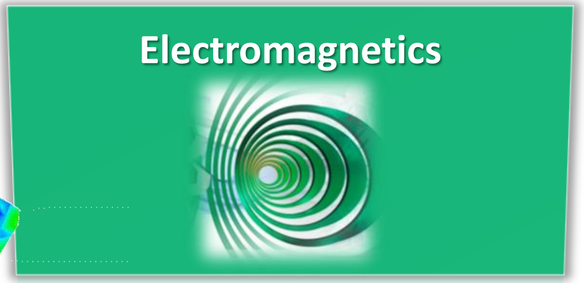
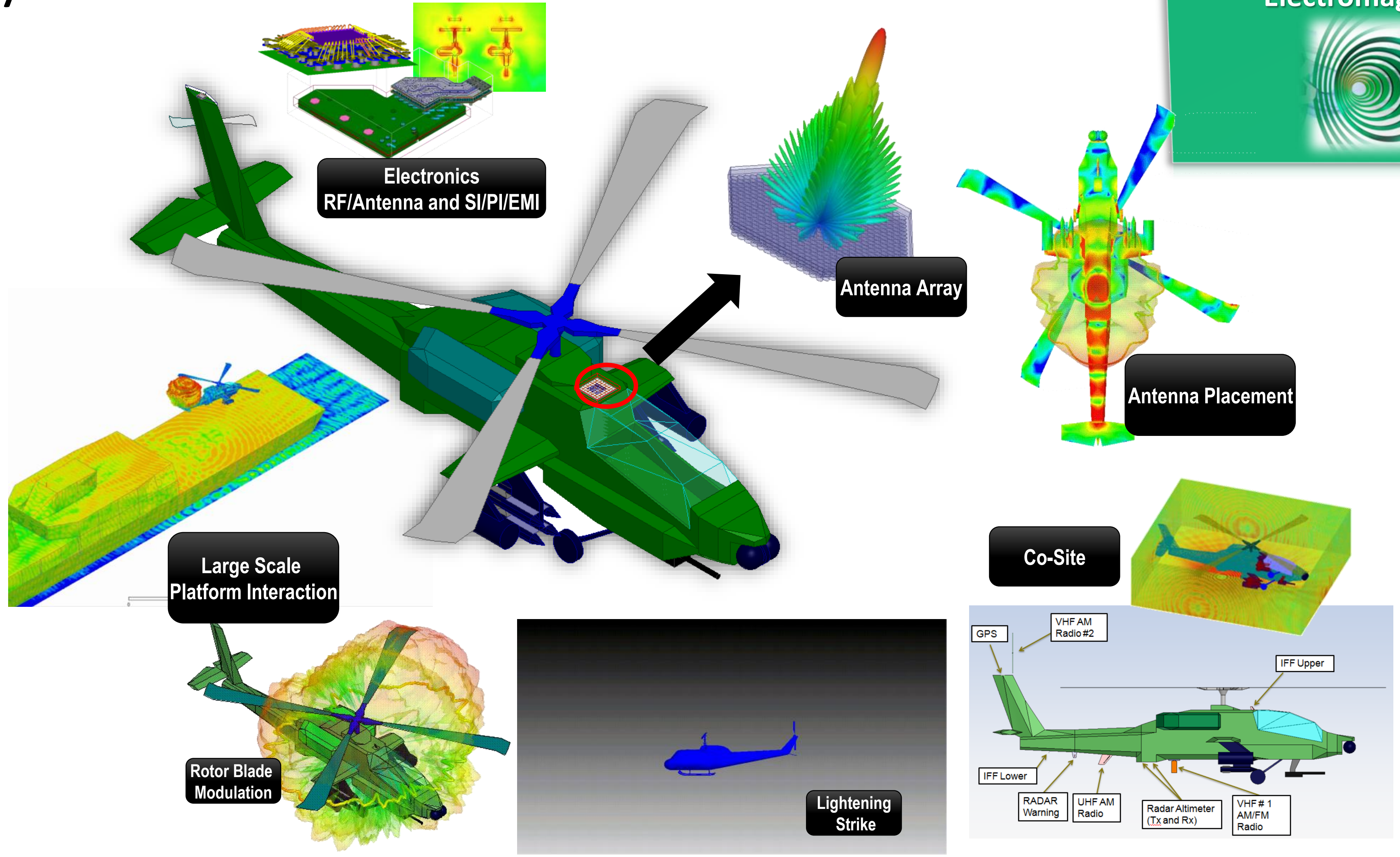
Ansys Solutions for Industrial IoT

Matt Commens

Ansys Product Management

Ansys Electronics





Ansys HFSS

High **F**requency **S**tructure **S**imulator

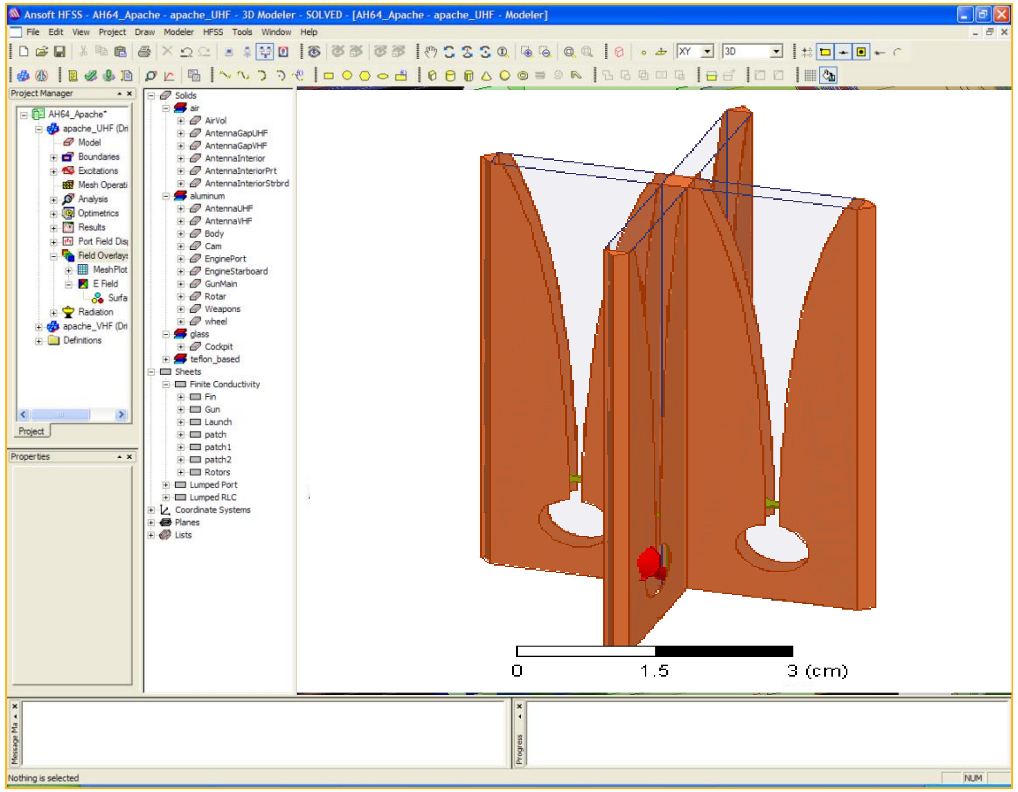
Electromagnetics 3D Finite Element Solution

Gold Standard for Accuracy

Integrated interface
- **3D Modeling**
- **Automatic Meshing**
- **Post-processing**

Inputs
- **Geometry**
- **Material**
- **Excitations**
- **Frequencies**

Outputs
- **S-parameters**
- **Electromagnetic Fields**
- **Thermal Loads**



HFSS Foundational Technology Breakthroughs for FEM

Spurious Free Vector Basis Functions

- Enables reliable FEM solutions of Maxwell's equations
- M. L. Barton, Z. J. Cendes, "New vector finite elements for three-dimensional magnetic field computation", *J. Appl. Phys.*, vol. 61, no. 8, pp. 3919-3921, 1987

Automatic Adaptive Meshing for Accuracy and Efficiency

- Z. J. Cendes and D.N. Shenton, "Adaptive mesh refinement in the finite element computation of magnetic field", *IEEE Trans. Magn.*, vol. MAG-21, pp. 1811-1816, Sept. 1985

Transfinite Element Method

- Enables highly accurate and efficient extraction of network parameters (S, Y, and Z)
- Z. J. Cendes and J. F. Lee, "The transfinite element method for modelling MMIC devices", *IEEE Trans. on Microwave Theory and Techniques*, vol. 36, no. 12, pp. 1639-1649, December 1988

Domain Decomposition Method

- Enables distributed memory computing
- Key for many advanced solver features
- M. N. Vouvakis, Z. J. Cendes, and Jin-Fa Lee, "A FEM domain decomposition method for photonic and electromagnetic band gap structures", *IEEE Trans. Antennas Propag.*, vol. 54, no. 2, pp. 721-733, February 2006

Key Capabilities: Automatic Adaptive Meshing

HFSS is accepted as the industry gold standard for accuracy

- This begins and ends with automatic **adaptive** meshing

Mesher and solver work hand in hand to…

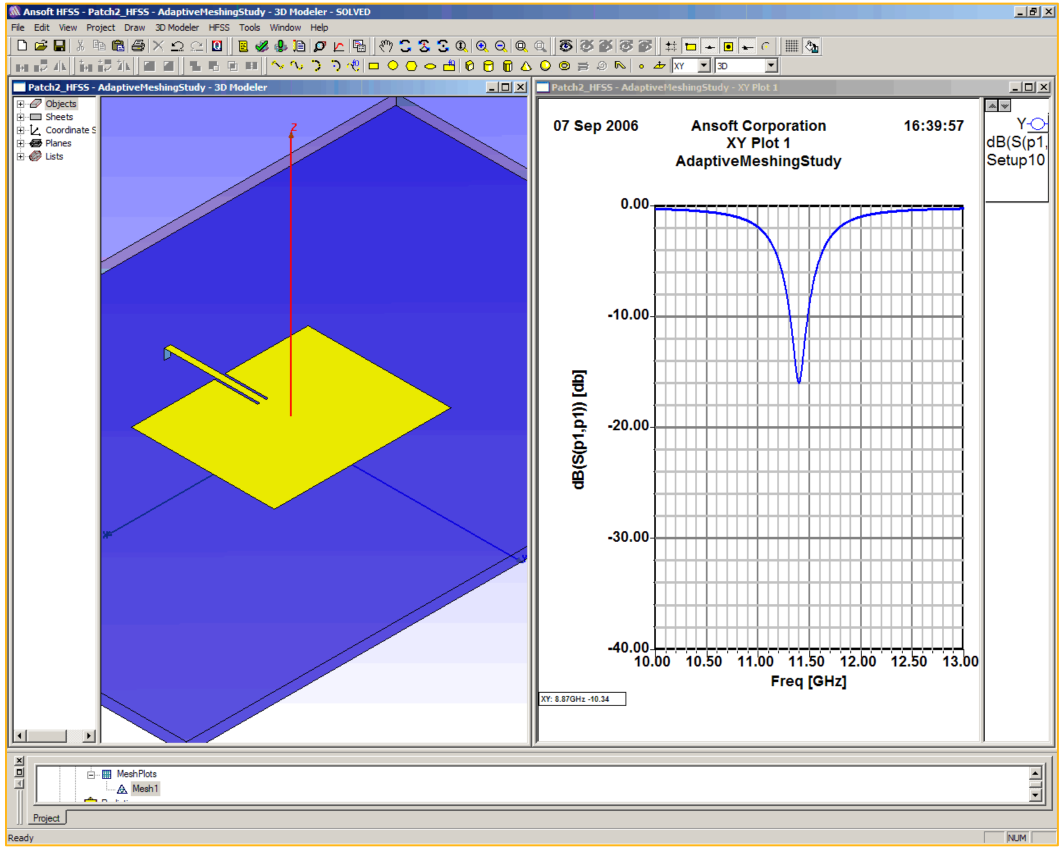
- Determine where the mesh needs to be dense: **Efficiency**
- Represent the behavior of the electromagnetics: **Accuracy**

The physics defines the mesh, the mesh does not define the physics

Provides accurate and **reliable** solutions

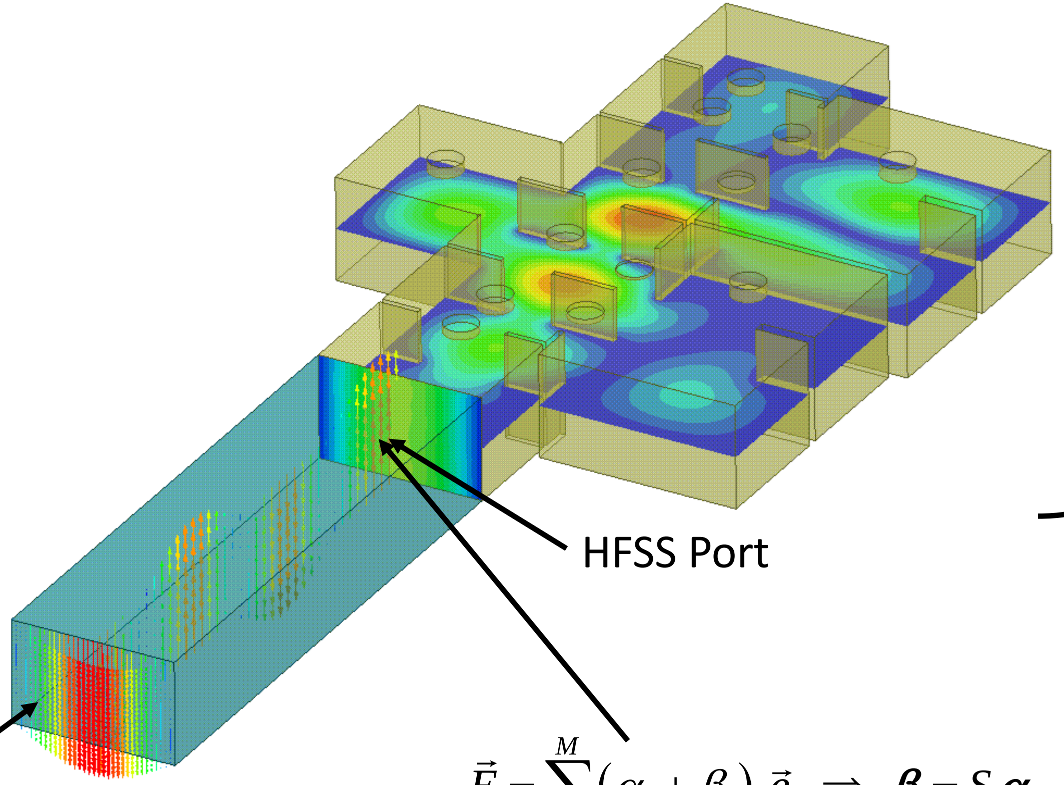
Generate final designs through simulation

