Aerial Omniverse Digital Twin for 6G RAN

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Introduction

Key challenges/opportunities for 6G RAN R&D platform:

- **How to bring air interface design and network operations closer?**
  - **Goal:** observability at design time of actual network efficiency
  - **Observation:** deployment and operations are site-specific

- **How to train and exercise AI-based concepts before field?**
  - **Goal:** identify where AI can make the largest difference
  - **Observation:** analysis requires large-scale and highly realistic simulation environments

RAN Digital Twin - Requirements

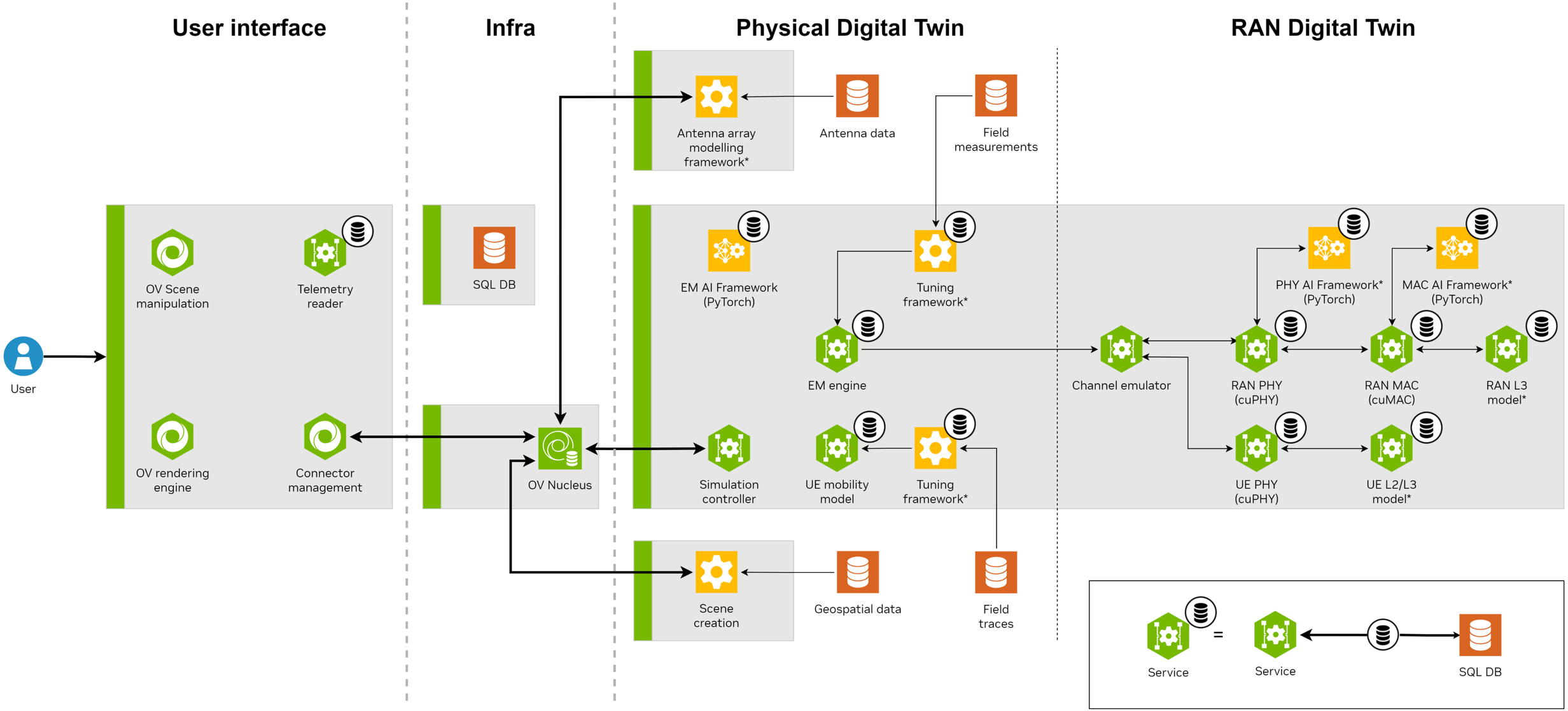
The answer to such questions is a new class of

