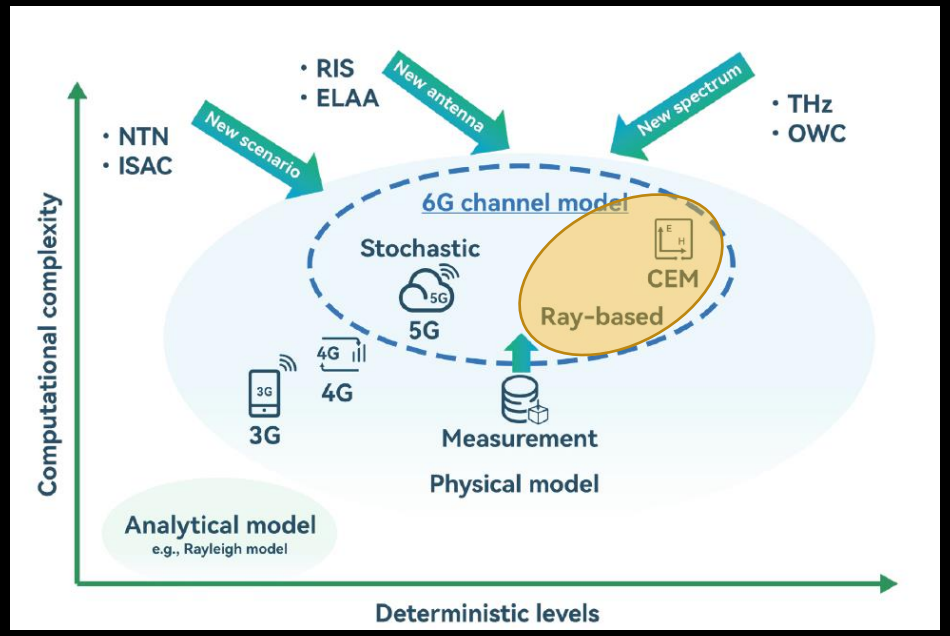
GOVERNMENT INITIATIVES (AGI)

Modeling Dynamic Wireless Channels in Interactive Terrestrial Environments

Peter Douglass, Technical Support Engineer

29 October 2024

Modeling and Simulation for Wireless Connectivity



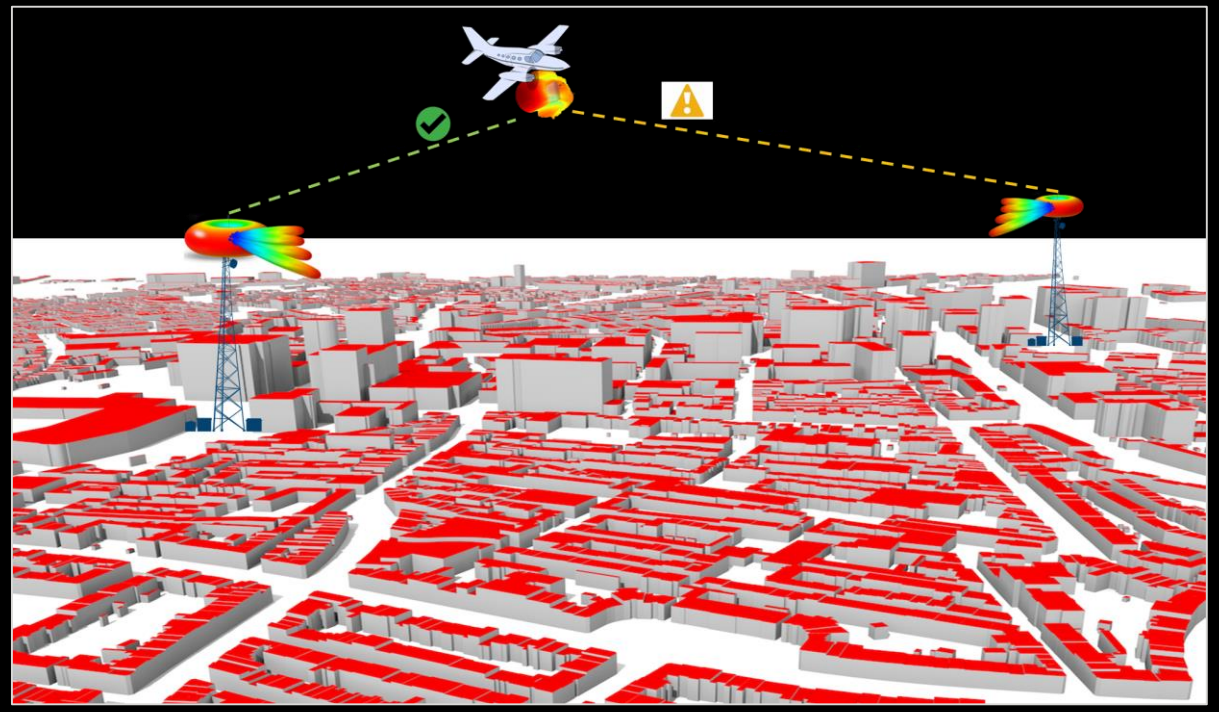
Simulation Challenge: Advancements in high-frequency modern RF solutions requires us to go beyond statistical/analytical models to arrive at trusted simulation results

Ansys GPU-SBR simulation engine combines computational electromagnetics (CEM) and ray-tracing

Source: "6G: The Next Horizon: From Connected People and Things to Connected Intelligence", Huawei White Paper

Wireless channel modeling in *accurate* virtual twin environments

Simple geometry works for < 2 GHz (low FR1 bands)…



Open Street Maps city model
with simple “block” buildings

…but for FR2 bands, better fidelity is needed.

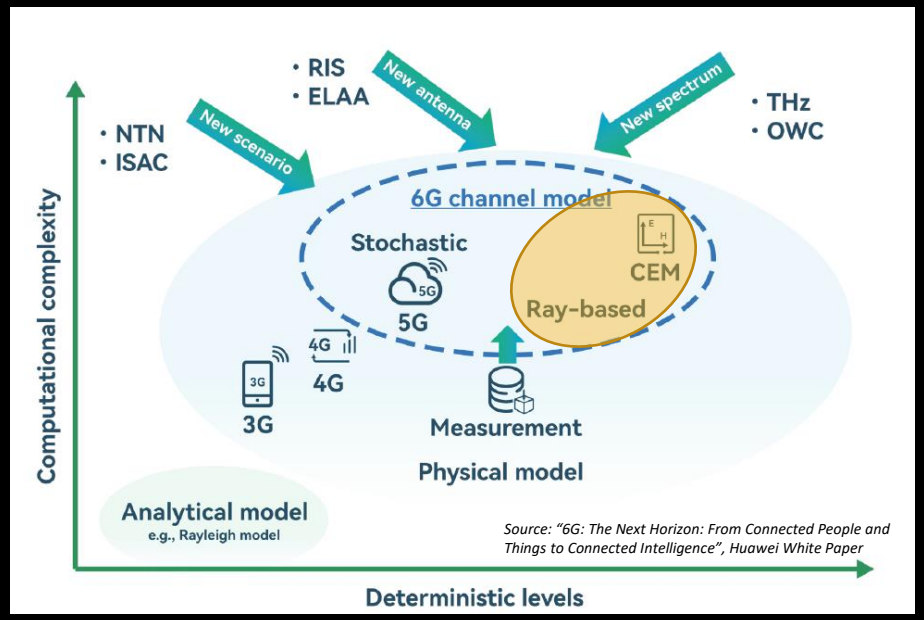
5cm Resolution City Model
Based on measurements

aerometrex

Denver city model courtesy of Aerometrex
https://aerometrex.com
> 10M geometry facets

Challenges to wireless systems and near field radar modeling

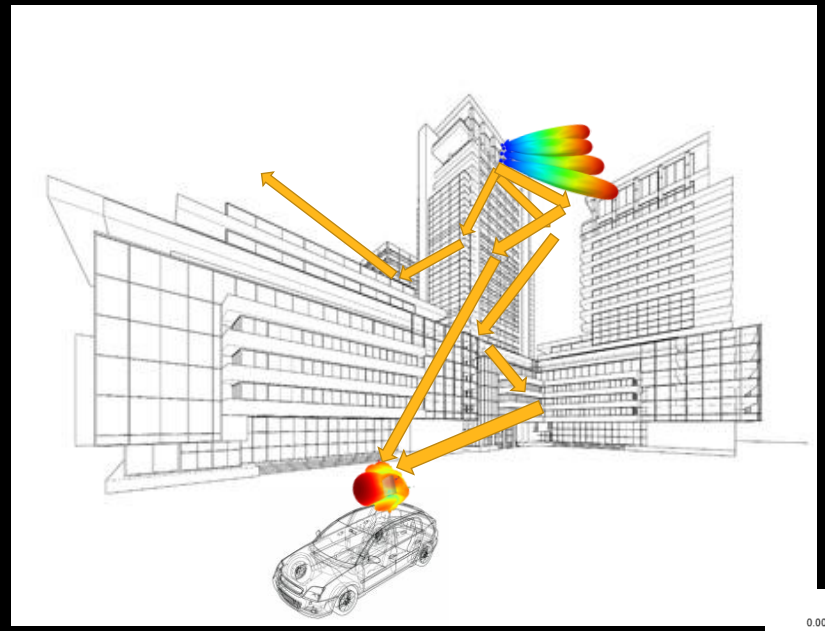
- Physical propagation in the terrestrial domain is a major challenge to communications and sensors
- RF propagation impacts of interfering RF systems compounds challenges
- Motion of RF systems causes channels to change rapidly
- Rise of high-resolution digital terrain and structure modeling
- Need/desire to train AI at the PHY layers



5cm structural resolution

2cm structural resolution

Understanding Signal Delay Spread (3 Bounce Problem)