Eliminate prototypes, time and cost



Transfinite Elements

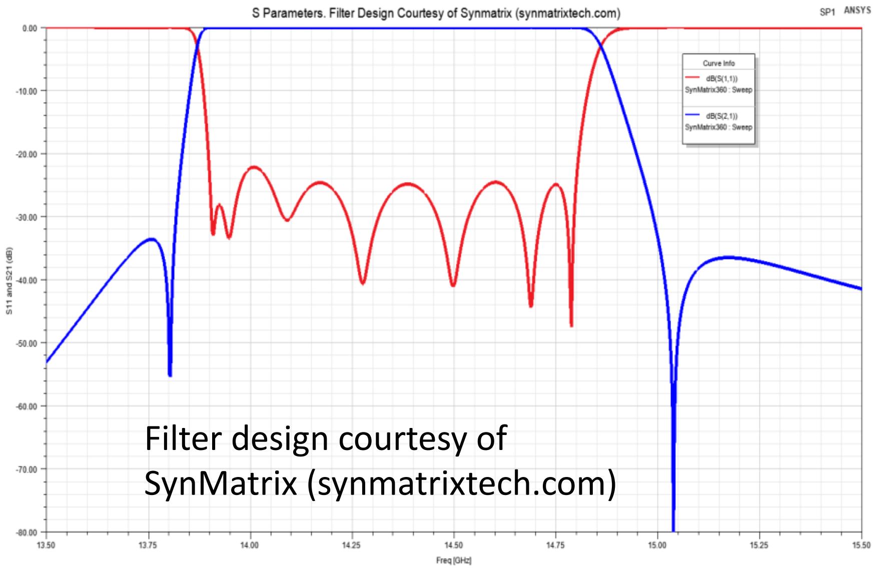
Physical Model



HFSS Port

Matched Generator

HFSS Model



$$\vec{E} = \sum_{i=1}^{M} \left(\alpha_i + \beta_i\right) \vec{e}_i \;\Rightarrow\; \boldsymbol{\beta} = S\,\boldsymbol{\alpha}$$

Fields on port expanded in terms of Eigen Modes of waveguide/transmission line:

- Each mode serves as a basis function on the port (accurate and efficient)
- By exciting the i^{th} mode ($\alpha_j = \delta_{ij}$), solver obtains i^{th} column of S

ANSYS HFSS Innovations Through the Years

- 1989 **HFSS v1.0**
  - Automatic adaptive meshing for accuracy
  - Transfinite element method
  - Vector finite elements with higher order
- 1999 **HFSS v7**
  - Matrix multi-processing
- 2005 **HFSS v10**
  - Spectral Decomposition Method (SDM), for parallel frequency points
  - Distributed Solve Option (DSO), for parallel design points
- 2007 **HFSS v11**
  - Iterative matrix solver
- 2008 **HFSS v12:**
  - Domain Decomposition (DDM)
  - Mixed Order Elements
- 2010 **HFSS v12.1**
  - HFSS-IE (3D MoM) with fast ACA solver
  - DDM with Mixed Order Elements
- 2011 **HFSS v13**
  - Finite Element – Boundary Integral (FEBI)
  - HPC meshing and fields post-processing
  - HFSS Time Domain Solver (hybrid), DGTD
- 2012 **HFSS v14**
  - Finite Antenna Array DDM
  - Hybrid FEM-MoM solver
  - HFSS-IE Physical Optics (PO) solver
- 2013 **HFSS 15.0**
  - Up to 2X faster matrix multi-processing
  - Parallel frequencies with MPI interconnect
- 2014 **HFSS R15.0.3**
  - Distributed memory direct matrix solver
  - Hierarchical HPC, Parameters w DDM
  - Phi meshing fast meshing for layered media
  - GPU support for HFSS Transient
- 2015 **HFSS R16**
  - HFSS Time Domain Solver (implicit), FETD
  - Auto-HPC setup
  - HFSS-IE MLFMM Fast Solver
- 2016 **HFSS R17**
  - Introduction of Savant SBR+ Solver
  - GPU for frequency domain solver
- 2017 **HFSS R18**
  - Broadband adaptive meshing
  - S-parameter only matrix solve
  - Multi-level hierarchical HPC
- 2018 **HFSS R19**
  - Improved GPU for Frequency domain
  - HFSS SBR+ GPU, 5x speed up
- 2019 **HFSS 2019R2**
  - Windows Azure Cloud
  - Fast HFSS Solve auto-setup option
- 2020 **HFSS 2020R1**
  - Improved distributed frequency efficiency
  - Improved GPU performance for SI/PI designs
  - Improved distribution for HFSS Regions in SIwave
- 2020 **HFSS 2020R2**
  - Reduced memory for Distributed Matrix solver
  - Direct matrix solve for 3D Component Array
- 2021 **HFSS 2021R1**
  - HFSS Mesh Fusion
  - Improved multi-port direct matrix solver
  - Improved iterative matrix solver

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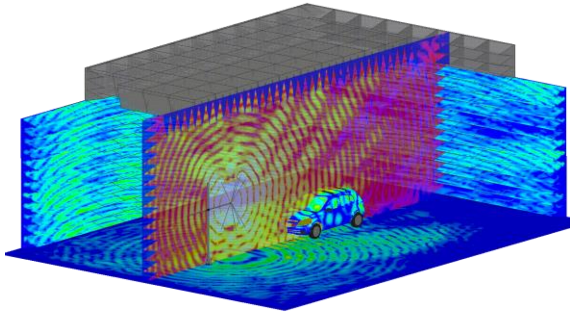
HFSS: Scaling to Extreme Complexity

- B. Boots, HFSS Simulation Technologies that Solve Complex Designs in Hours vs. Days

  *Solving models with up to **100M+ unknowns***

  Large system analyzed for comprehensive EM couplings

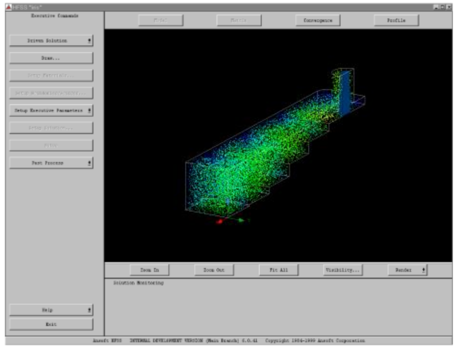


100M unknowns

Ansys Cloud

CAD Translation
Reduced memory footprint for Distributed Solver

10K unknowns
single frequency10+ hrs

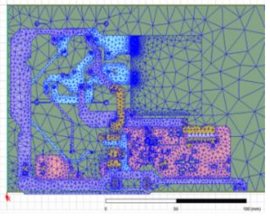


HFSS v1

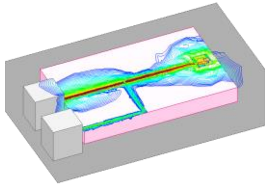
Phi Mesher
Distributed Matrix Solver

Auto HPC

10M unknowns



0.7M unknowns



HFSS 3D Layout

Macros and methodology
Seeding operations
Improved boundary conditions
Low frequency accuracy

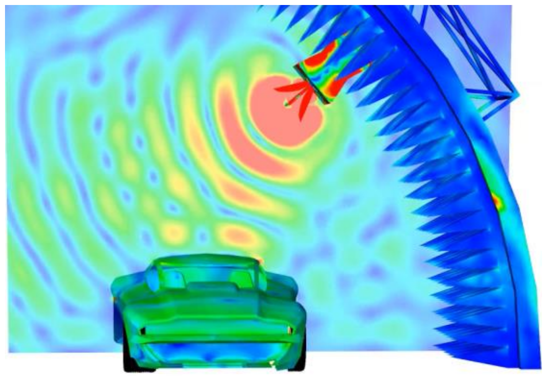
1990 1995 2000 2005 2010 2015 2020

"Gold standard" for device-level extraction

Ansys

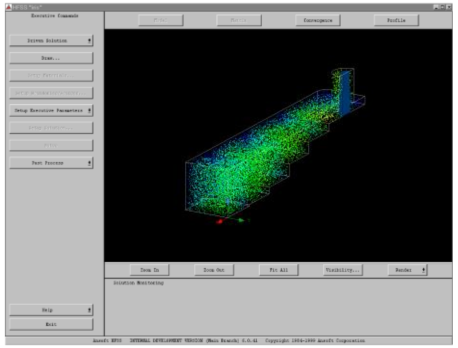
HFSS: …to Extreme Complexity and Beyond

- Today, 800M matrix unknowns, 8X capacity increase in two years



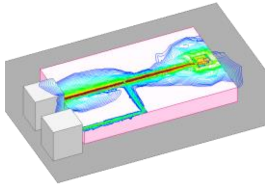
800M unknowns
In 2022
@"system-scale"

10K unknowns
single frequency10+ hrs



HFSS v1

0.7M unknowns



Macros and methodology
Seeding operations
Improved boundary conditions
Low frequency accuracy

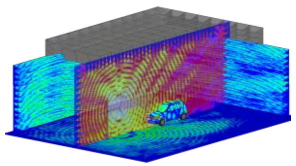
HFSS 3D Layout

Auto HPC

Phi Mesher
Distributed Matrix Solver

ECADXplorer Introduced
Improved GDS translation
Reduced memory footprint for Distributed Solver

100M unknowns



10M unknowns

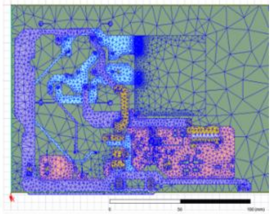


Figure 17. Overview of the HFSS model mesh.

1990 1995 2000 2005 2010 2015 2020 2022

"Gold standard" for device-level extraction

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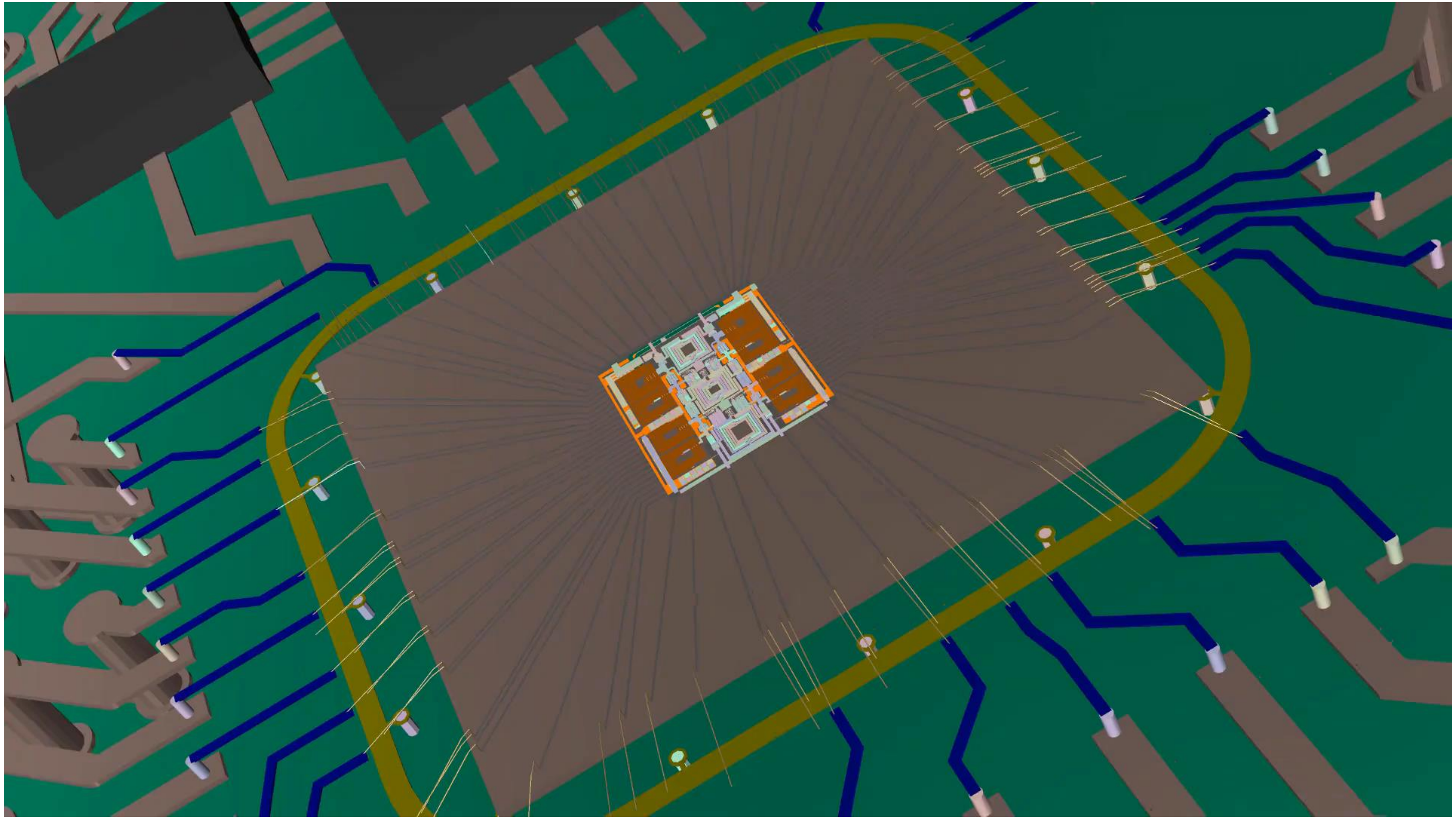
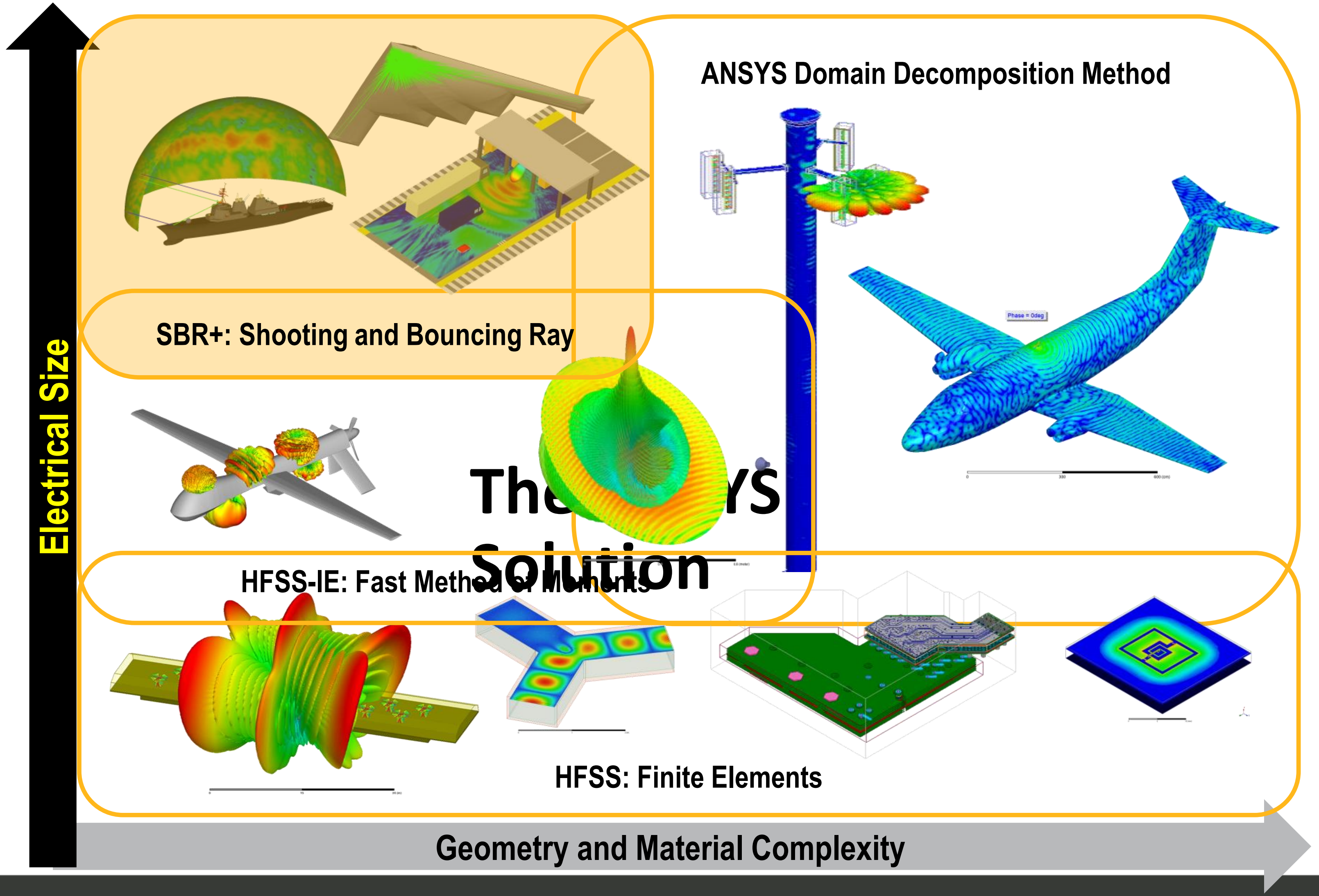
HFSS at Scale