- site-specific
- large-scale
- highly accurate

simulation tools: **RAN digital twin**

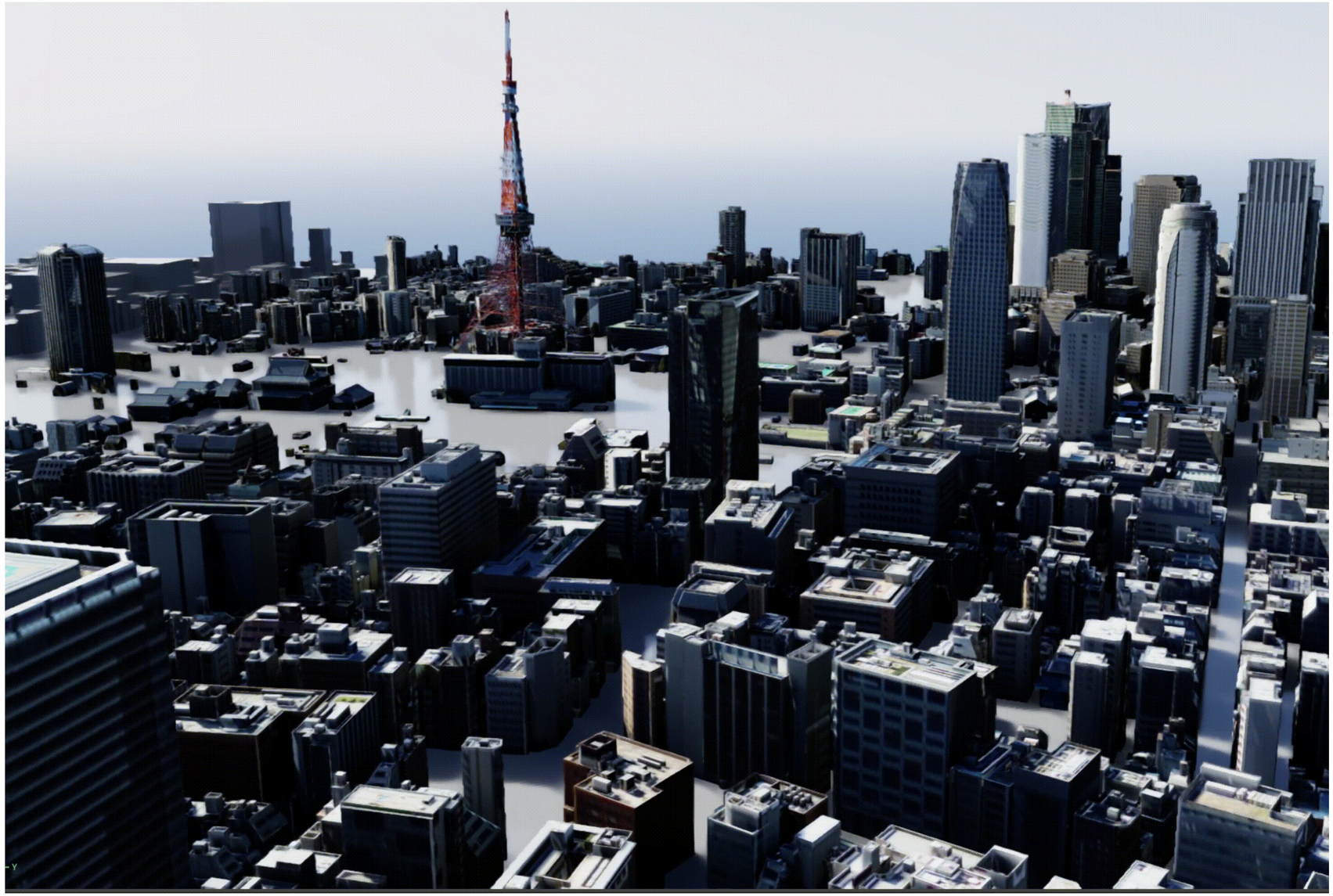
Area	Requirements
Scenario	City-scale, both outdoor and indoor
Wireless Channel	Site-specific
UE Mobility	Site-specific and capable of capturing stationary and transitory regimes
Antennas	Array properties fully simulated
Channel Application	Full channel emulation capable of representing Doppler effects and ICI
PHY	Full data plane to capture BLER in both stationary and transitory regimes
MAC	Full scheduler
AI	Offline and online training/inferencing through industry-standard frameworks
Scale	Hundreds of cells, thousands of UEs