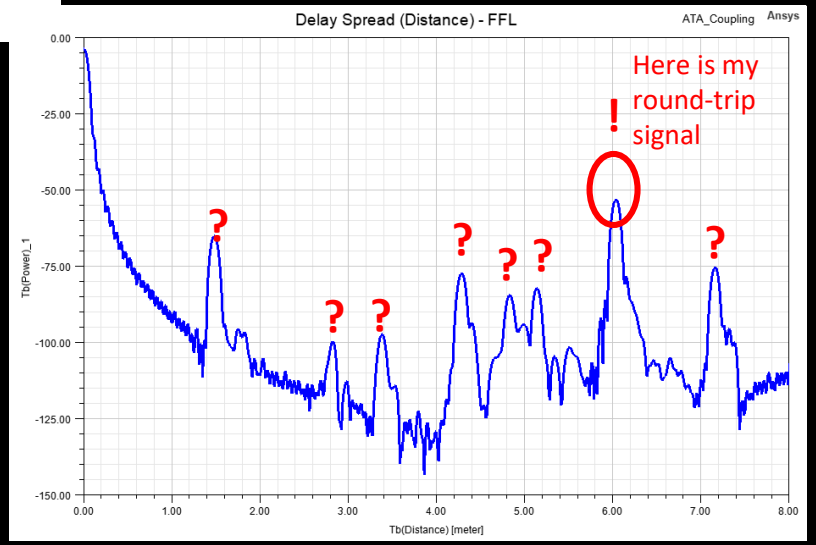


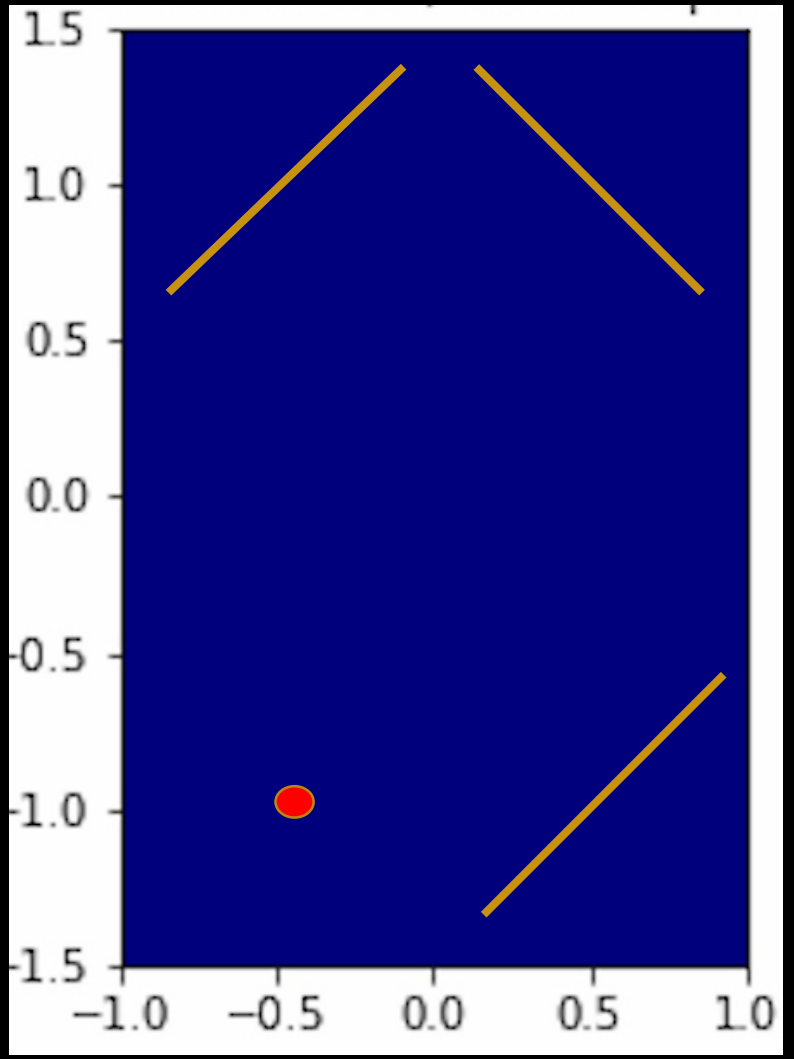
Complex RF Environment with surface reflections of many signals between transmitting and receiving antenna models

Without high-fidelity modeling & simulation, systems designers and network planners struggle to understand and design around these complexities

Why are we getting all these extra signal/pulse fronts?

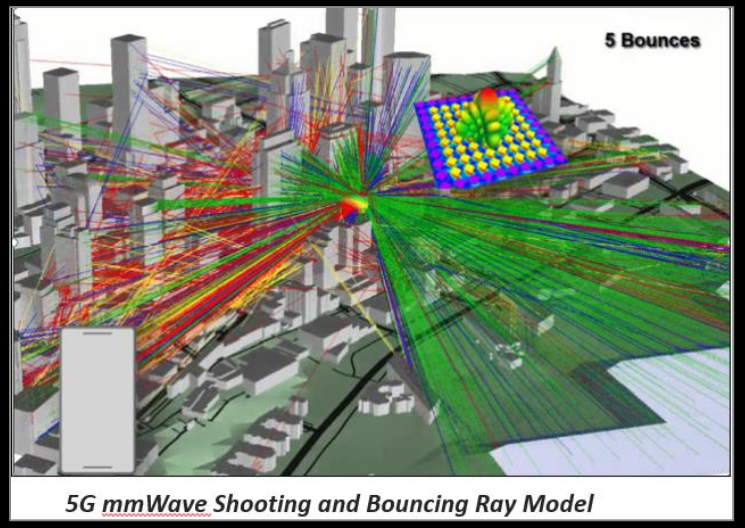
?



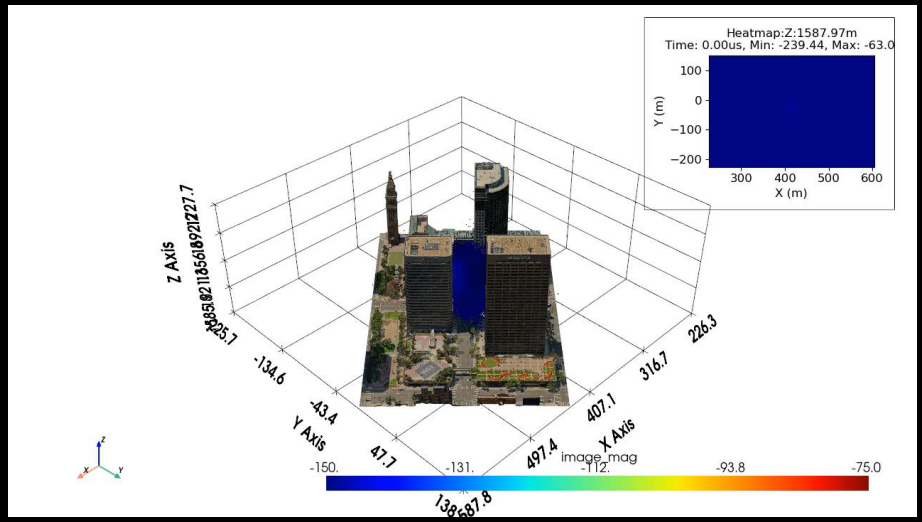


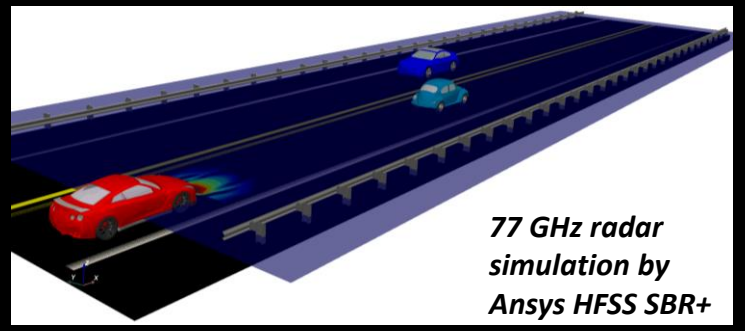
Wireless communication channel and radar modeling requirements

- Requires accurate near field and far field propagation models
- Must produce wideband channel models for transient behavior
- Frequent channel updates required – O(μsec) or less
- Very fast computation
- Consume accurate environment models

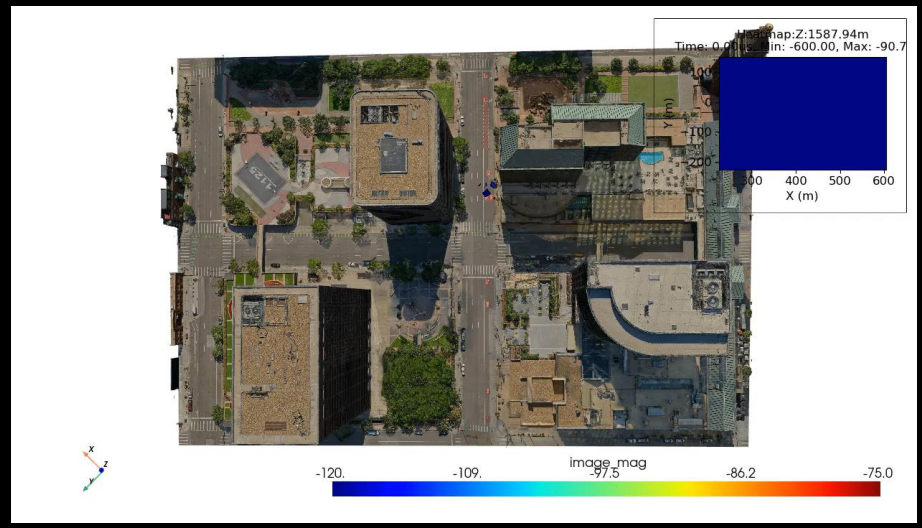


5G mmWave Shooting and Bouncing Ray Model





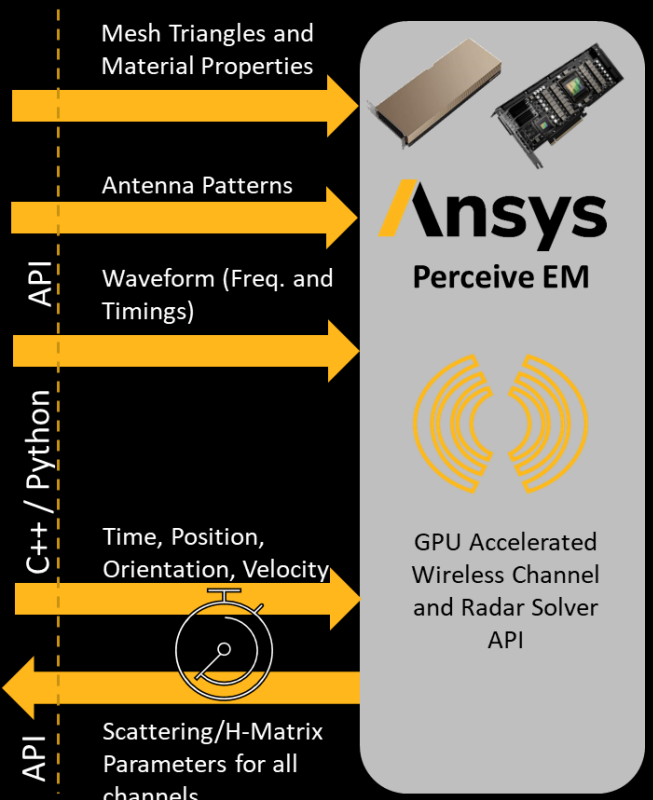
- Connect to realistic antenna system designs

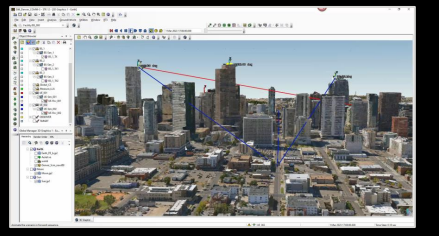


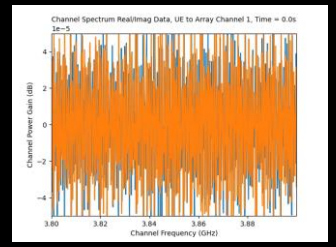
Data-on-demand real time wireless channel and radar solver