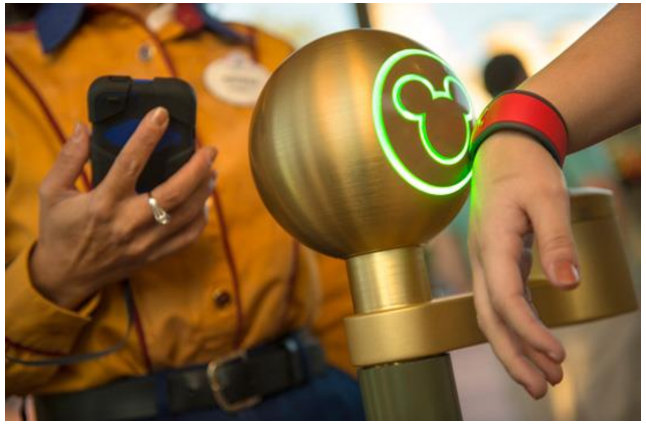


The Ansys Electromagnetics Simulation Portfolio

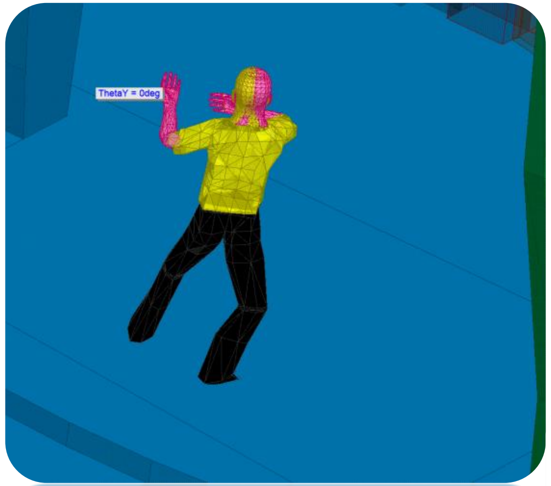


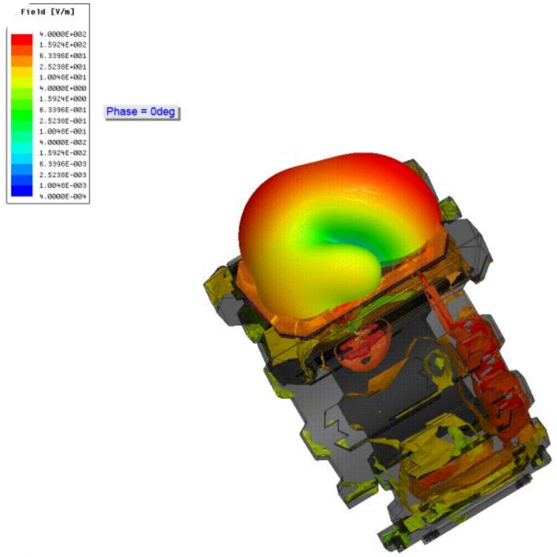
The Internet of Things

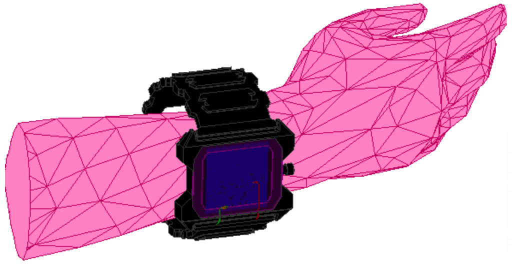
The Internet Of Things Is Already Here!



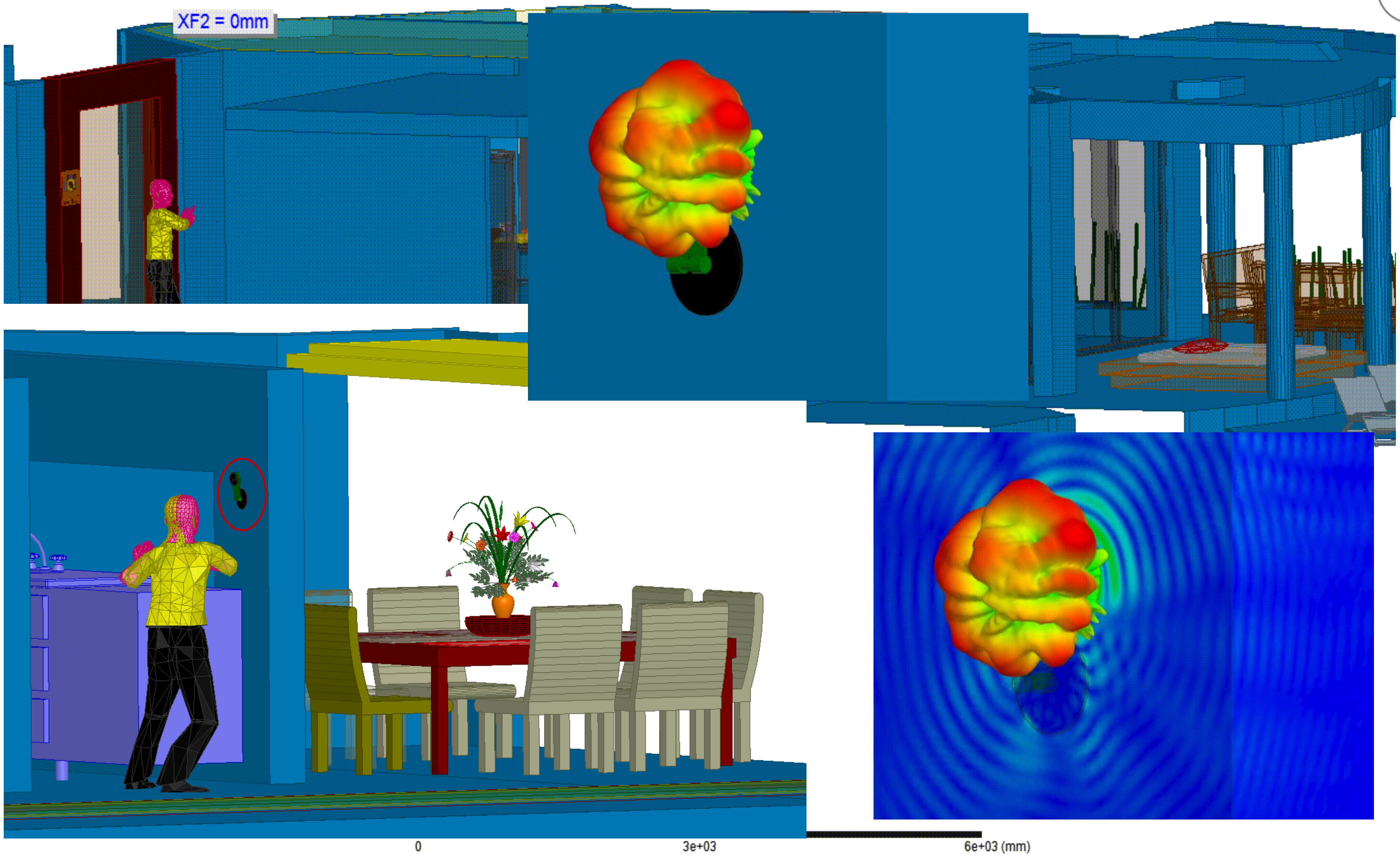
Human Model & Smart Watch …





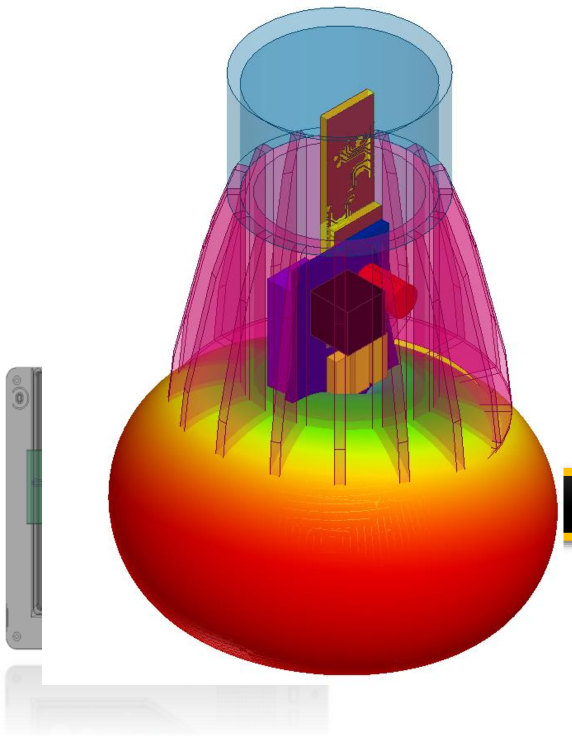


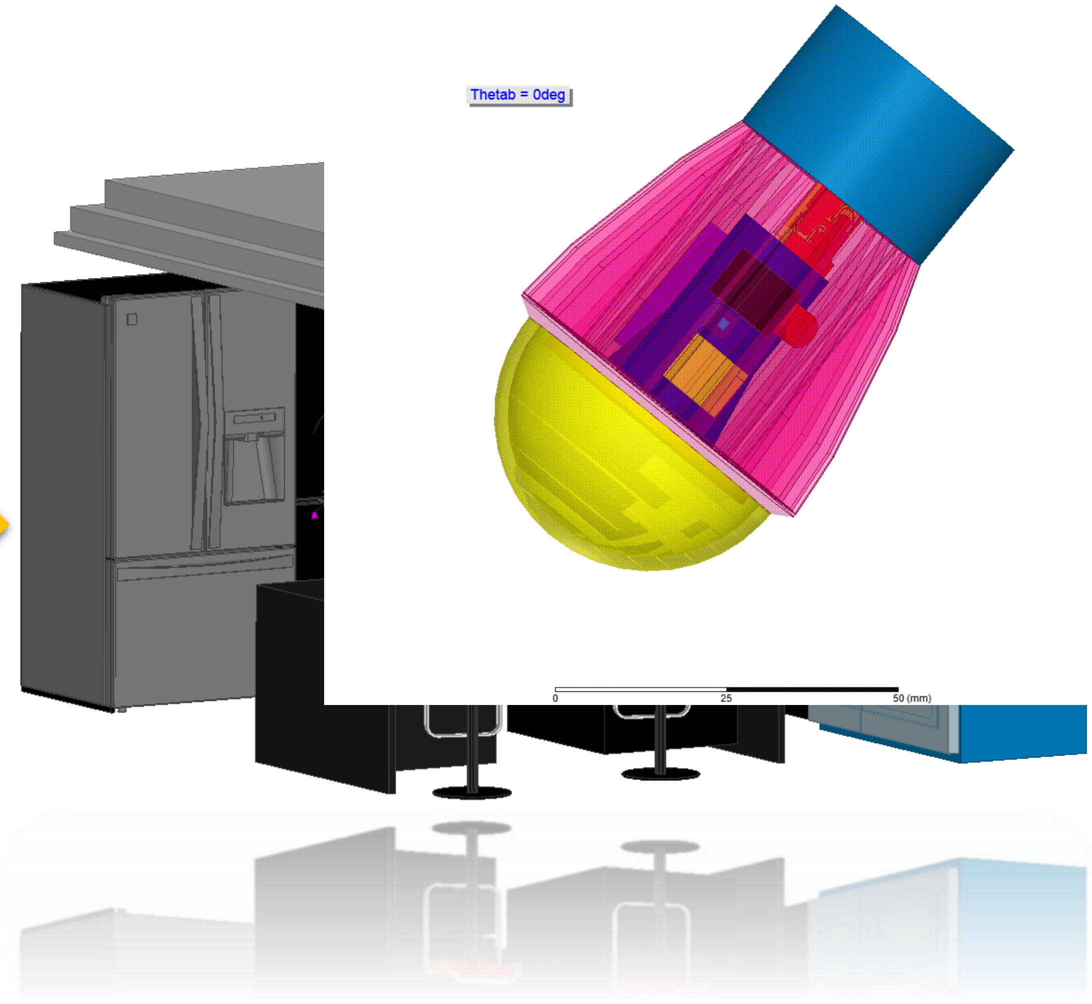
Smart Motion Detection & Surveillance Camera