Aerial Omniverse Digital Twin



[*] available in the future, contact us for detailed roadmap

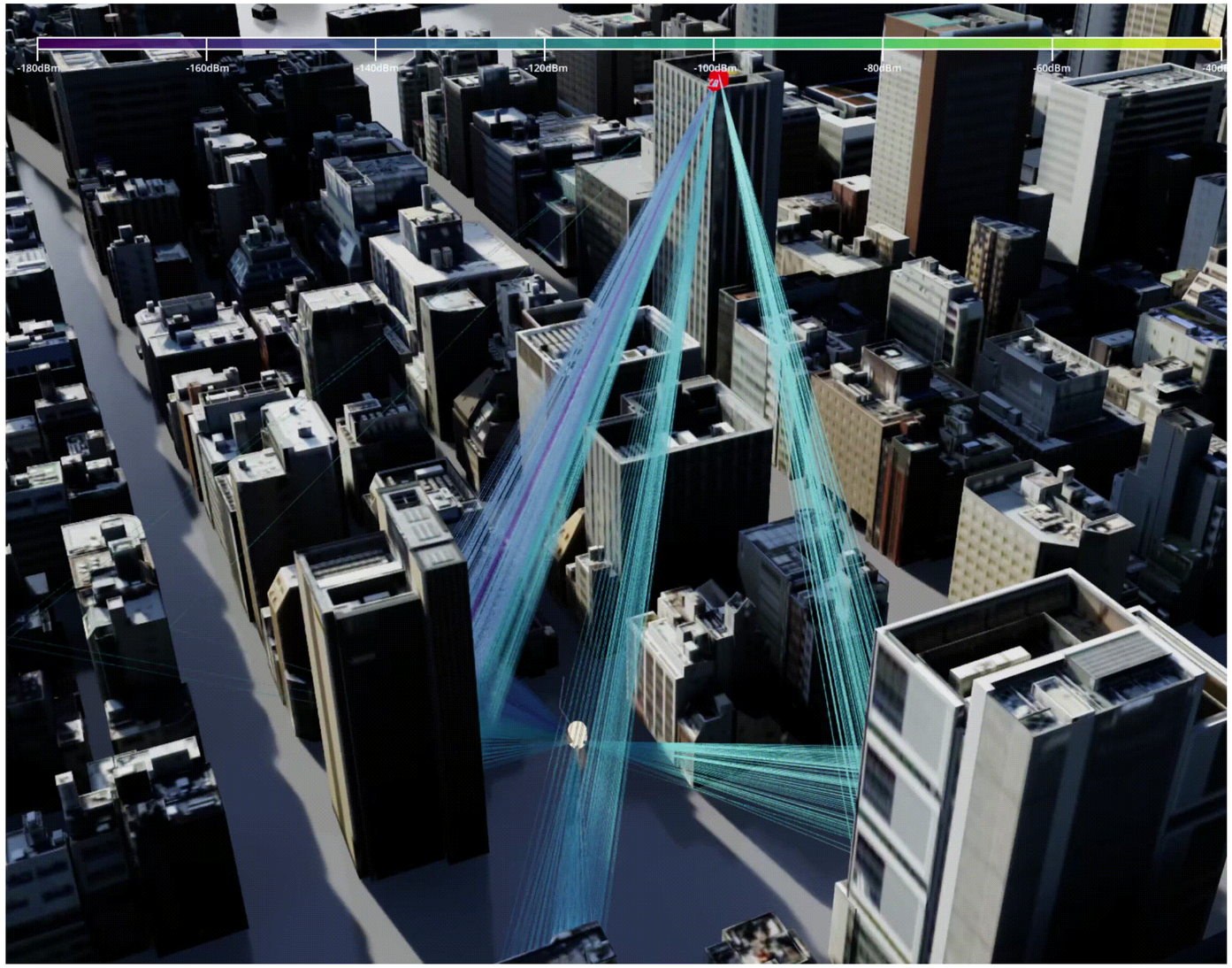
Aerial Omniverse Digital Twin – Scene Creation



