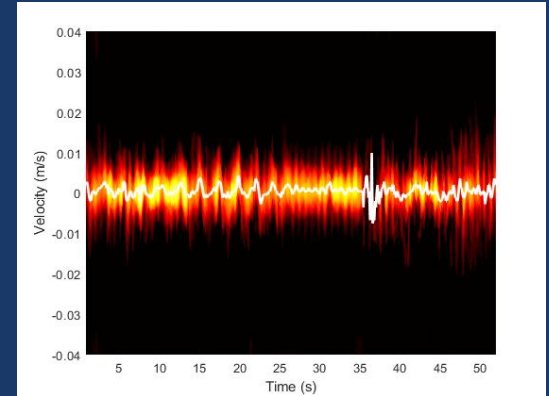
Accuracy Velocity Estimation
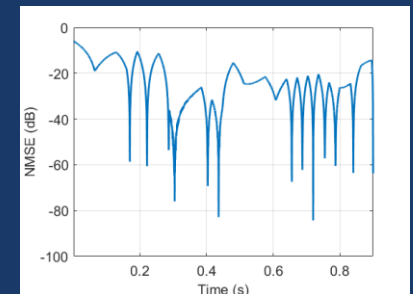
- S. Blandino, T. Ropitault, A. Sahoo, N. Golmie, "Tools, Models and Dataset for IEEE 802.11ay CSI-based Sensing". *Proceedings of IEEE Wireless Communications Networks Conference, 2022*.
- J. Wang, N. Varshney, Steve Blandino, J. Chuang, C. Gentile, N. Golmie, "Integrated Sensing and Communication: Enabling Techniques, Applications, Tools and Datasets, Standardization, and Future Directions," *IEEE Internet of Things Journal, Vol. 9. Issue 23, DOI 10.1109/JIOT.2022.3190845, 2022.*
- S. Blandino, T. Ropitault, C. da Silva, A. Sahoo, N. Golmie, "IEEE 802.11bf DMG Sensing: Enabling High-Resolution mmWave Wi-Fi Sensing," *in IEEE Open Journal of Vehicular Technology, Vol. 4, pp. 342-355, DOI 10.1109/OJVT.2023.3237158, 2023.*
- S. Blandino et al, Low overhead DMG sensing for vital signs detection, *International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2024*

https://github.com/wigig-tools/isac-plm

MATLAB ⭐ 110 ⑂ 26

5G NR Sensing

Feasibility of using 5G NR Positioning
Reference Signal (PRS) to perform sensing.

Urban Macro Environment
UAV Height=50m

*Investigating "**Miss
Detection**" and
"**Position Error**" for
different propagation
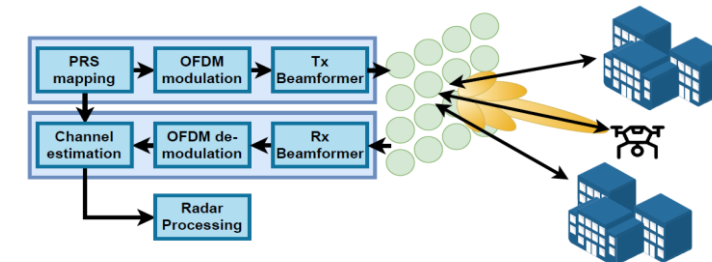environments and
UAV heights*

Augmenting protected area radars

*S. Blandino et al Detecting Airborne Objects with 5G NR Radars, submitted for
review to IEEE Military Communications Conference (MILCOM 2025)*
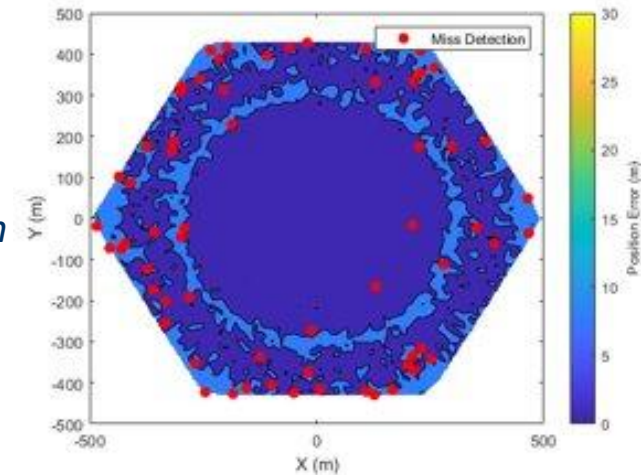
Open-source code using MATLAB 5G Toolbox

https://github.com/usnistgov/5GNRad

Partnerships and Collaborations

NIST/CTL Facilities
https://www.nist.gov/ctl/facilities

Documentary standard development
3GPP, IEEE, ITU

Measurements

nextg.nist.gov

Internship Opportunities:
Students and associates work across NIST's laboratories, supporting efforts to advance our understanding of measurement science and emerging technologies.