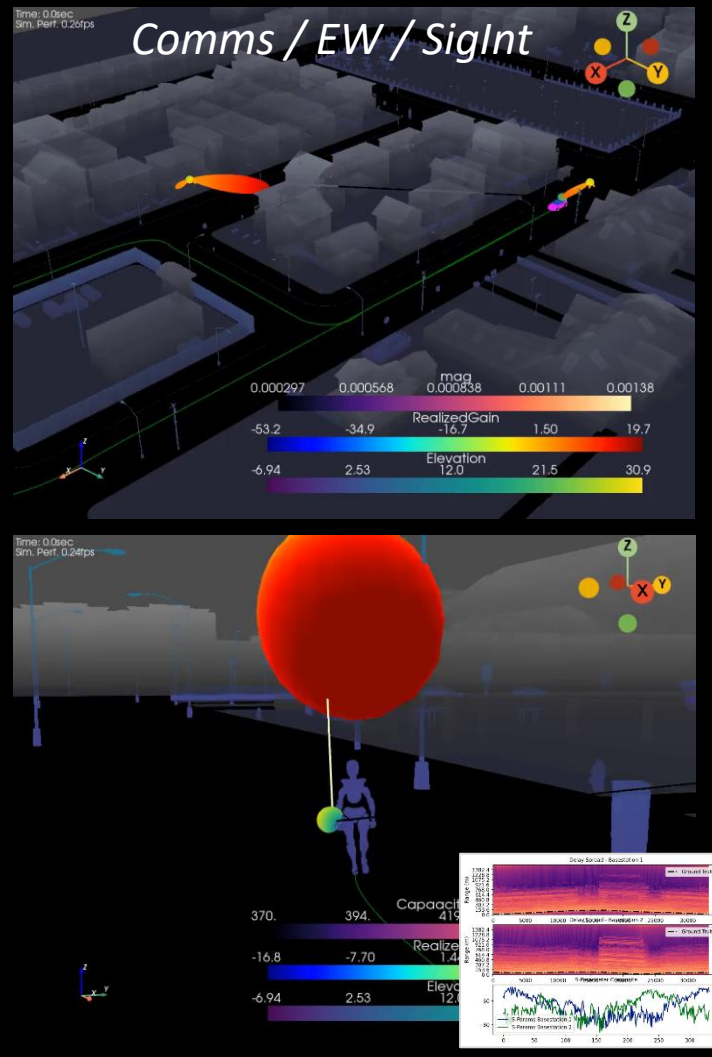
Ansys Perceive EM Solver

- **Generates wireless channel models** and **radar response** at high channel sounding rates/PRFs
- Operates at or near **real-time** on GPU devices for moving antennas, arrays, and MIMO radar systems
- **I/Q Data on Demand** for dynamic scenes
- **API-driven** for custom PHY L1 and radar modeling workflows (C++, Python APIs)
- **Physics-accurate** antennas, environments and platform motion (including micro-Doppler)
- **High-fidelity EM physics solver** based on Shooting and Bouncing Rays Physical Optics (SBR-PO) framework



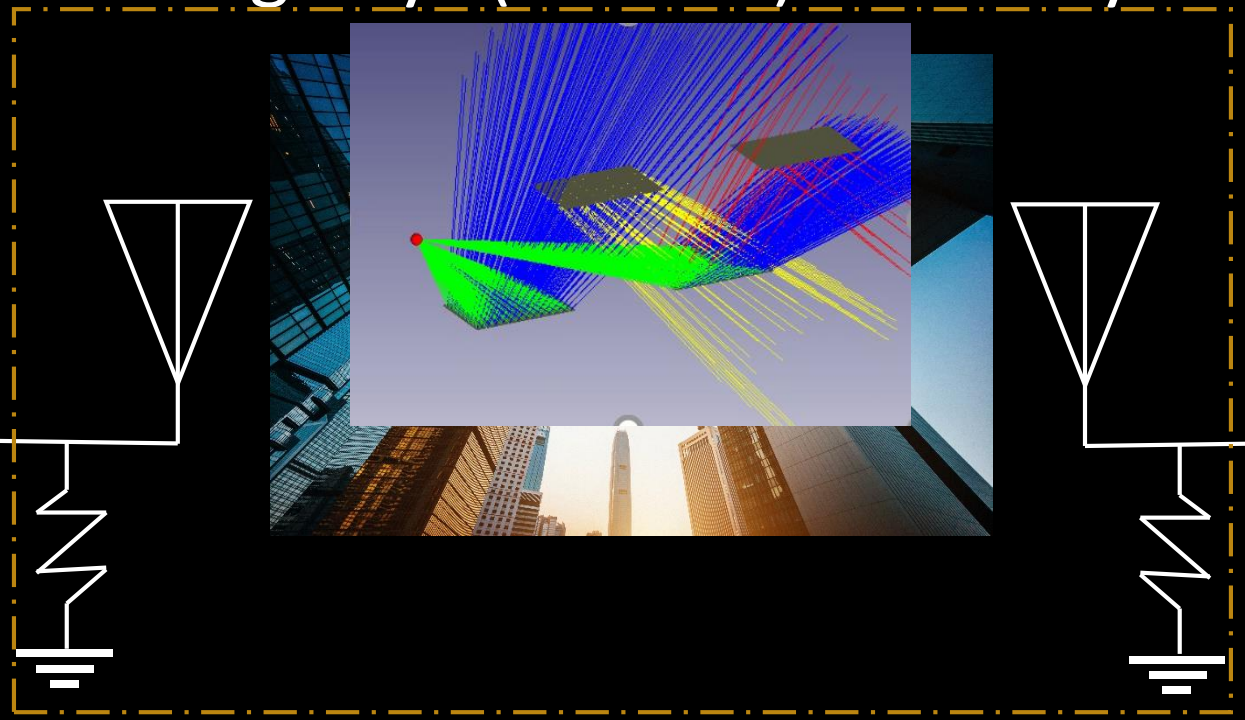






***Perceive EM solver** applied to 5G channel modeling, and used in MRT mMIMO beamforming (single subcarrier/symbol)*

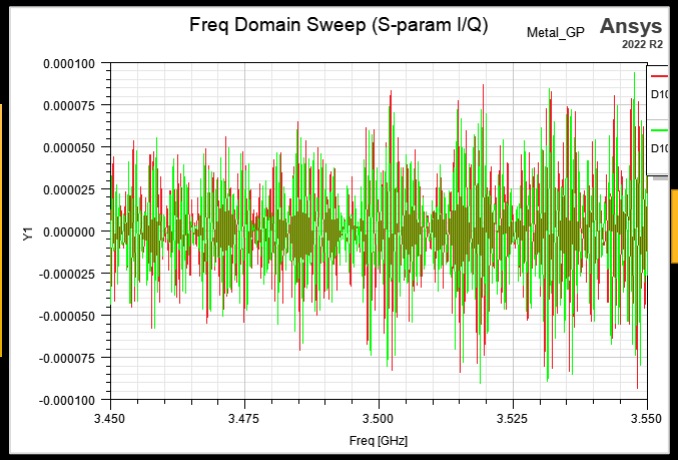
Shooting and Bouncing Rays (SBR-PO) EM analysis for channel modeling



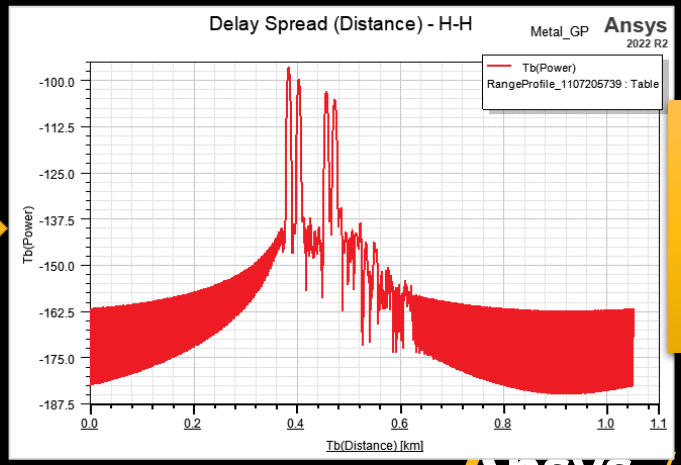
Freq Sweep Generator

I, Q Voltage Samples

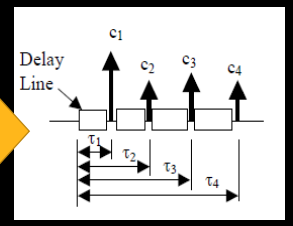
Complex Frequency Response (CFR)



IFFT

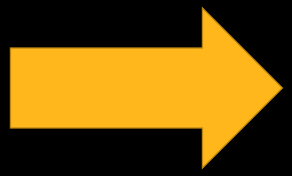


Complex Impulse Response (CIR)



Tapped delay-line model

Perceive EM enables Ansys RF Comms and Radar solution workflows



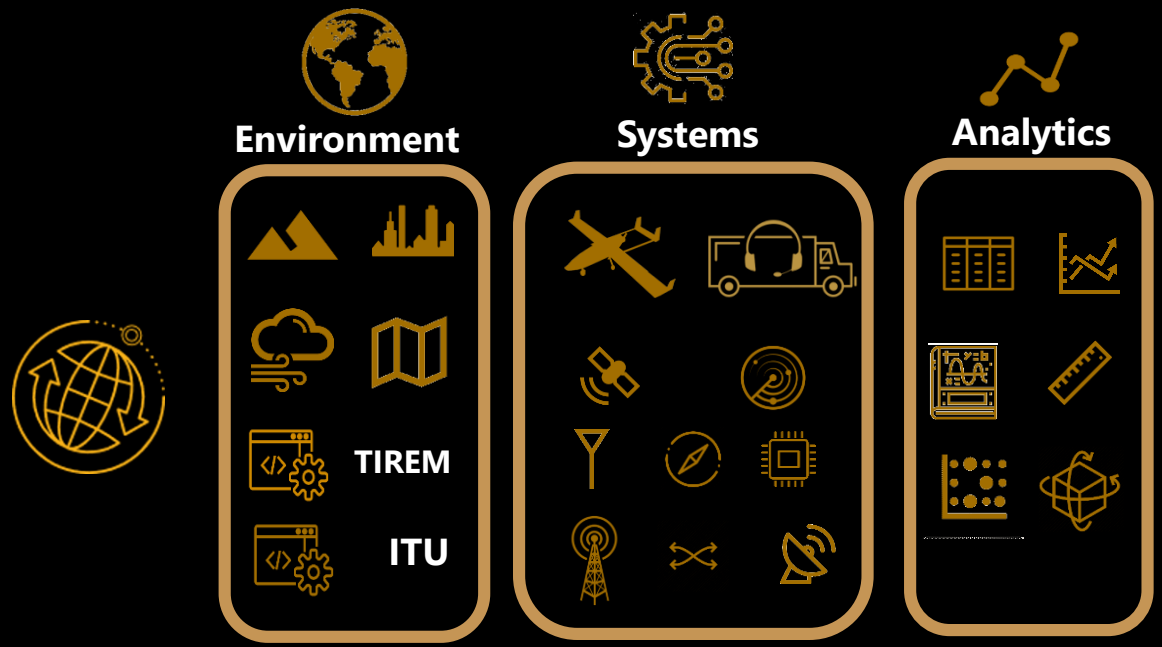
- **Perceive EM → Solver Engine API**
  - Enabling Workflow Development for Radar and Communications Systems