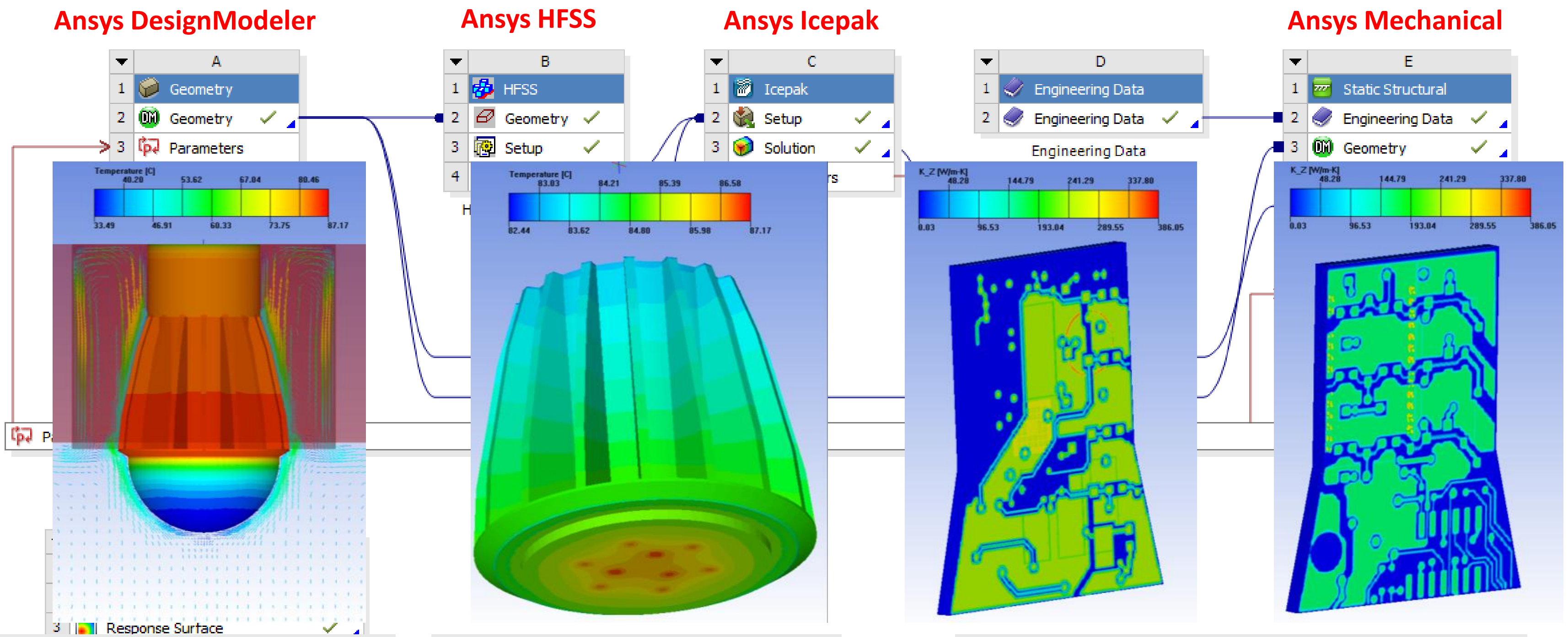
Energy Control Unit + Light Bulb

HFSS





Thermal Analysis of LED Light Bulb

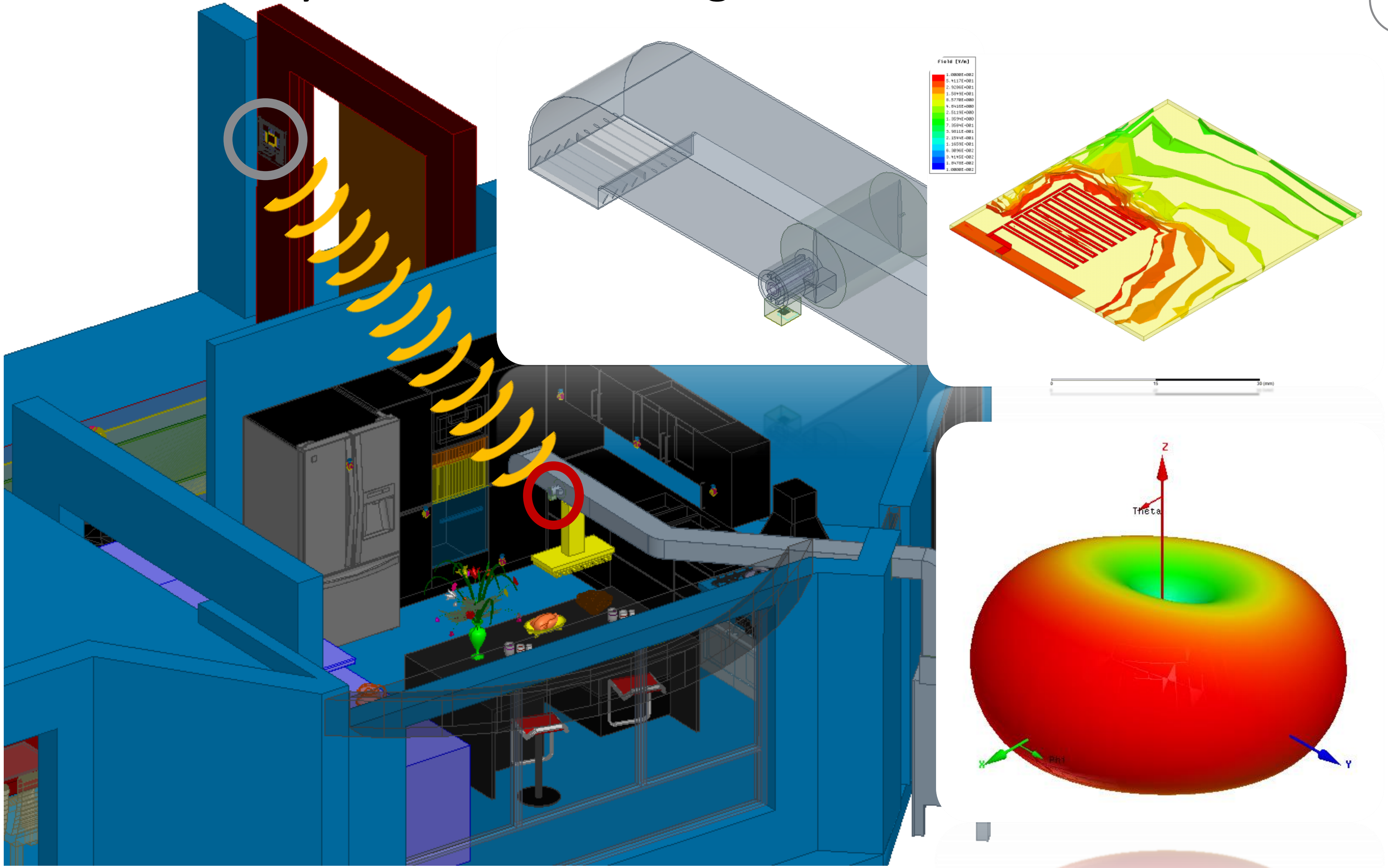


Temperature contour of the LED light bulb (external parts)

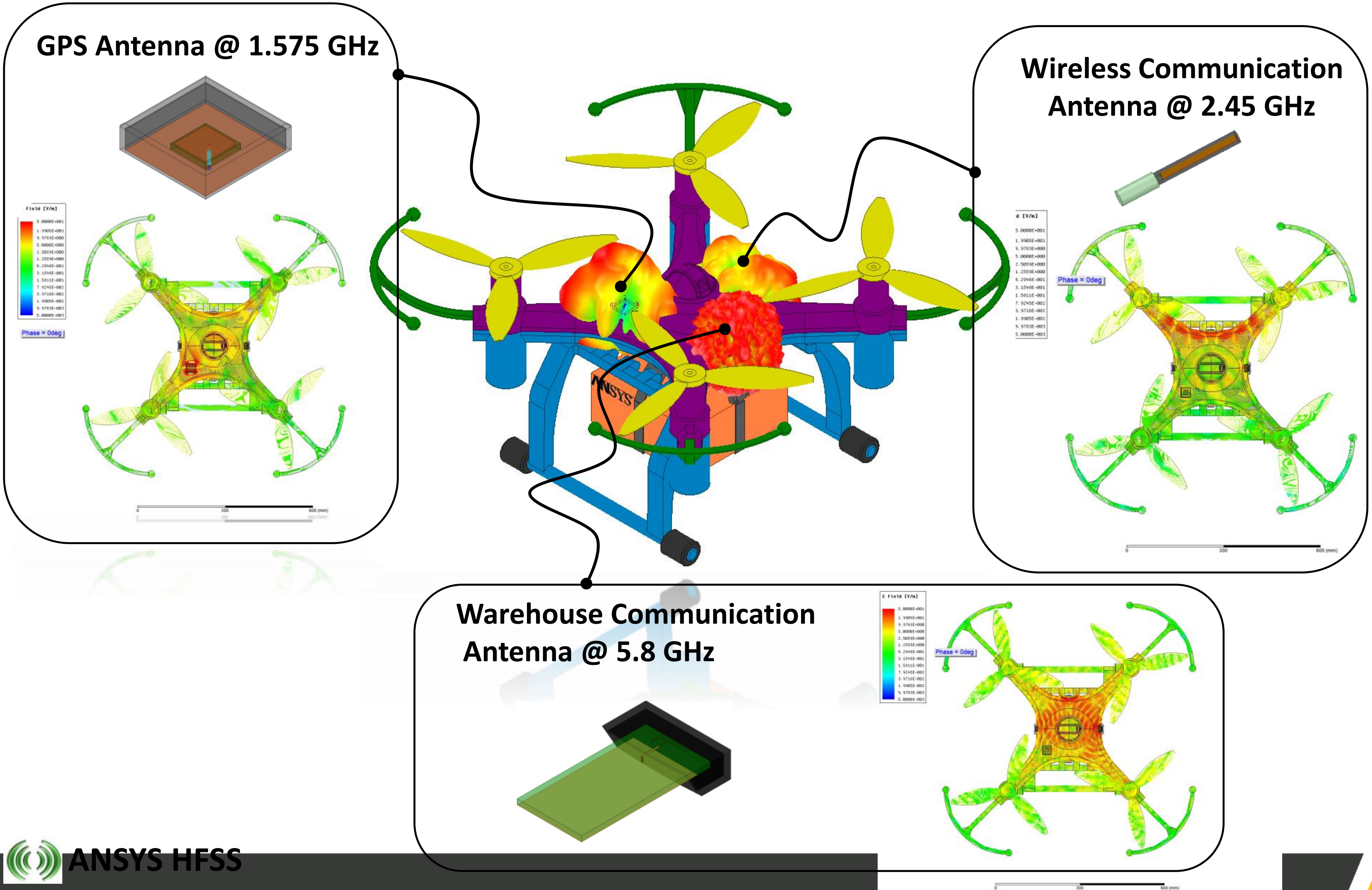
Temperature contour of the LED heatsink and LED sources

Orthotropic thermal conductivity map (K_z) of the PCB left: top layer; right: bottom layer

Smart Home HVAC System with Sensing Actuator

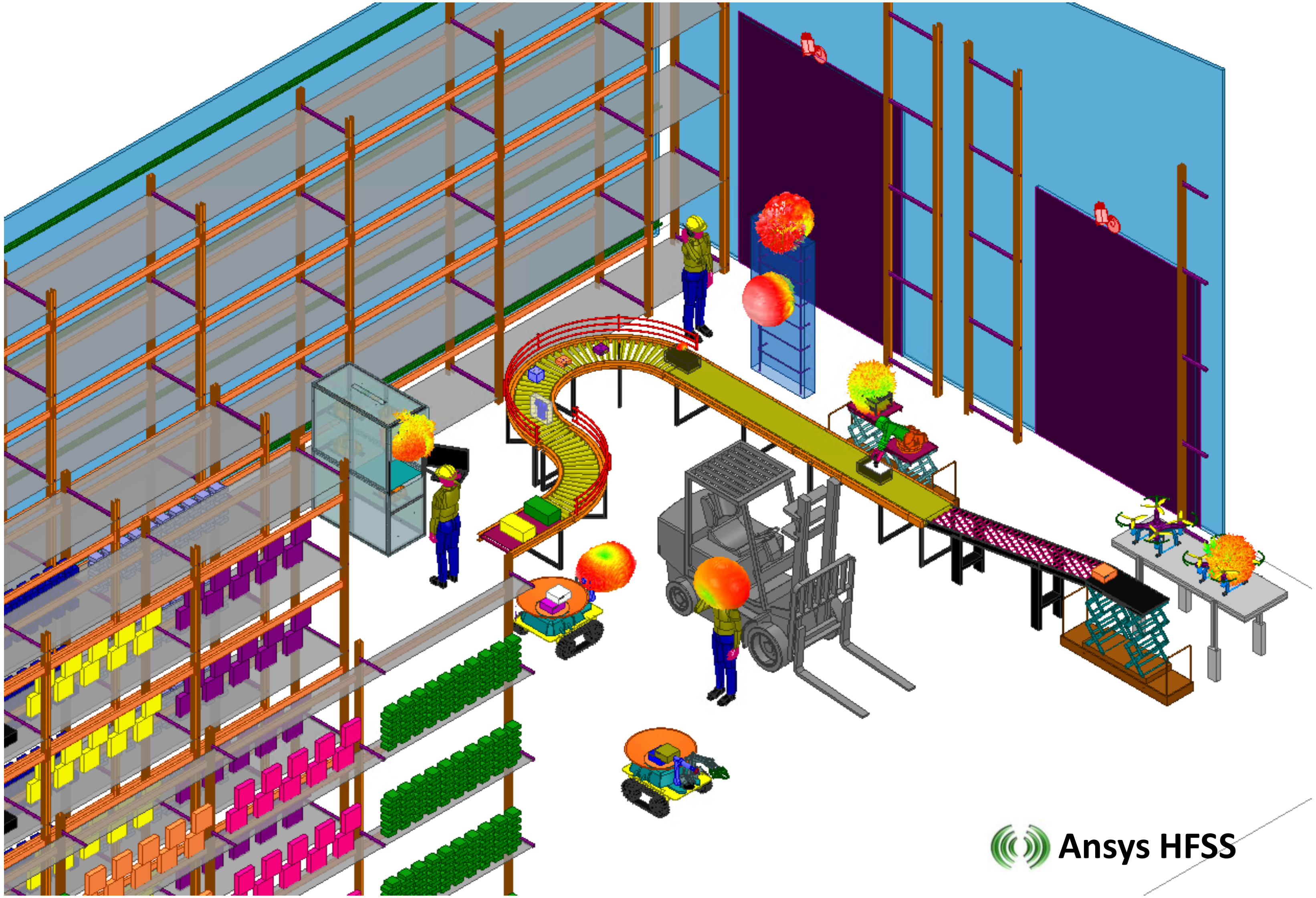


Ansys Industrial Drone Model



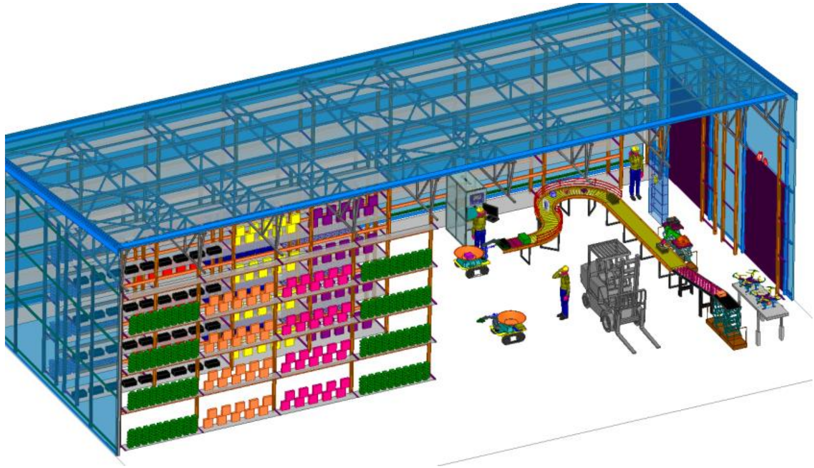
Full Warehouse RF Modeling

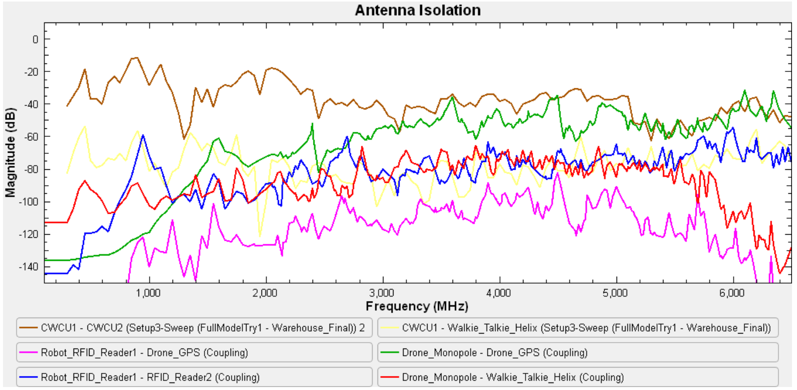
Electronics



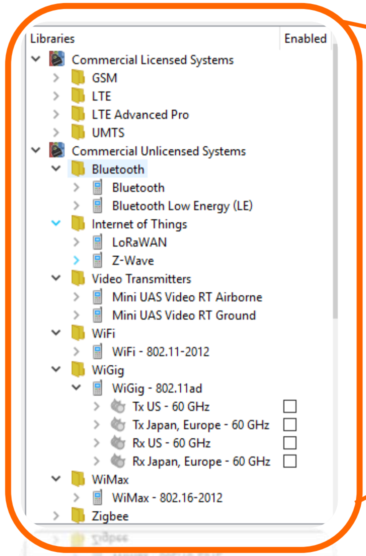
Ansys

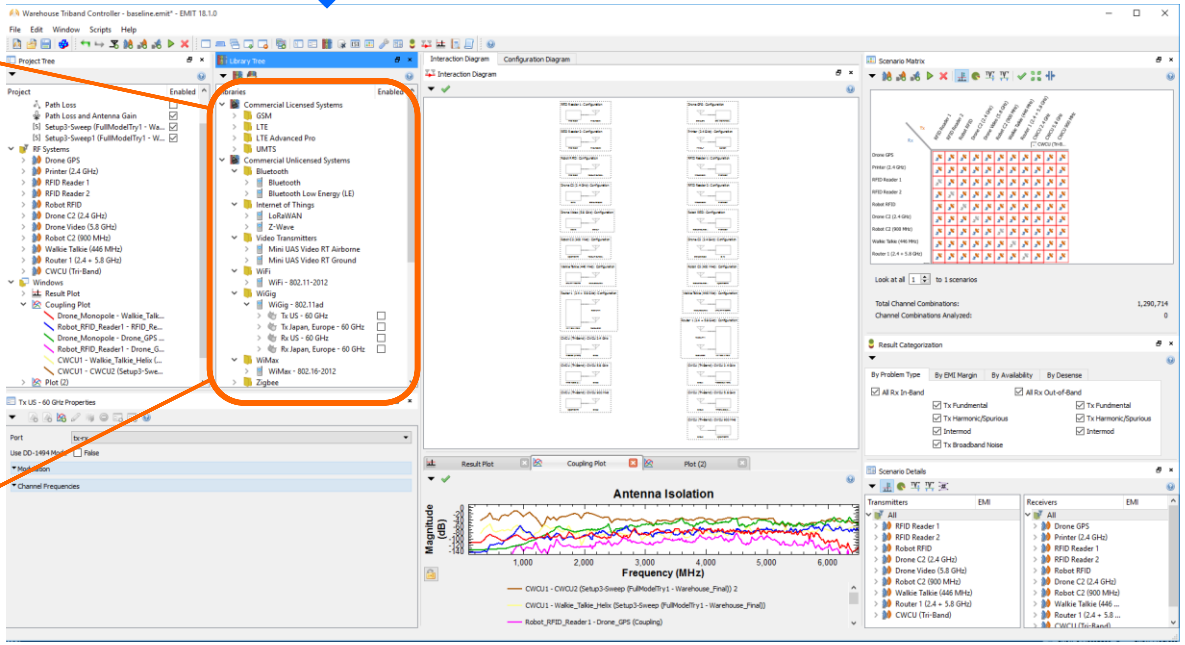
Full Warehouse RF Interference System





Electronics





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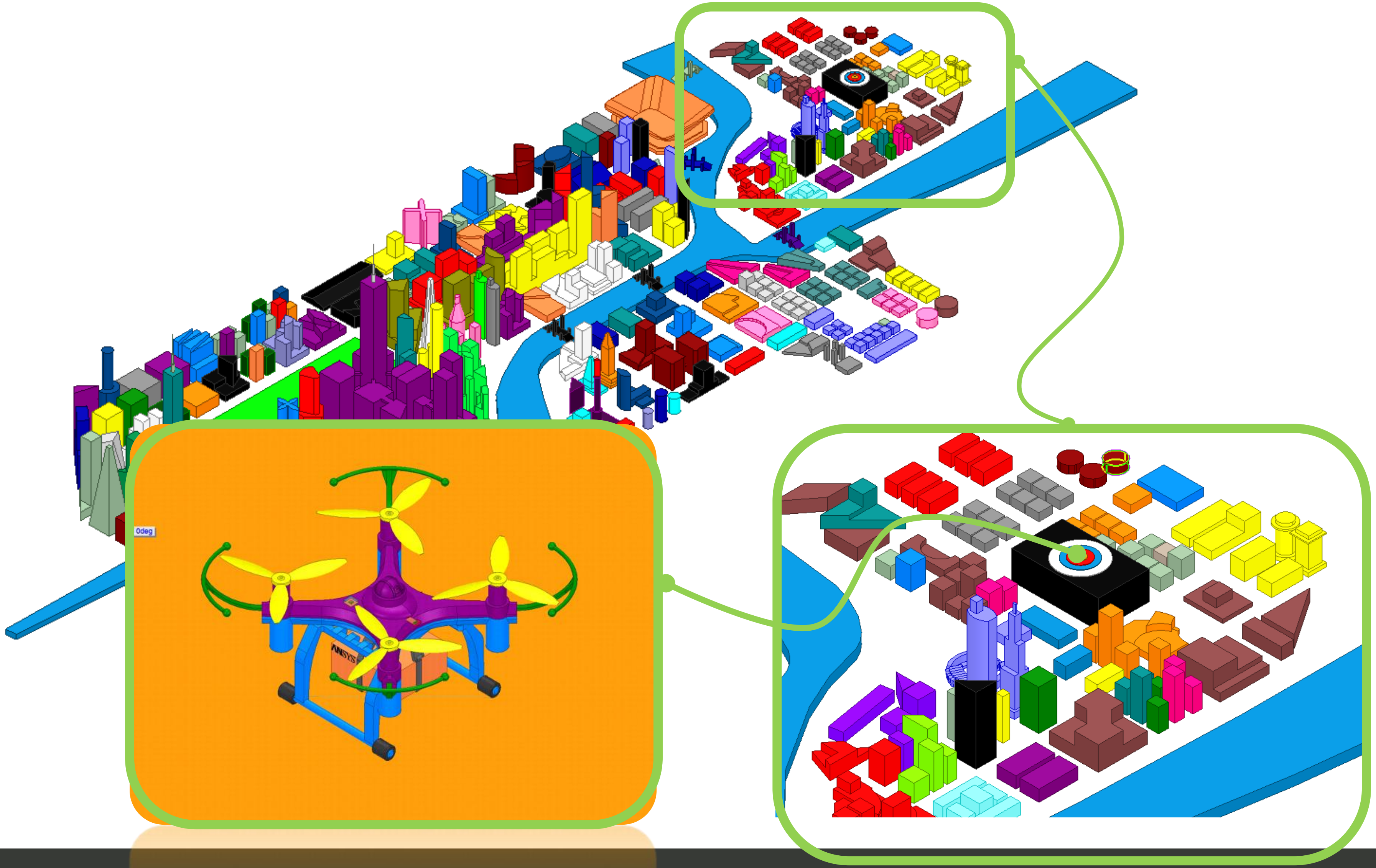
Touchdown – Mission Accomplished …

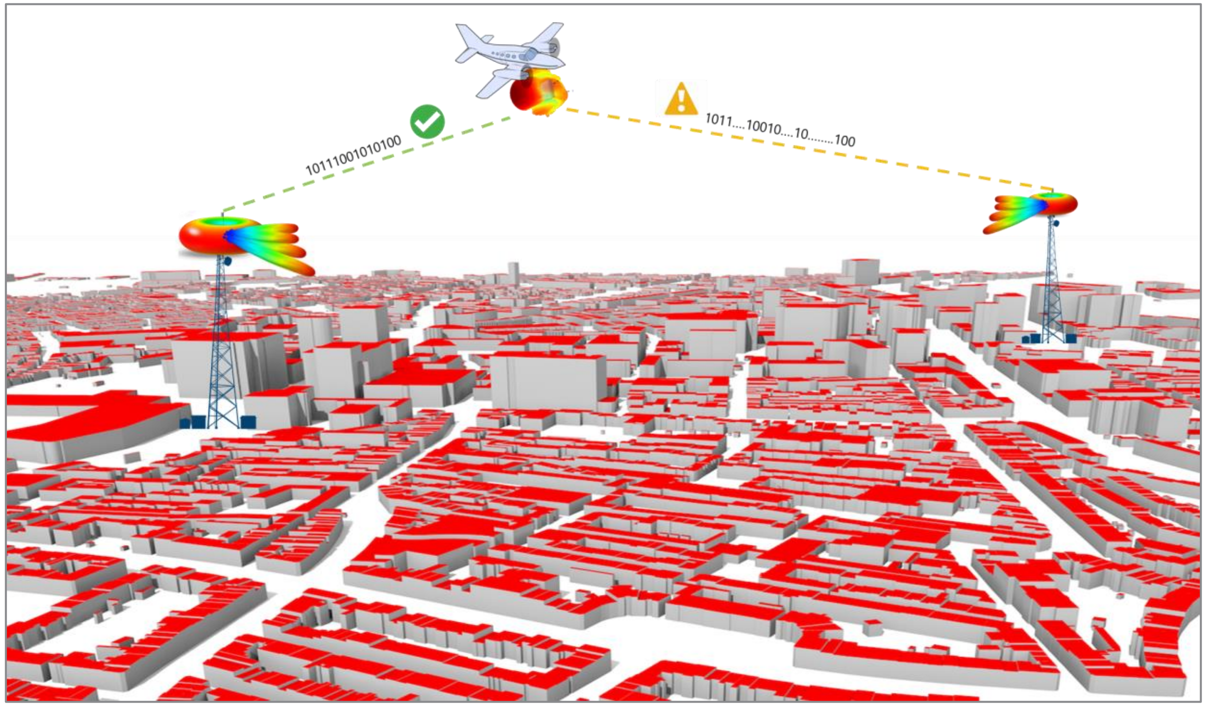


Ansys

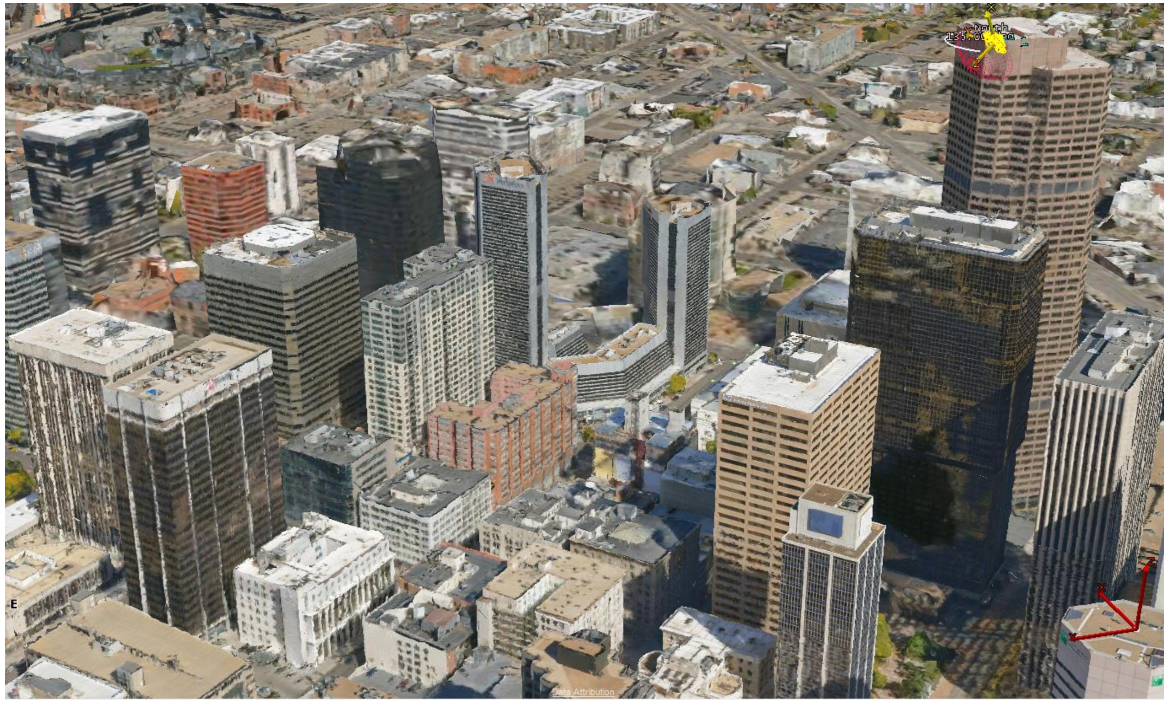
Wireless channel modeling in *accurate* virtual twin environments

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

…but for FR2 bands, better fidelity is needed.