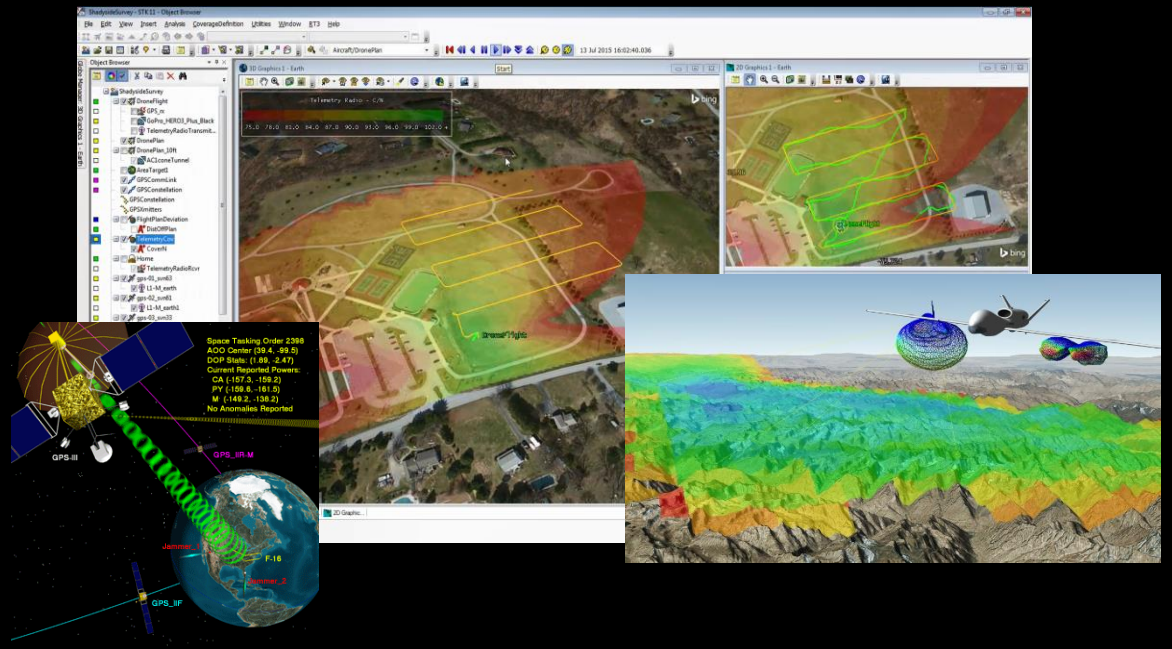
- **Ansys RF Channel Modeler → Communications & Radar Imaging Workflow**
  - Workflow for Wireless Communications Simulation
  - All domain operations (land, air, sea, space)
  - Utilizes Perceive EM “under-the-hood”

- **Ansys AVxcelerate Sensors → Automotive Sensor Workflow**
  - Workflow for Automotive Multi-Sensor Simulation
  - Specialized for driving simulation
  - Utilizes Perceive EM “under-the-hood” for radar

Digital Mission Engineering (DME) with Ansys Systems Tool Kit (STK)

- Flagship software w/ ~30 yr. heritage of systems modeling & simulation software for aerospace / defense industry
  - Satellite Systems & Mission Design
  - Ground/Terrestrial Systems/Aircraft
  - Radar/Comm/RF
  - Missile Defense



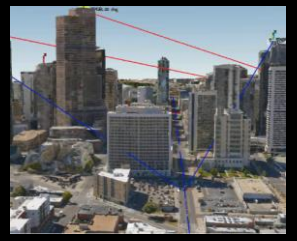


AGI
An Ansys Company

Ansys
RF Channel Modeler

Terrain, Buildings, Static Objects, Shapes, Materials

3D Tiles



"Data-on-Demand" mode

MATLAB API

Results

Downstream Tools (radios, radar signature proc, etc.)

Time-Based Wireless Channel Models (HDF5 Database)

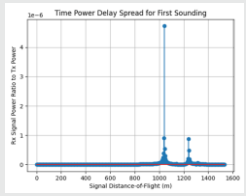
Ansys RF Channel Modeler

Analysis Area Configuration

Subscriber and Scene Setup

Analysis Setup

Antenna Import (HFSS Support)



Plotting

Mesh Triangles and Material Properties

Time, Position, Orientation, Velocity

Waveform (Freq. and Timings)

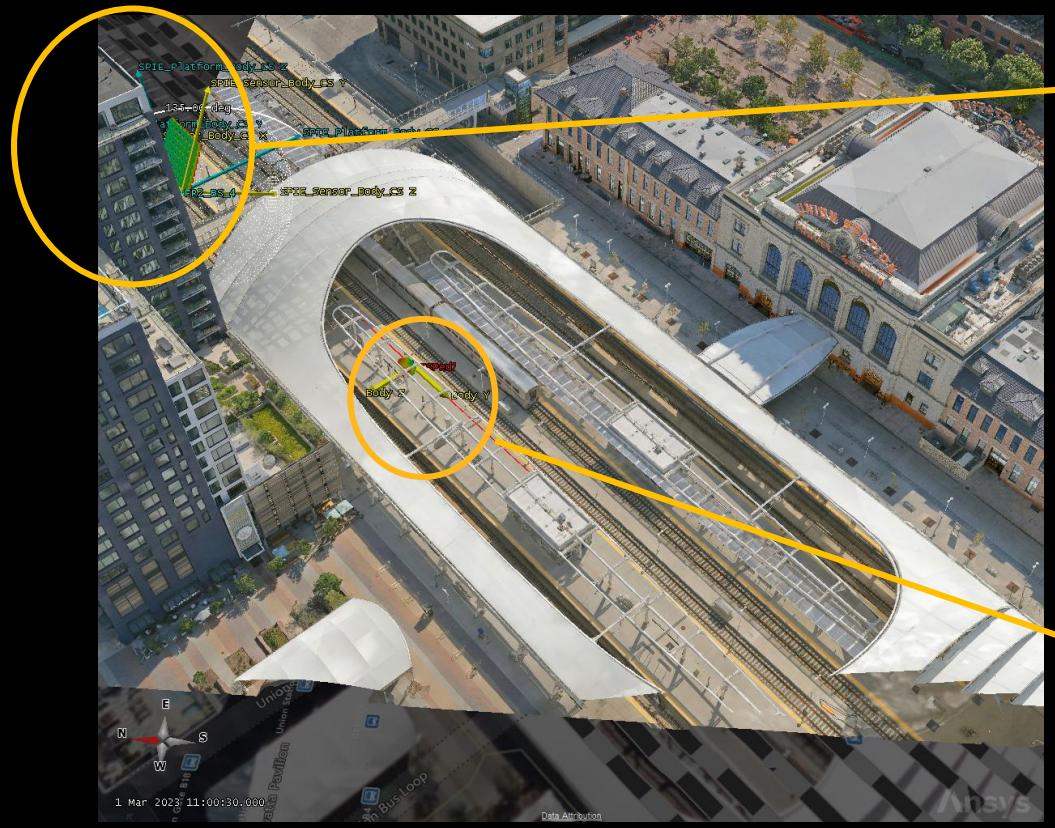
Antenna Patterns

Scattering/H-Matrix Parameters

Perceive EM

RF/radar Channel Modeling for low, mid, mmw & THz Band systems

Scene Summary:
10msec channel soundings
28GHz, 400MHz BW @ 1024 Samples
128 Channel → 1.3M samples per second



28 GHz Base Station
- 8 x 8 dual-polarized elements
- 128 total channels
- Ansys HFSS Embedded Element Patterns

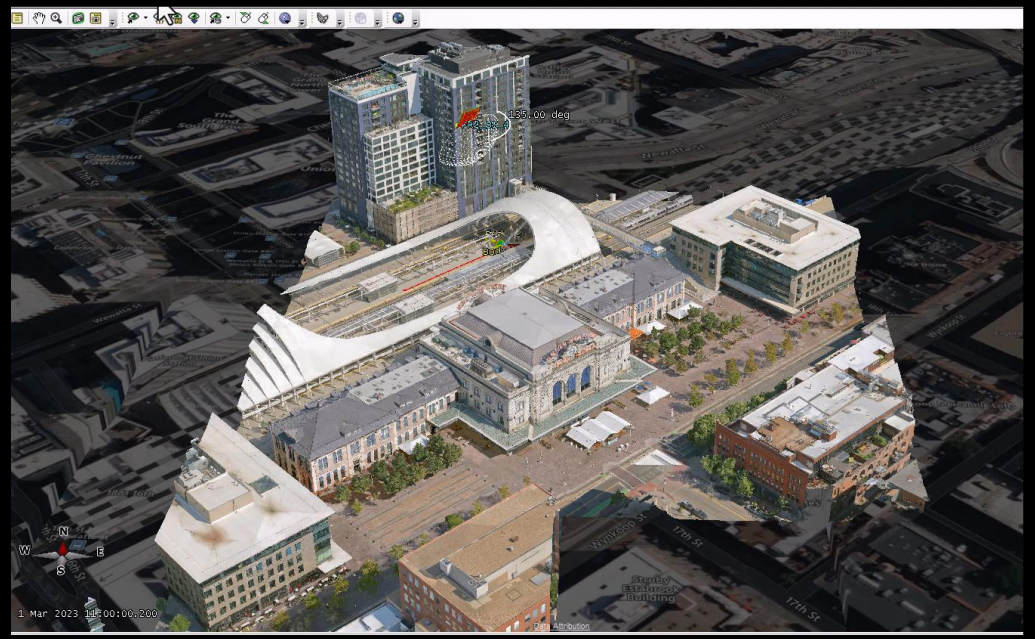
28 GHz Mobile Device
- Single element/pol
- Packaged antenna model from HFSS simulation

aerometrex

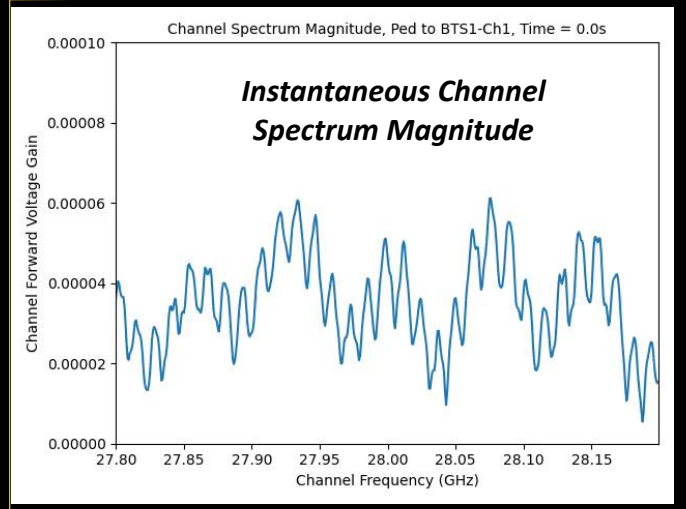
Denver city 3D Tile model courtesy of Aerometrex
https://aerometrex.com (2cm Resolution Scene)

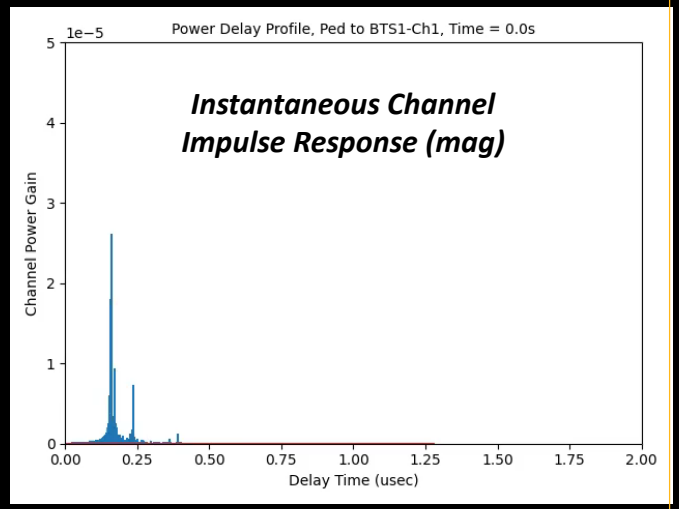
RF/radar Channel Modeling for low, mid, mmw & THz Band systems

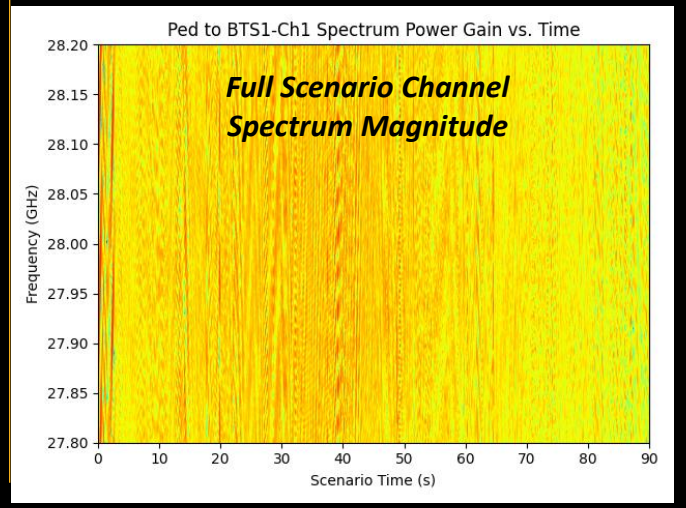
f_c = 28 GHz
BW = 400 MHz

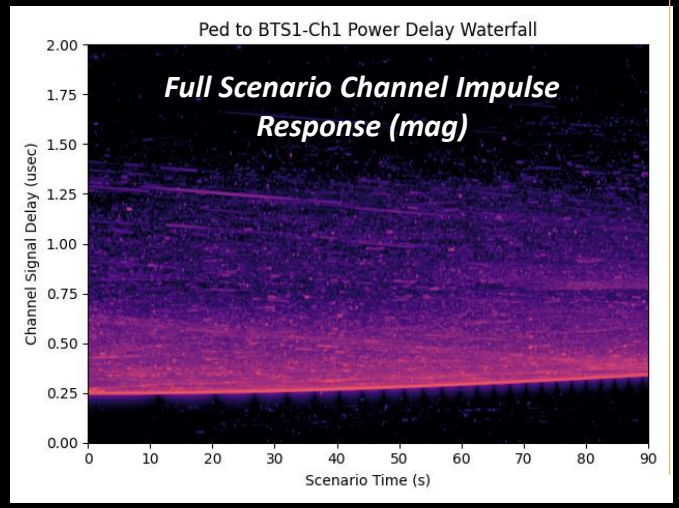


Channel for Pedestrian Mobile to Array Channel 1, Polarization 1







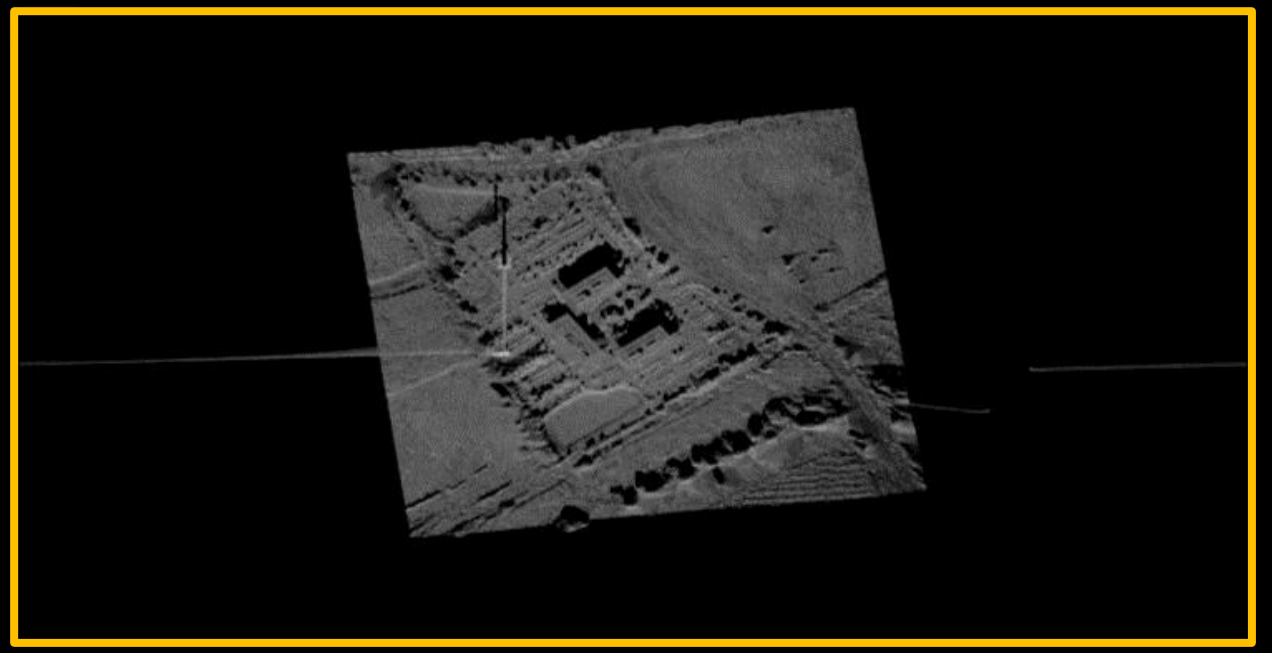


Denver city 3D Tile model courtesy of Aerometrex
https://aerometrex.com (2cm Resolution Scene)

Compute Time: 135 secs for 128 channels on laptop + RTX A5500 GPU

RFCM example SAR data collection over AGI HQ

Synthetically generated SAR image with rotating wind turbine
Imaging spotlight SAR platform at 50 deg Elevation



BLUE PLANE = Radar Illumination Direction
(Uniform Phase Front)

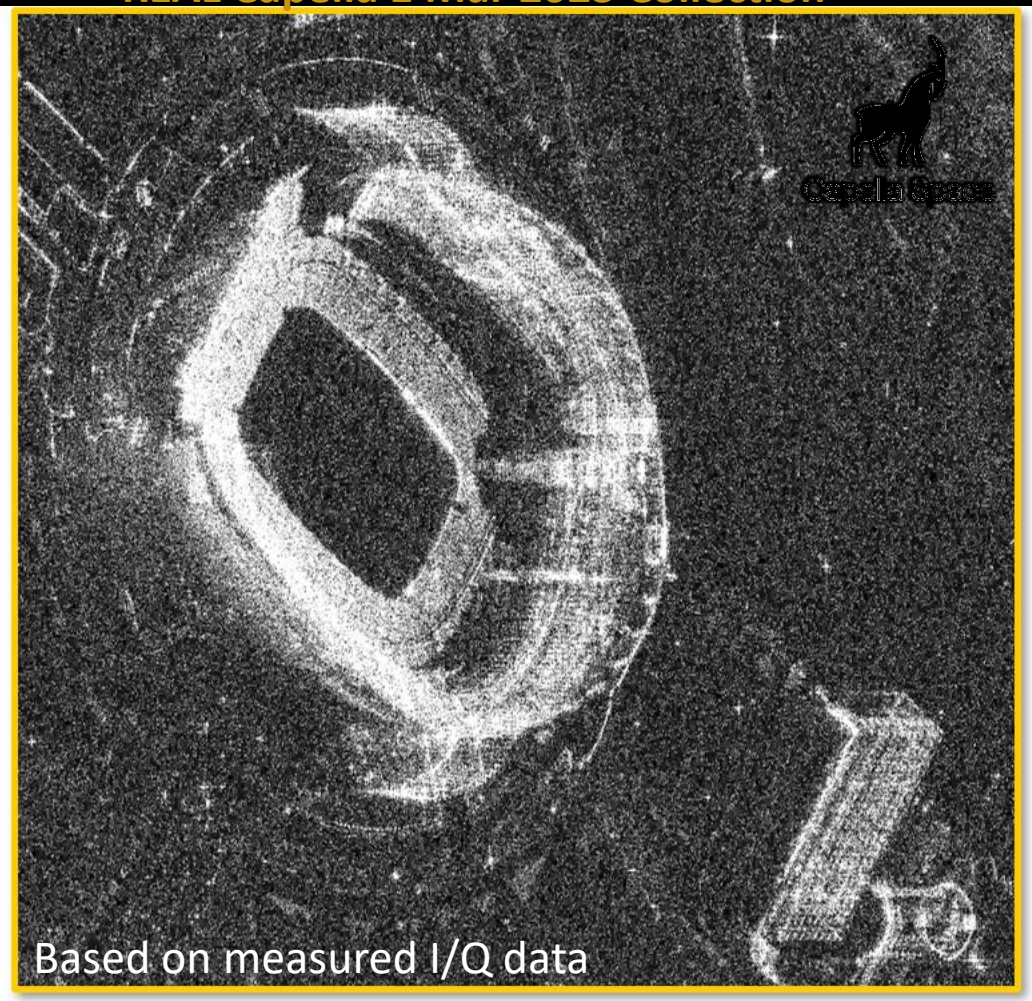
RED PLANE = Radar Image Plane

RFCM *utilizes* ***Perceive EM*** *to generate SAR images*
(360 degrees, every 2 degrees, total of 181 images, 15 minutes)