Open Street Maps city model
with simple “block” buildings



aerometrex

5cm Resolution City Model
Based on measurements

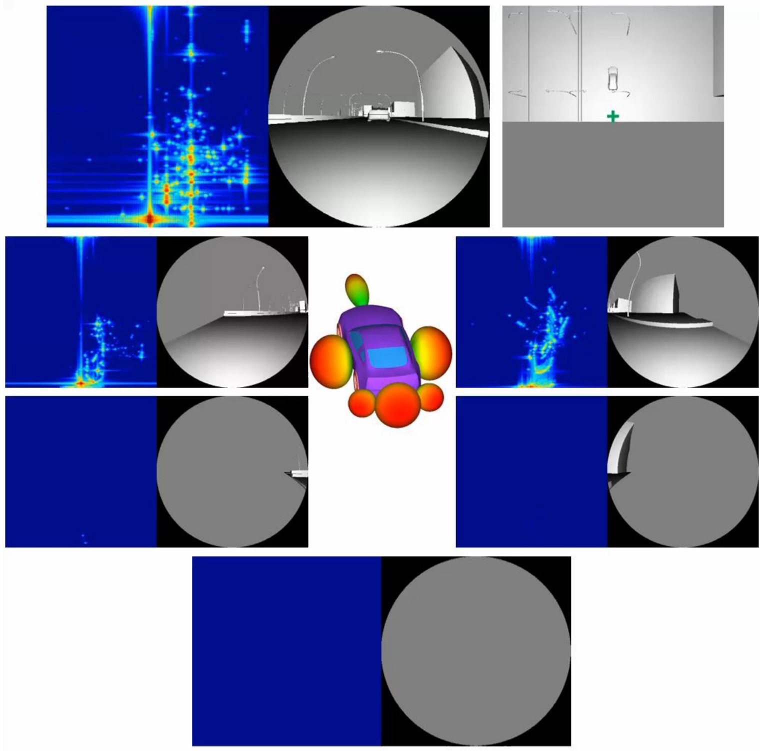
Denver city model courtesy of Aerometrex
https://aerometrex.com
> 10M geometry facets

Ansys

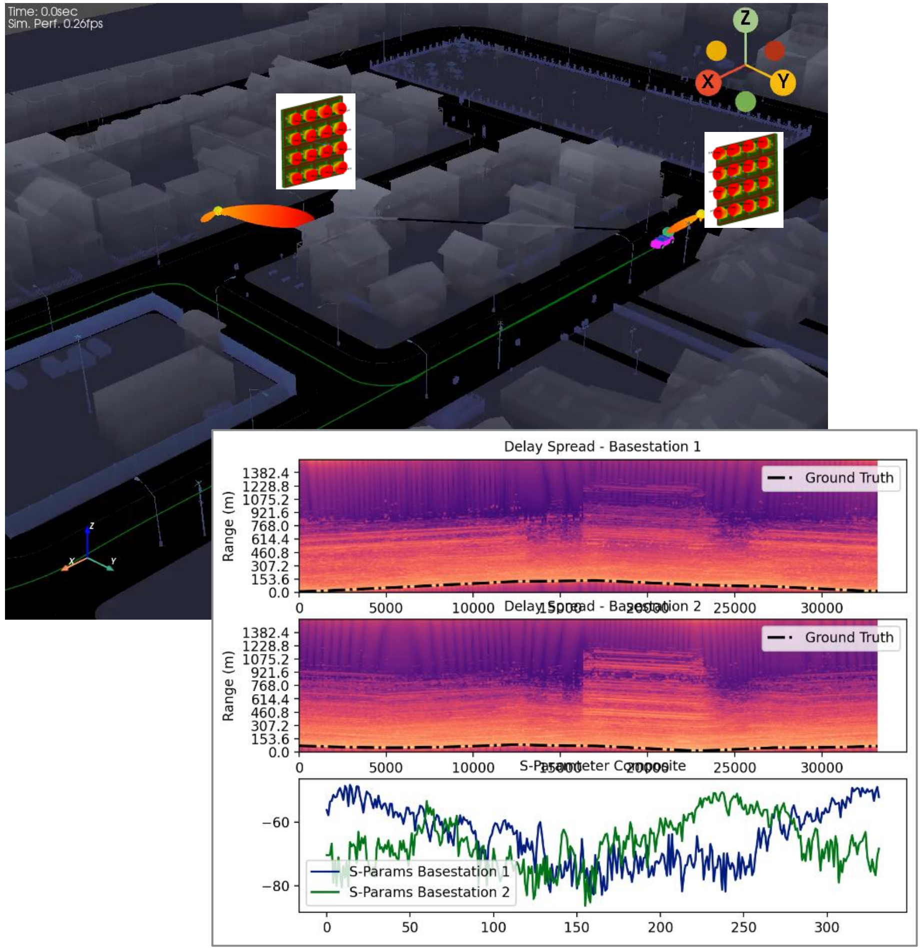
Real-Time high-frequency wireless channel and radar modeling

- **Shooting and Bouncing Rays (SBR) EM simulation on GPU**
- **Physics-accurate** antennas, environments and platform motion (including micro-Doppler)
- **Produces synthetic radar data** for switchable waveforms
- Operates at or near **real-time** on high-end Nvidia GPU devices for MIMO radar systems
- Available through API or through application mission simulation (STK or AVxCelerate)

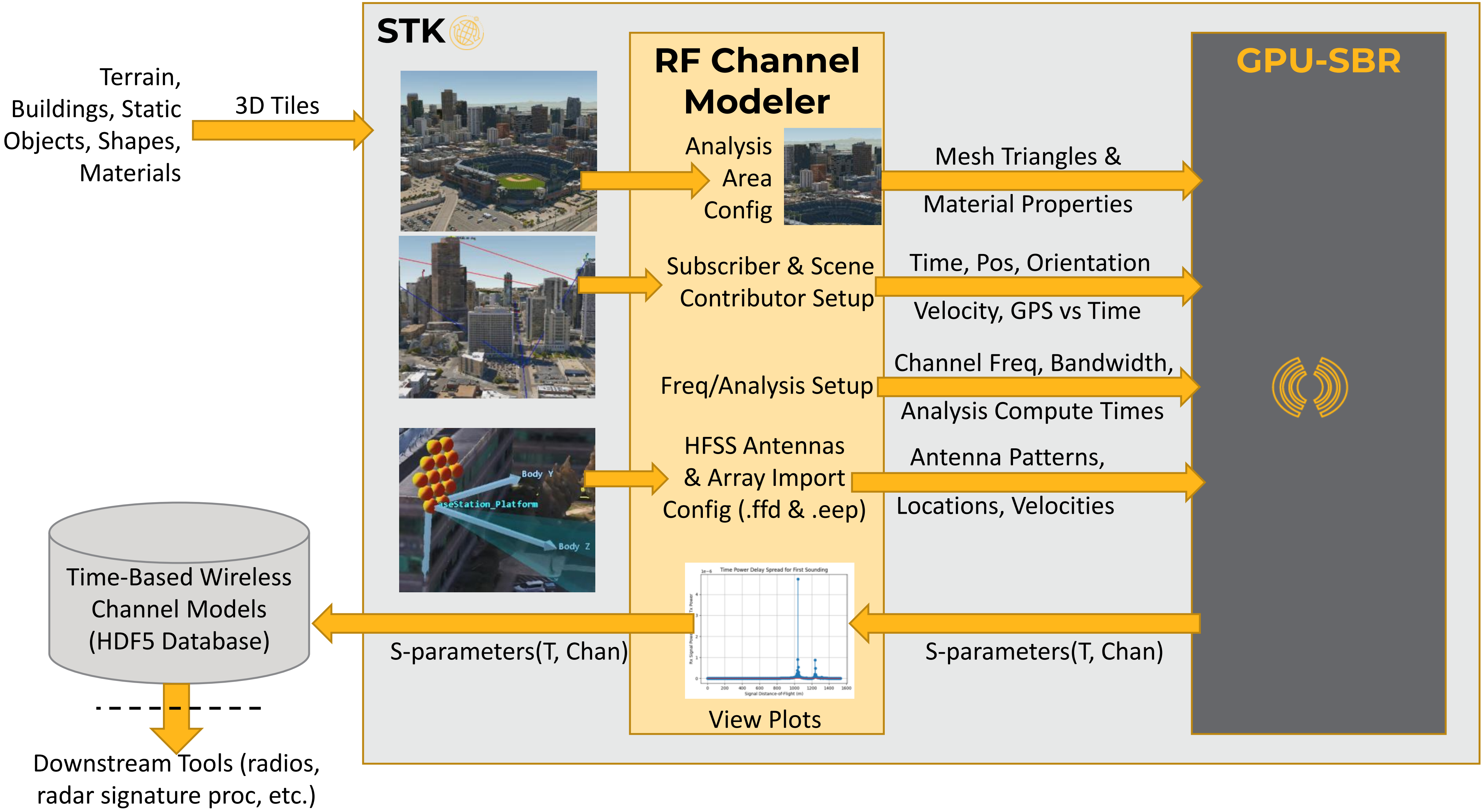
Ansys Real Time Radar simulation *applied to 6 radars on the same vehicle, showing synthetic range-Doppler signatures*



Ansys GPU-SBR simulation *applied to 5G MIMO wireless channel modeling, showing MRT adaptive beamforming*

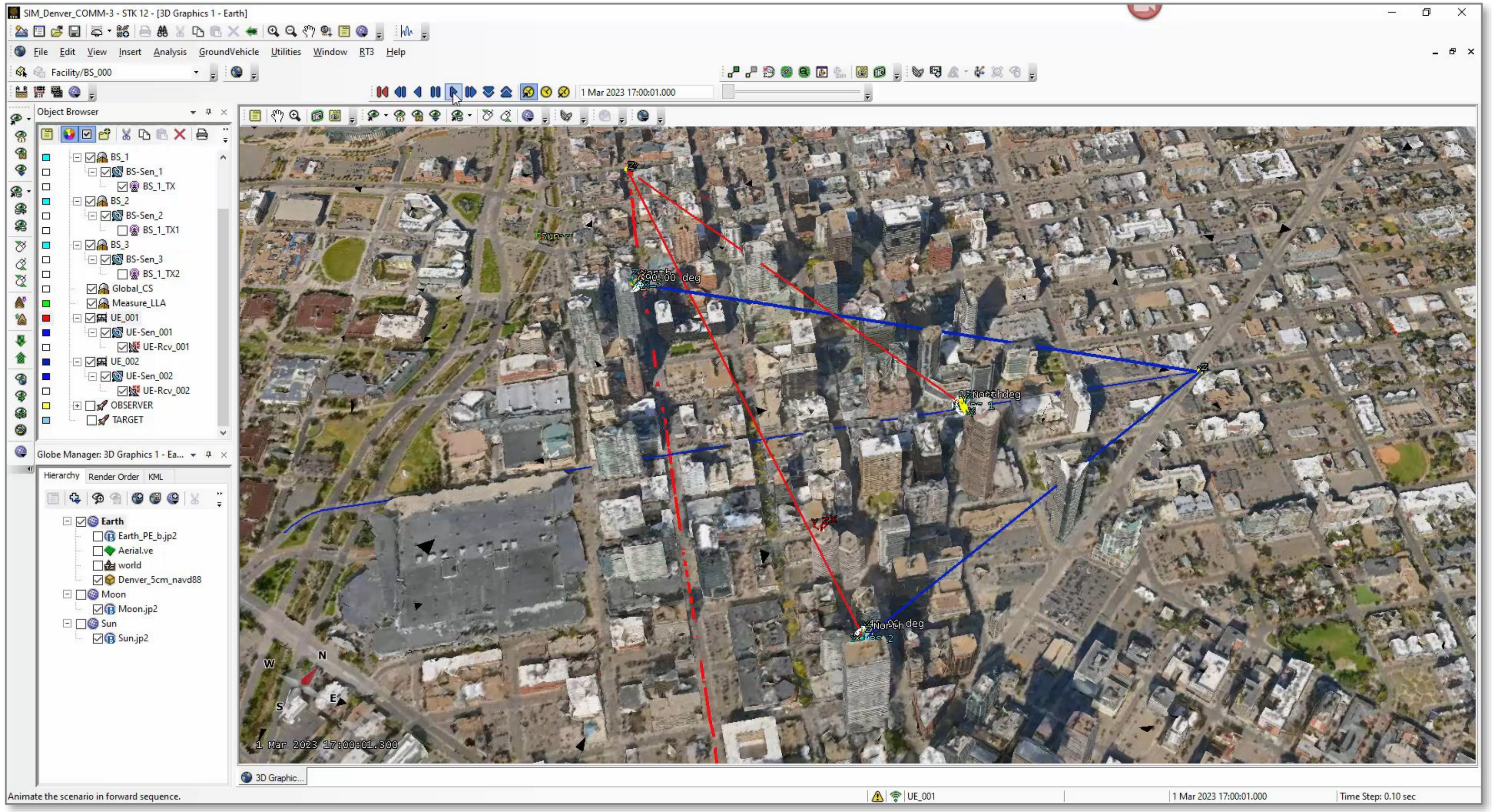


Introducing the STK RF Channel Modeler for 2024R1!