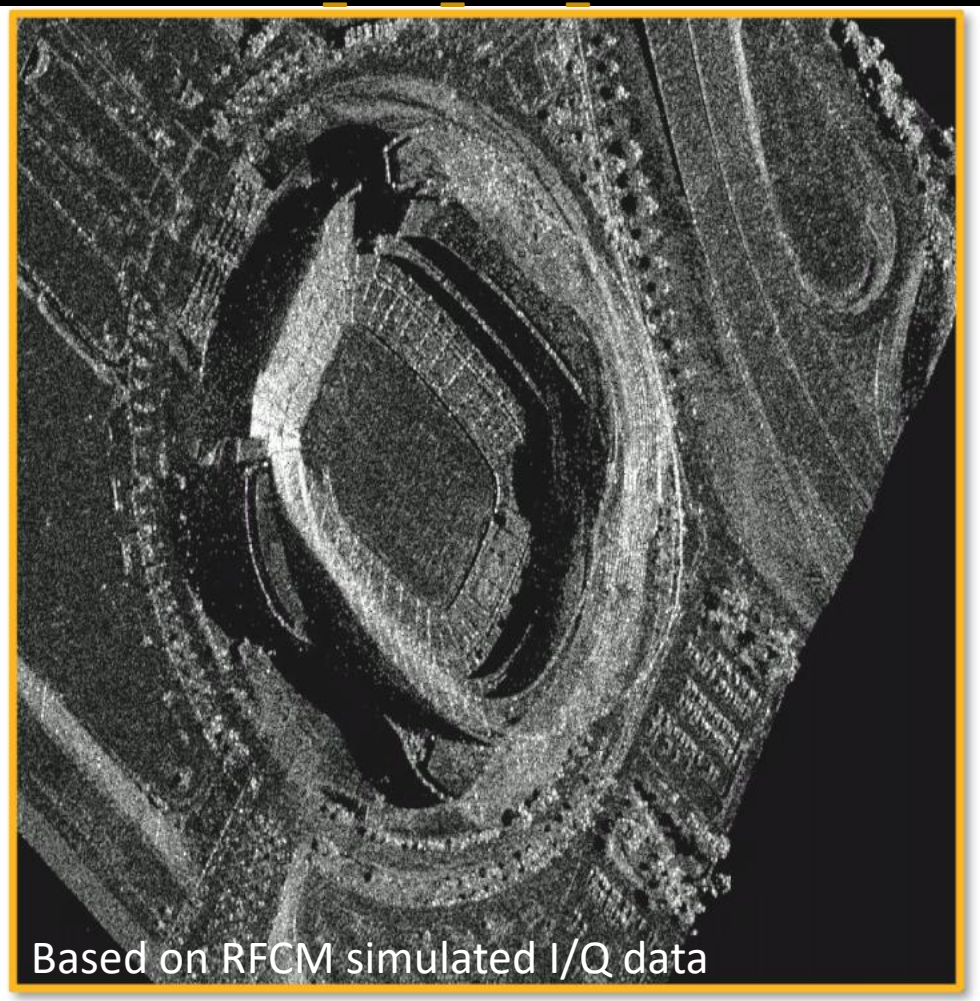
Creation of Synthetic SAR data collections AI training

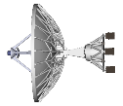
Real vs Synthetic SAR Imagery

REAL Capella 1 Mar 2023 Collection



SYNTH_Data_60dB_1-Bounce





Channel Modeling and Radar Imaging in Partner Applications

5G/6G Hardware-in-the-Loop (HiL) Testing and Validation

Base band Content → Transmitter (KEYSIGHT) → RF Channel + Antennas (Ansys) → Receiver (KEYSIGHT) → Base band Data Recovered

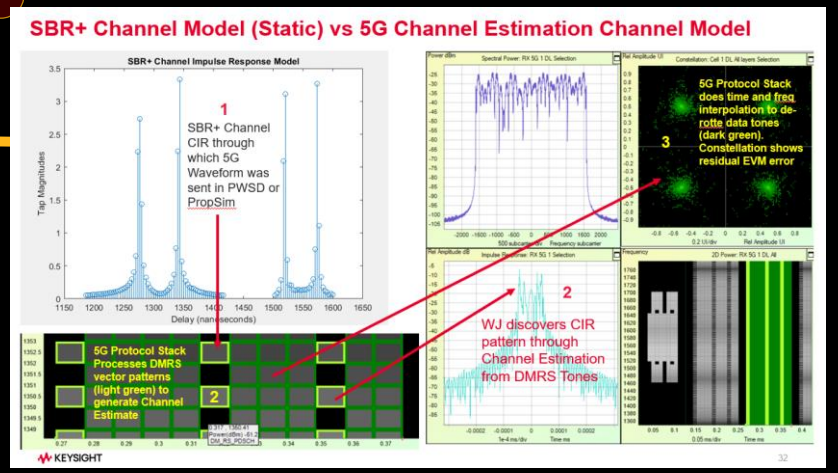
5G Baseband Processor

Digital Data

5G Remote Radio Unit

RF Signals (to Antennas)

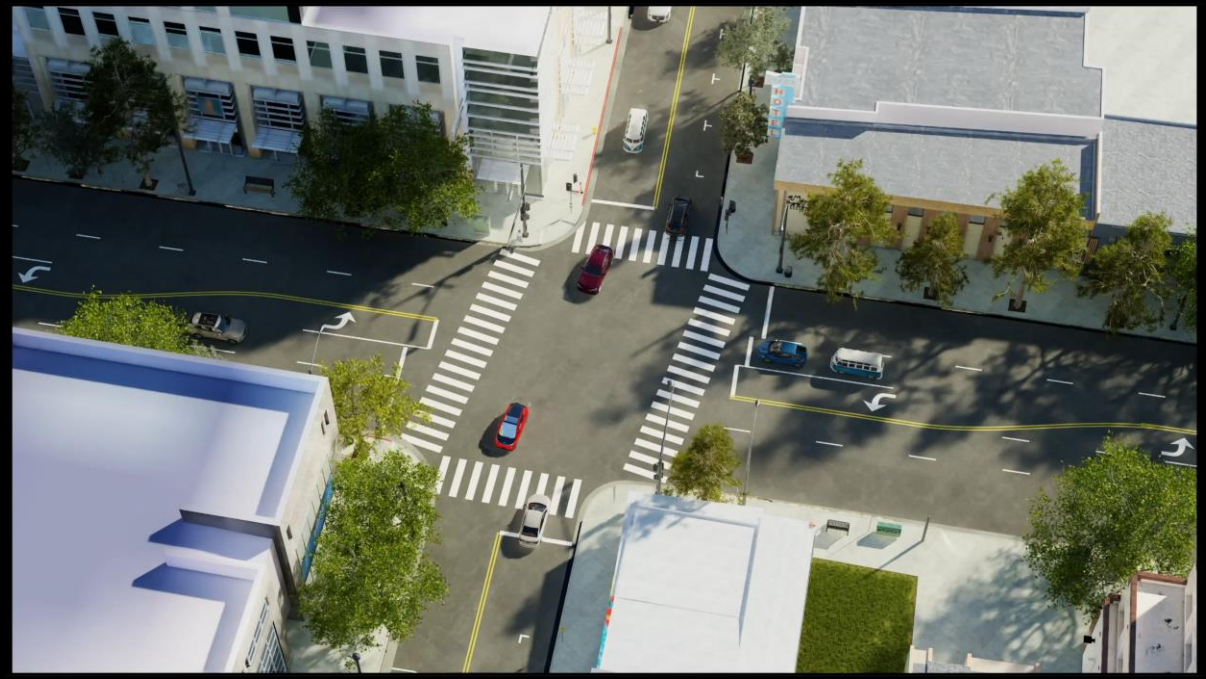
FPGA-based Wireless Channel Emulator
Keysight PropSim GCM

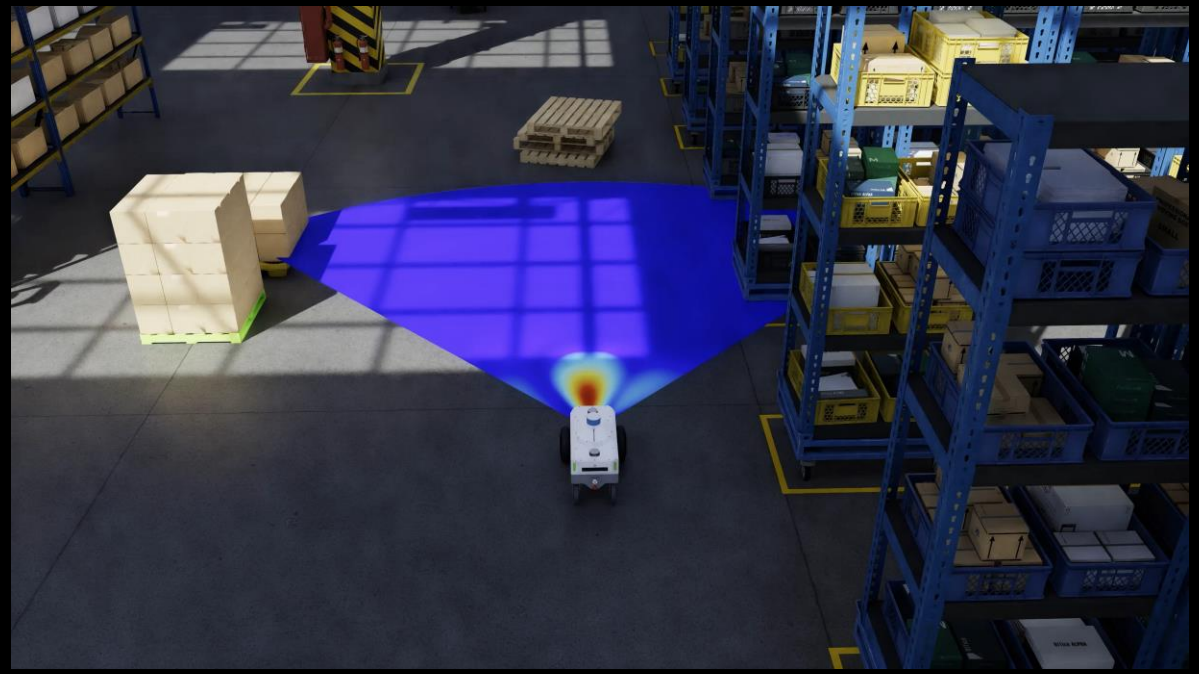


5G System Metrics and KPIs

5G Link Layer waveform and protocol analyzers

NVIDIA OMNIVERSE + Ansys Perceive EM



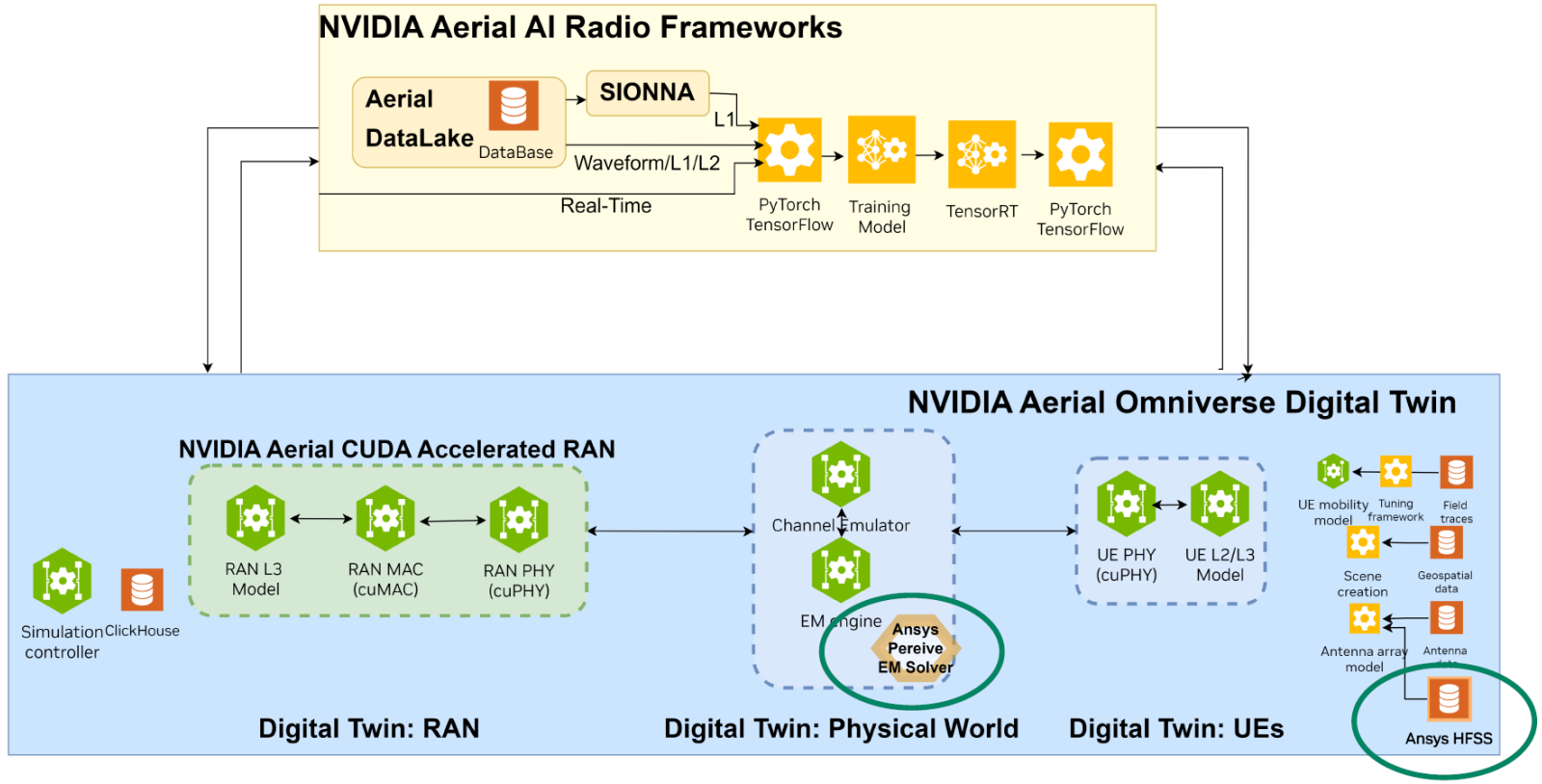


Omniverse as a Platform Visualization and EM Simulation

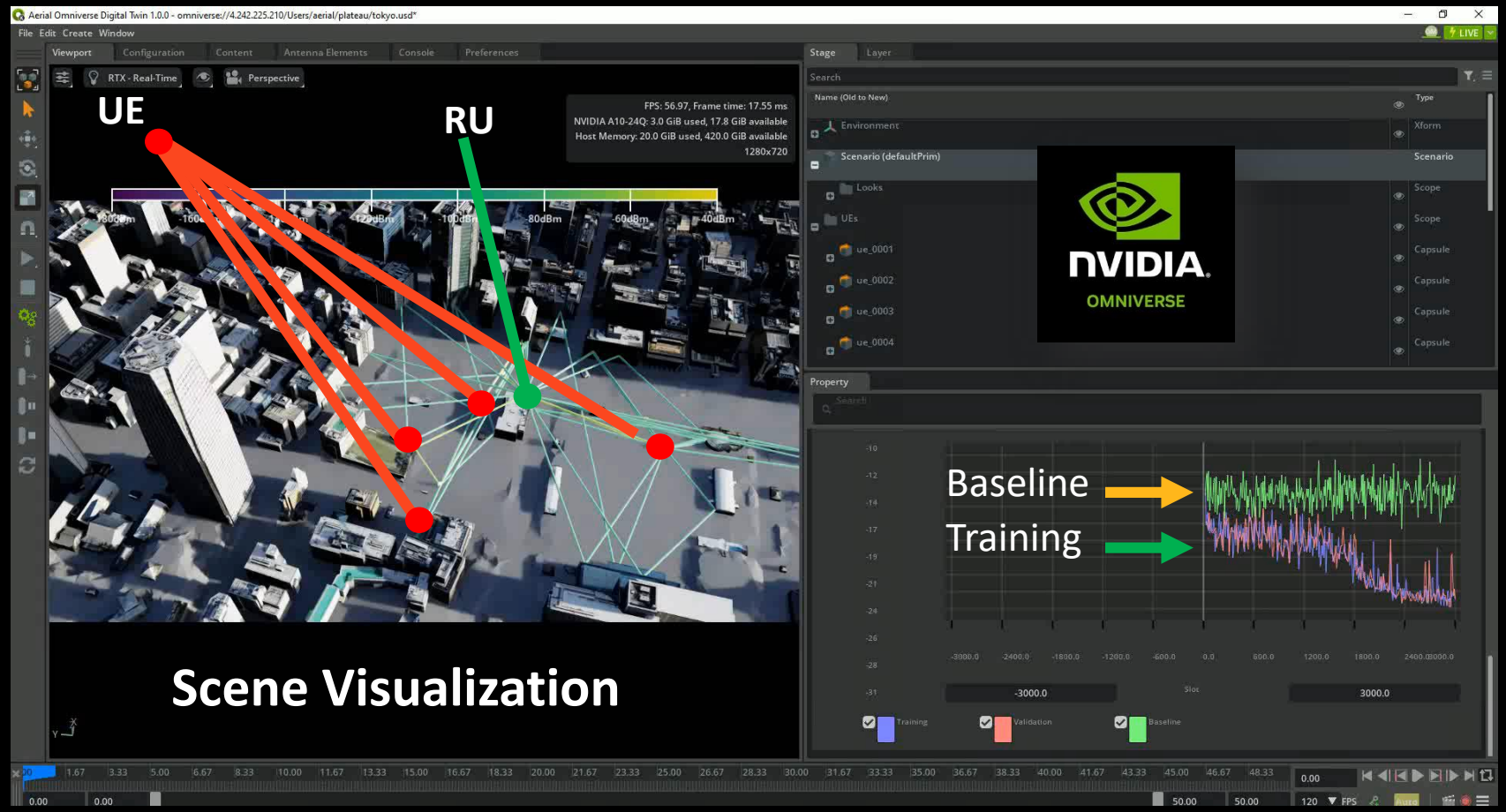
Ansys integrated with Aerial Omniverse Digital Twin

Being part of System-Level Simulation with AI/ML in the loop

- System-Level Simulation with digital twin of RAN, Physical World and UE. Leverage AI/ML agents in the loop
- Using *Ansys Perceive EM Solver* as an alternative to AODT EM Solver, and *Ansys HFSS* as one of antenna profile formats



NVIDIA AODT channel predictor AI training powered by Ansys Perceive EM

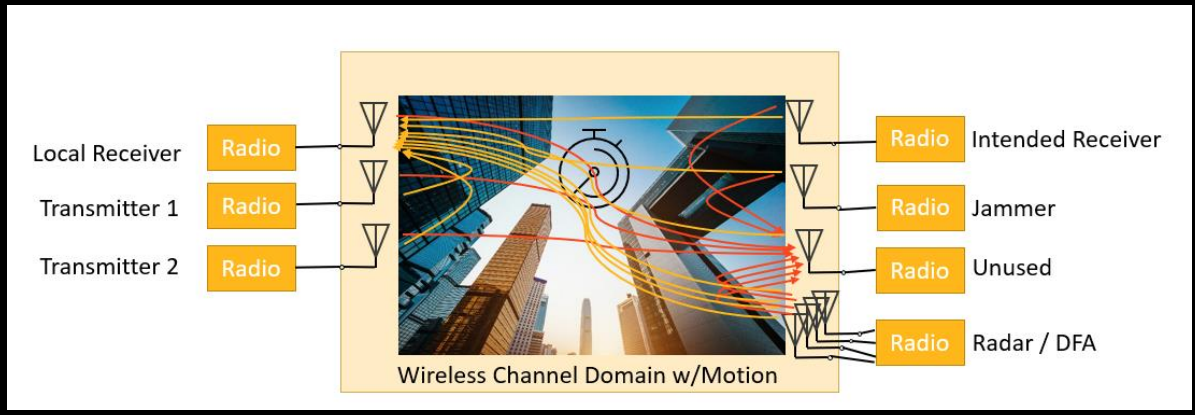


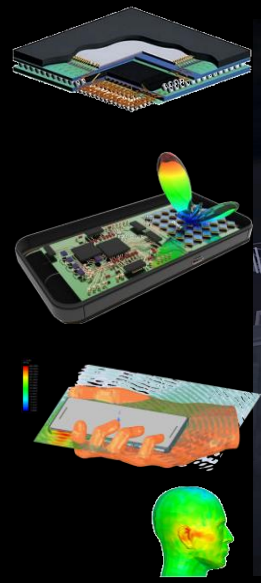
A proof-of-concept demonstration

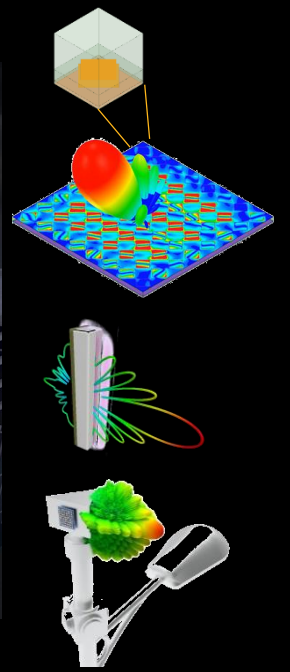
Ansys
PERCEIVE EM

In conclusion…

- High Fidelity and high-speed channel modeling: Perceive EM
- Comm channel and radar modeling in the same solver
- API solver access for R&D and custom solutions
- API-solver applied to Ansys Solutions (RFCM, AVx)
- API-solver applied to partner Solutions (Keysight, NVIDIA, more to come!)