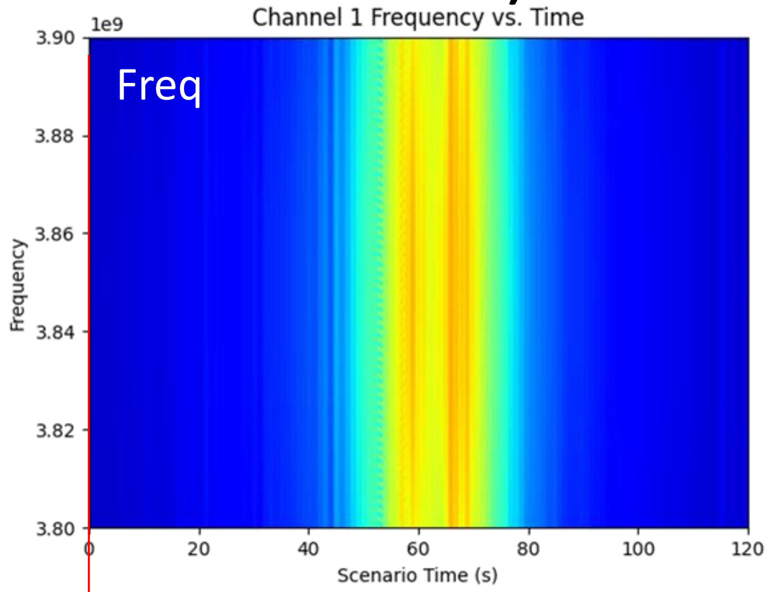
Frequency and Time domain response (Mobile-to-Mobile)

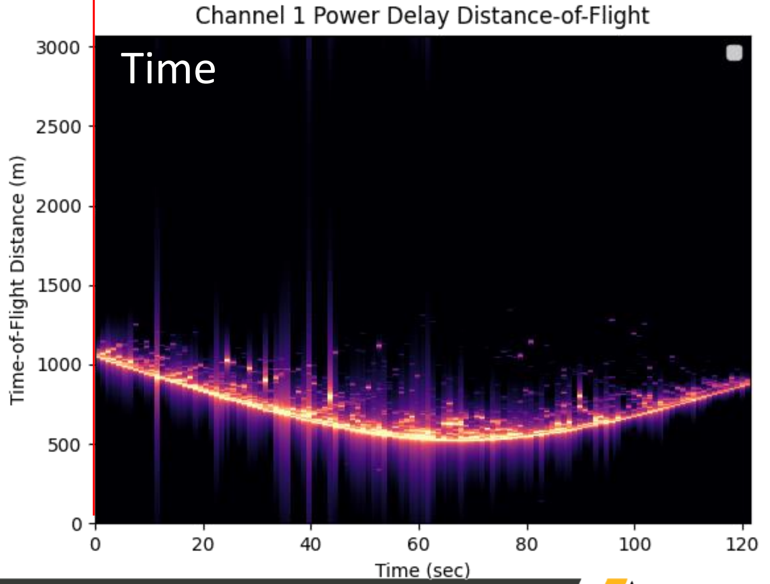
Complete wideband MIMO channel modeling at real-time rates



100 MHz Bandwidth channel modeled at 3.87 GHz

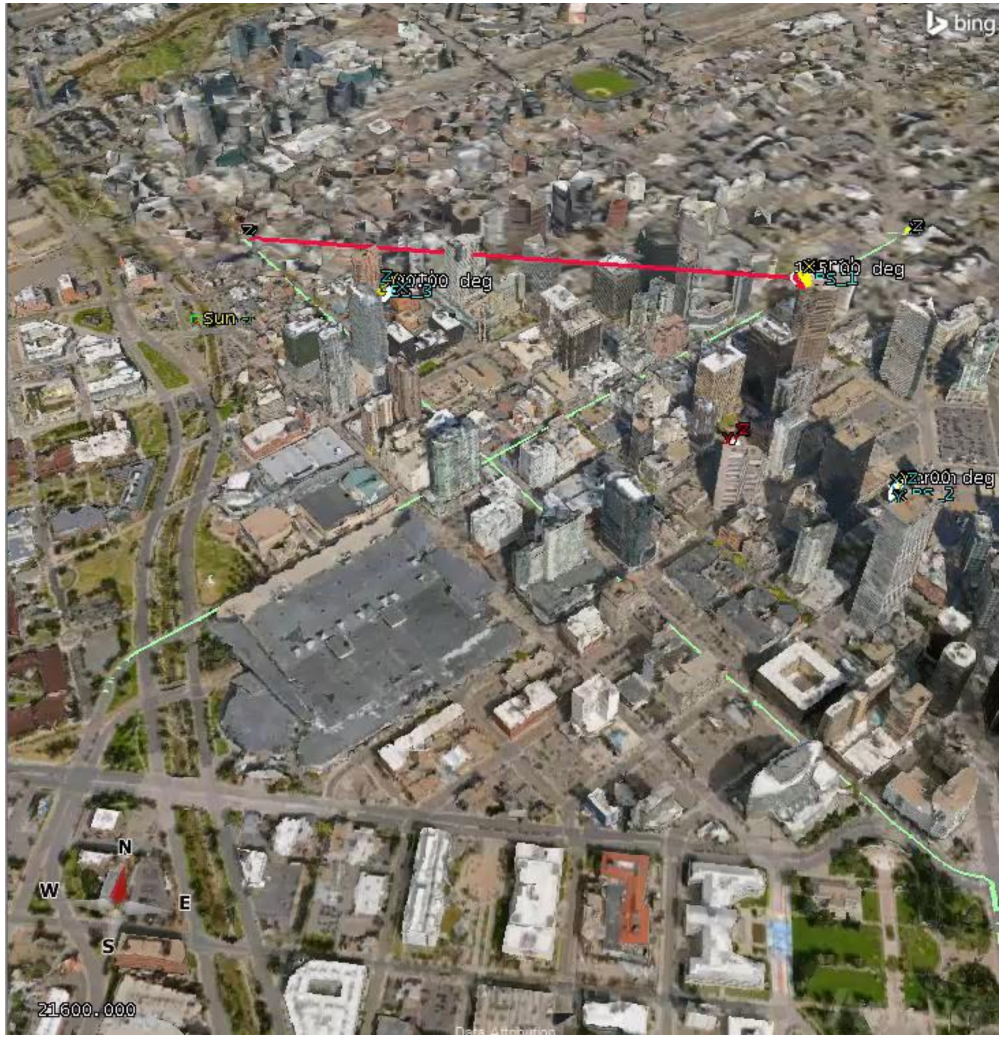
Channels sampled every 0.01 sec over 120 sec





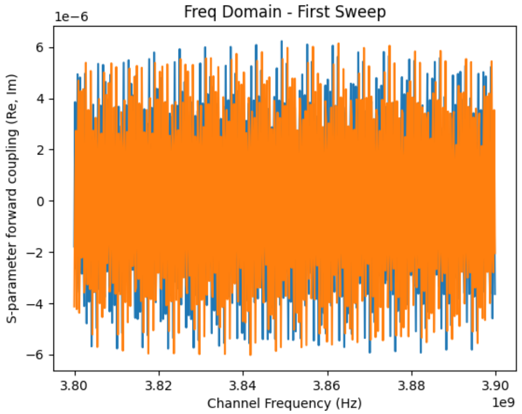
Scenario animation in STK

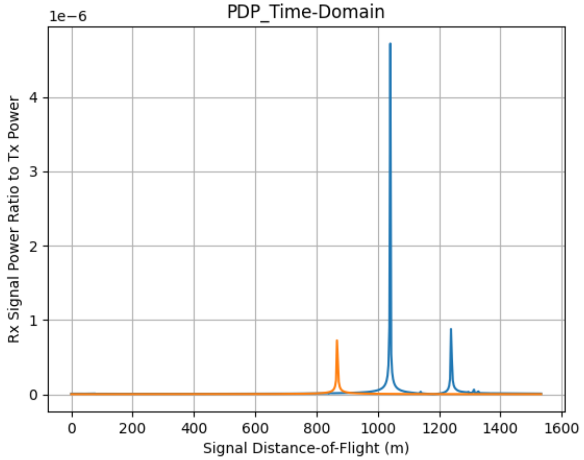
- **64 total channels sounded every 0.01 sec**
  - Each BTS has 32 Rx channels
  - Each UE has 2 Tx channels
- **120 scenario seconds (2 minutes) computed**
  - 12,000 soundings per channel
  - Total of 768,000 channel soundings
- **100 MHz bandwidth computed**
  - 512 frequency samples/sounding
  - Total of 393,216,000 freq samples
- Data computed on Dell laptop with NVidia Quadro RTX5000 GPU
  - Approx 20 minutes to simulate in STK

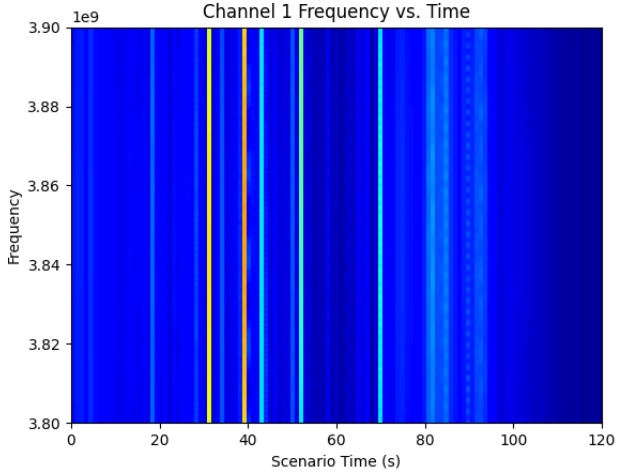


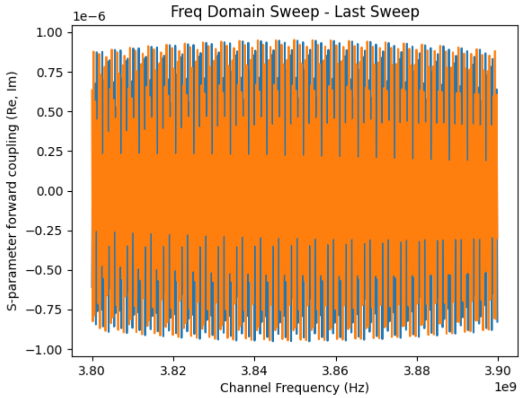
UE1 to Base Station (UL) antenna/pol 1

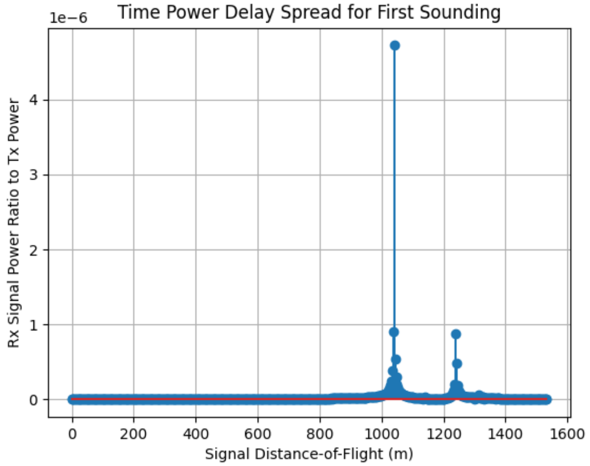
Not shown: 63 additional channels (UE1/2 to gNodeB antenna system)

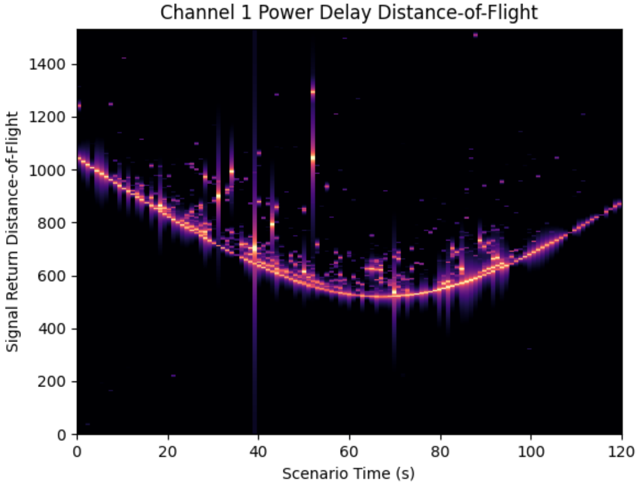








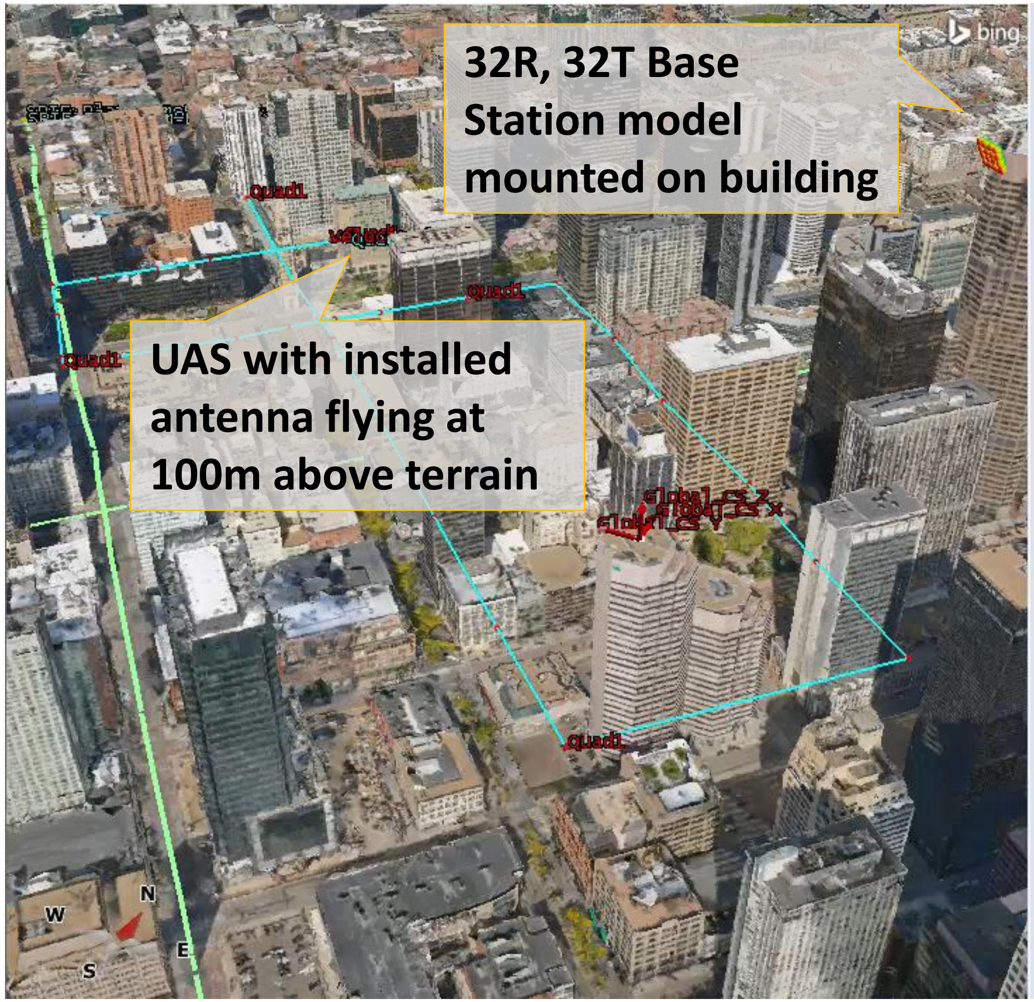




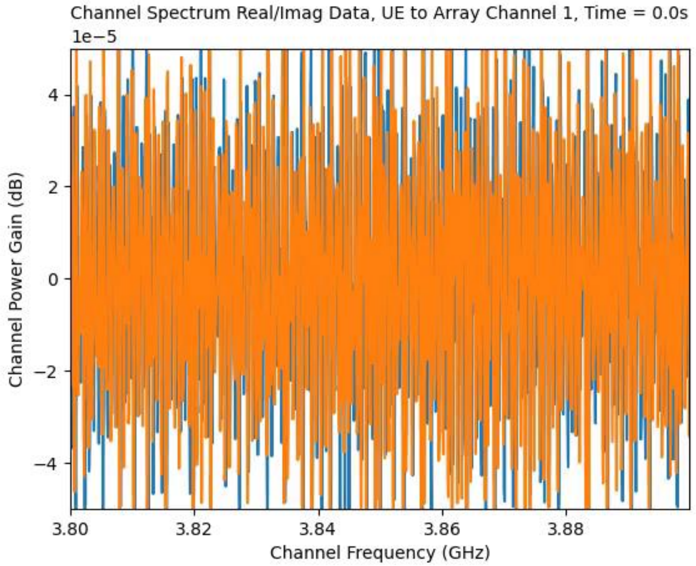
12,000 channel soundings
Over 120 scenario_seconds

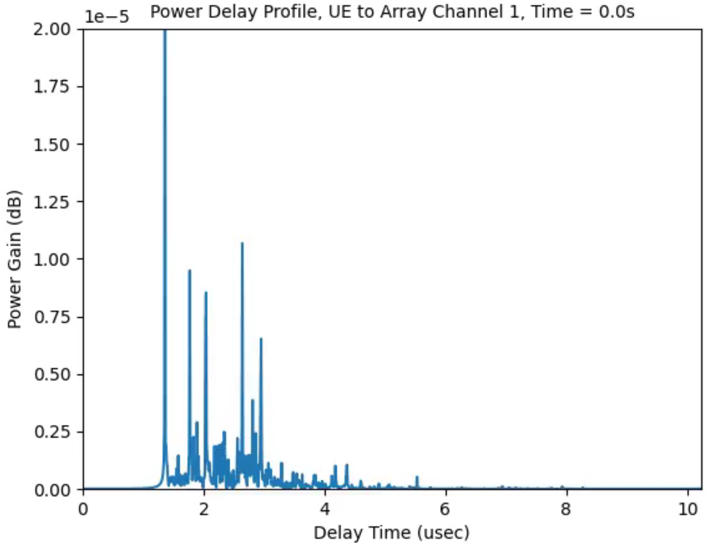
Ansys

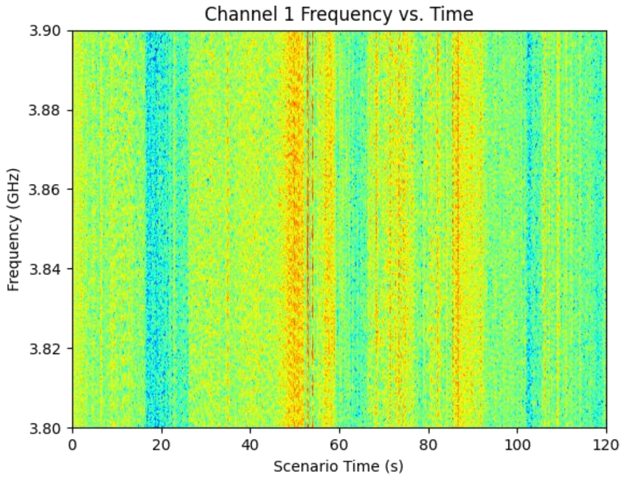
Wideband Channel Modeling for mobile airborne subscribers

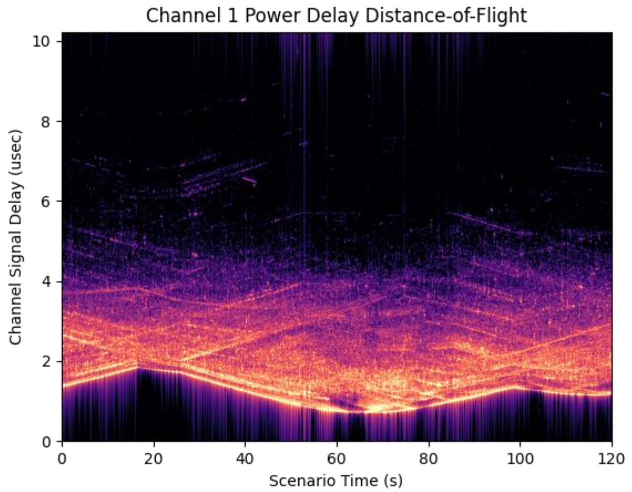


Not shown: 31 additional channels (UE to gNodeB antenna system)









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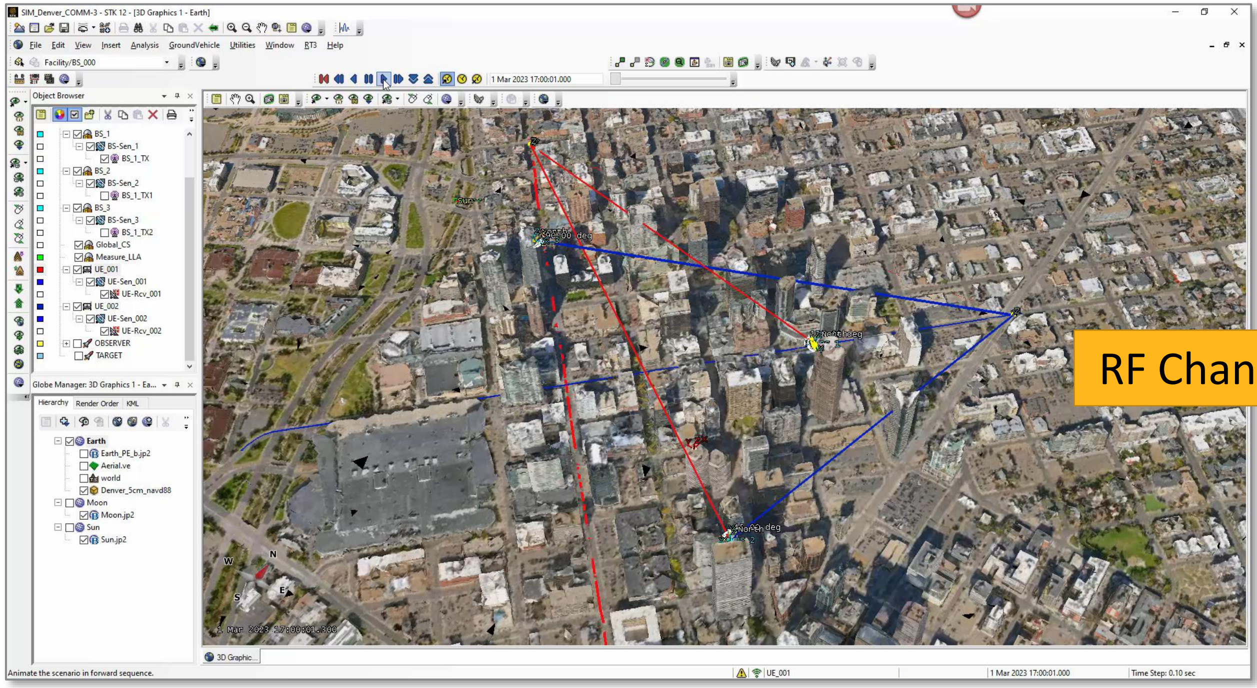
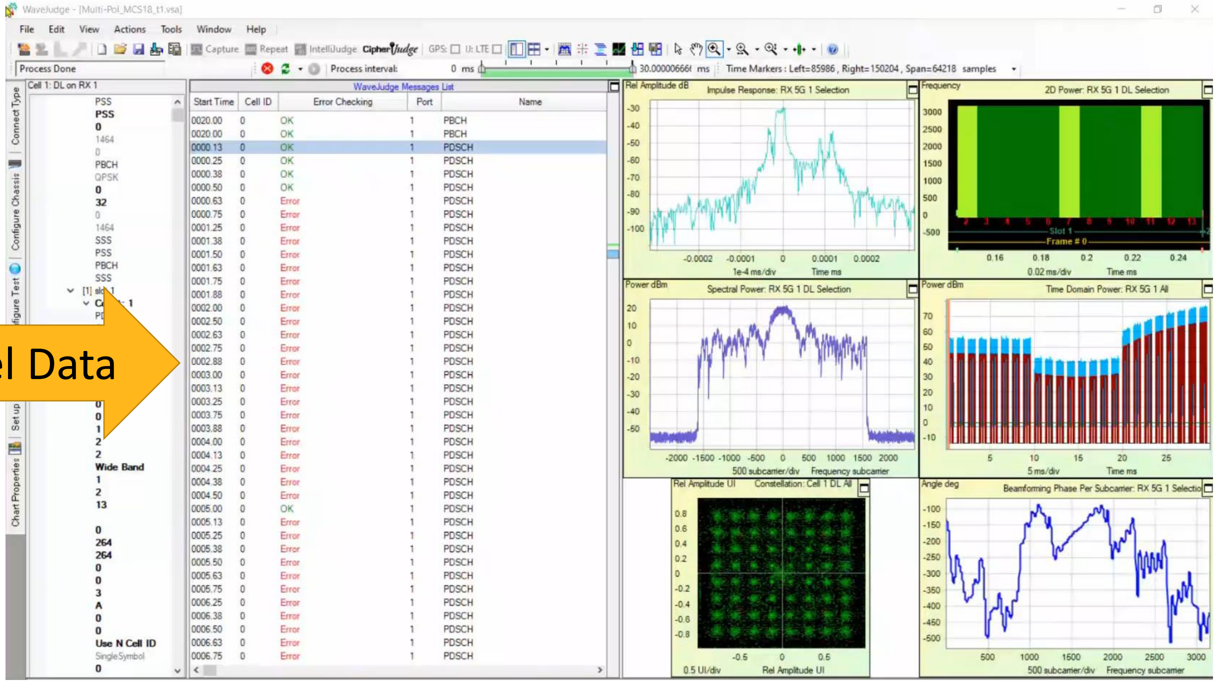
Future: Collaboration with Keysight for HiL radio testing/validation

Ansys STK RF Channel Modeler



RF Channel Data

Keysight PropSim/WaveJudge

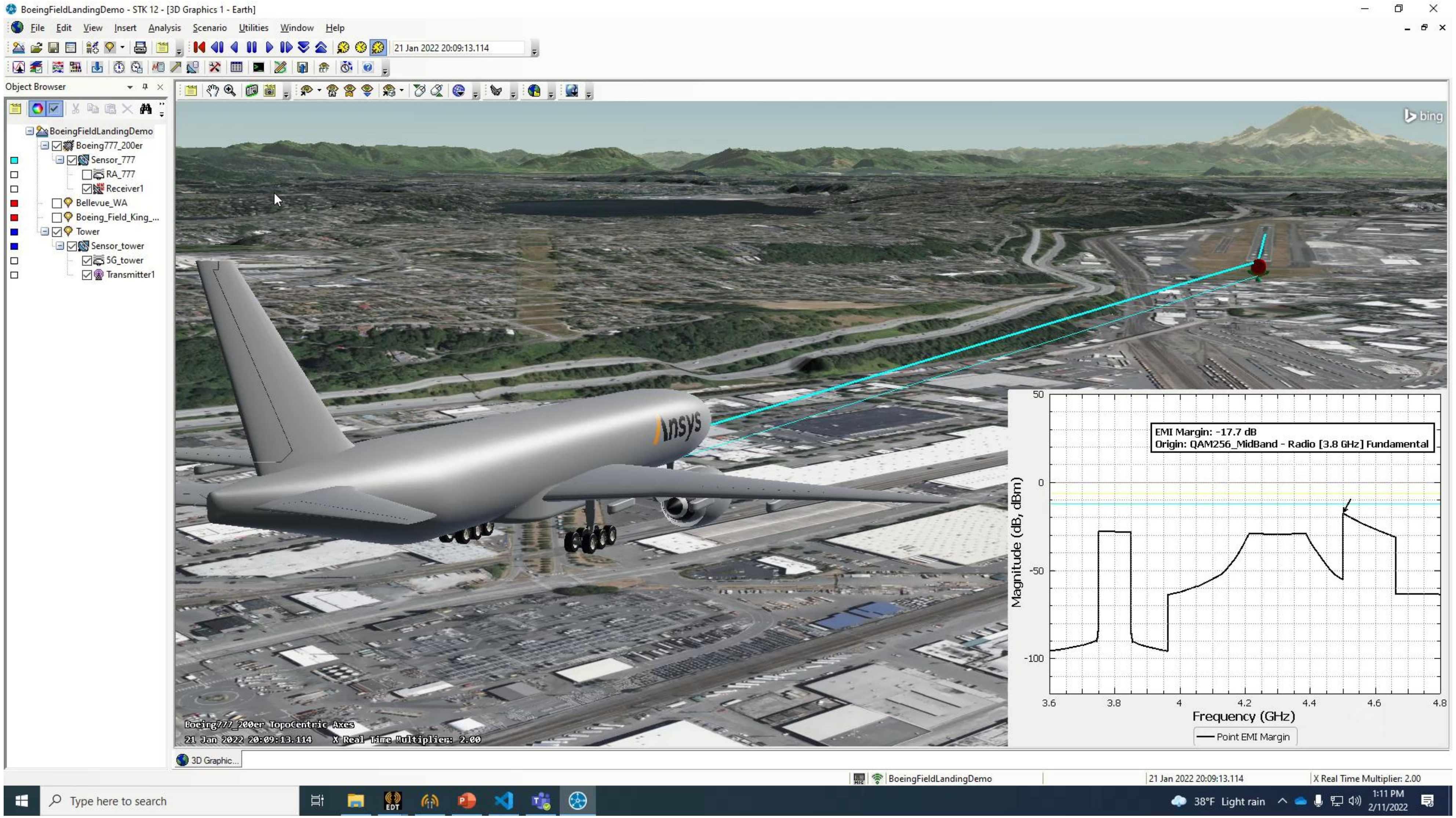


100 MHz Bandwidth channel modeled at 3.87 GHz

Channels sampled every 0.01 sec over 120 sec

Keysight PropSim GCM and WaveJudge show 5G Block-Level KPIs for Level1-Level2 emulation

5G Deployment and Aircraft Radar Altimeters



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Thank You