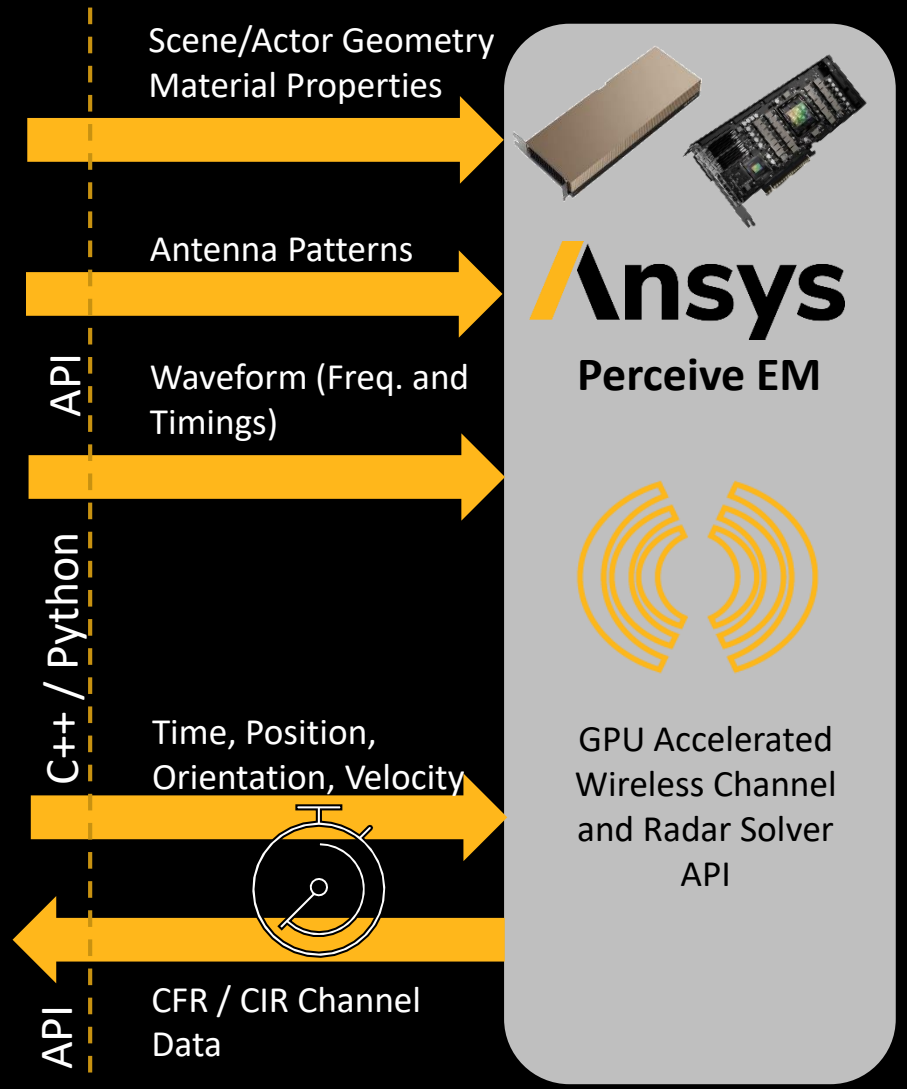






Ansys

GOVERNMENT INITIATIVES (AGI)



Synthetic Data generation driven by Digital Mission Engineering

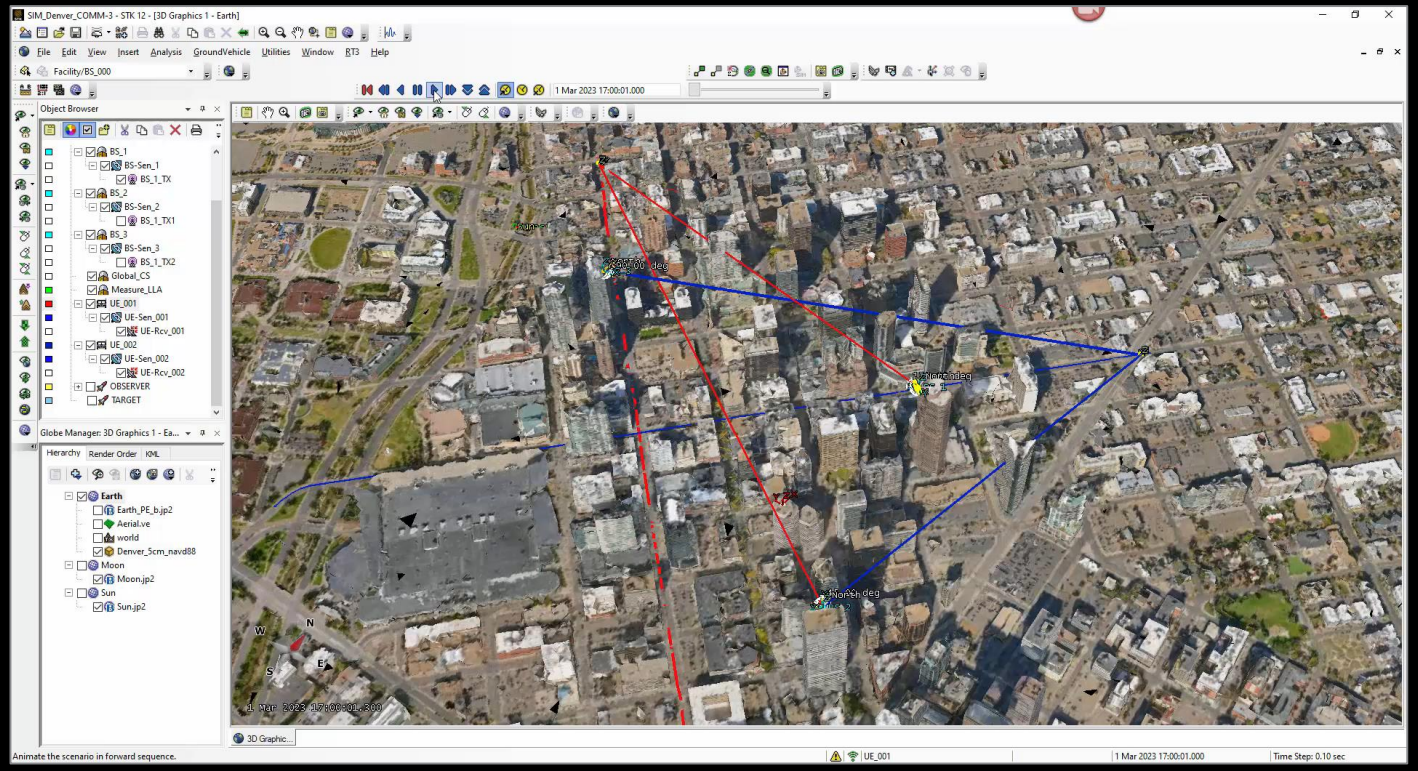
- AI/ML requires DATA (lots of data) to learn/train, test/validate, and operate
- Synthetic sensor data generation requires:

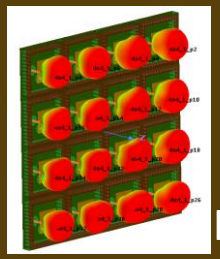
Strengths of Synthetic Data for AI/ML

Limitless cases	Controlled Environ	Virtual=Secure	Exact Ground Truth	Automatic Annotation

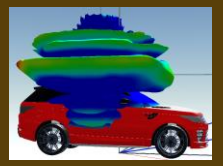
Introducing **Ansys RF Channel Modeler**

Wireless channel modeling in dynamic environments for multi-domain access points and subscribers





Base Station
(32R, 32T)
3 x Building Tops



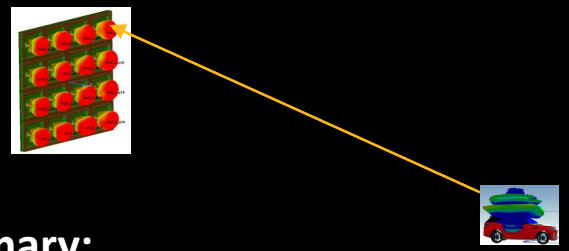
UE1
UE2

HFSS Antenna Models (3.8 GHz)

aerometrex

Denver city model courtesy of Aerometrex
https://aerometrex.com
> 10M geometry facets

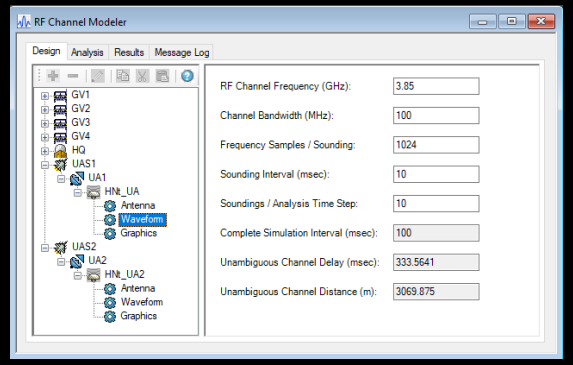
C-Band comms example in RFCM

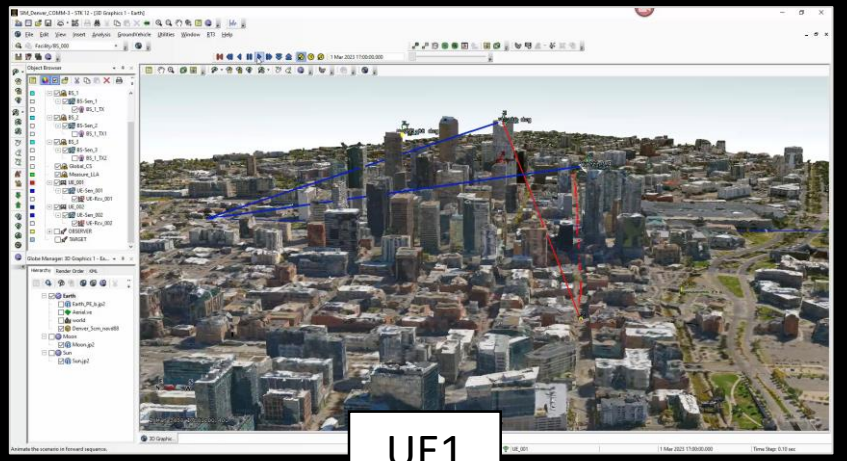


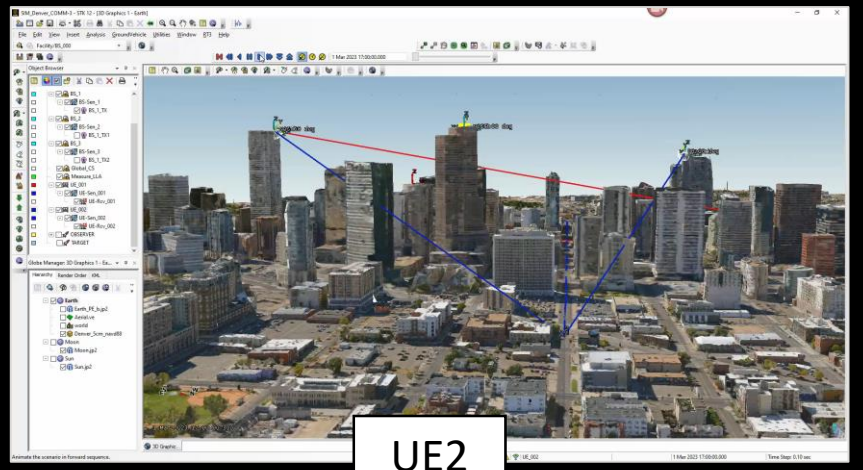
Scene Summary:
10msec channel soundings
BTS – 32 Antennas
UE – 2 Antennas
C-Band, 100MHz BW @ 512 Samples

2 min scenario → 768,000 channel soundings → 393M frequency samples

(~2.6x faster than real time simulation)







Not shown: 63 additional channels (UE1/2 to gNodeB antenna system)