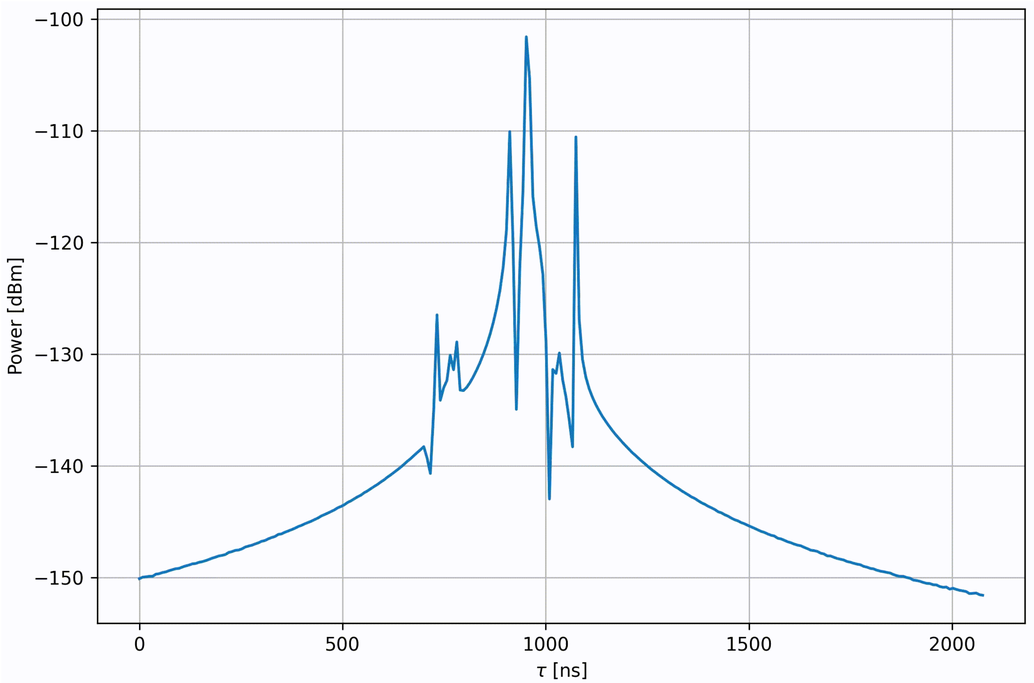
- Import pipeline for CityGML
  - buildings
  - terrain
  - textures
  - land use*
  - roads*
  - waterways*
  - procedural vegetation*
  - inferred indoor planning*
- Tested with PLATEAU open data

[*] available in future release, contact us for roadmap

Aerial Omniverse Digital Twin – EM Engine



Resulting PDP (power delay profile)



Supported Physics
specular reflection (R)
diffuse scattering (S)
diffraction (D)
transmission*
vegetation attenuation*
atmospheric effects*

Benchmark (NVIDIA L40)	
#triangles in scene	2.92m
emitted rays	500k
(#R,#D,#S)	(5,1,1)
MIMO (DL)	4x8 (d. pol.)
runtime w/ 1UE (ms)	<120 / p
runtime w/ 10UE (ms)	<300 / p

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Aerial Omniverse Digital Twin – UE Mobility Model

- City-scale outdoor mobility
  - constrained random way-point model
    - remove simulation transients [†]
    - impose desired user density across domain [†]
  - vehicular mobility*
  - indoor mobility*
  - drone mobility*
  - behavioral mobility*, e.g.,
    - collision avoidance
    - group mobility
    - traffic lights
    - crossings

[†] T. Balercia, A. Bilgic, H. Canales and V. Frascolla, "Pedestrian Mobility Modelling for the Simulation of Heterogeneous Wireless Infrastructures," *2010 IEEE International Conference on Communications*, Cape Town, South Africa, 2010, pp. 1-6, doi: 10.1109/ICC.2010.5502134.

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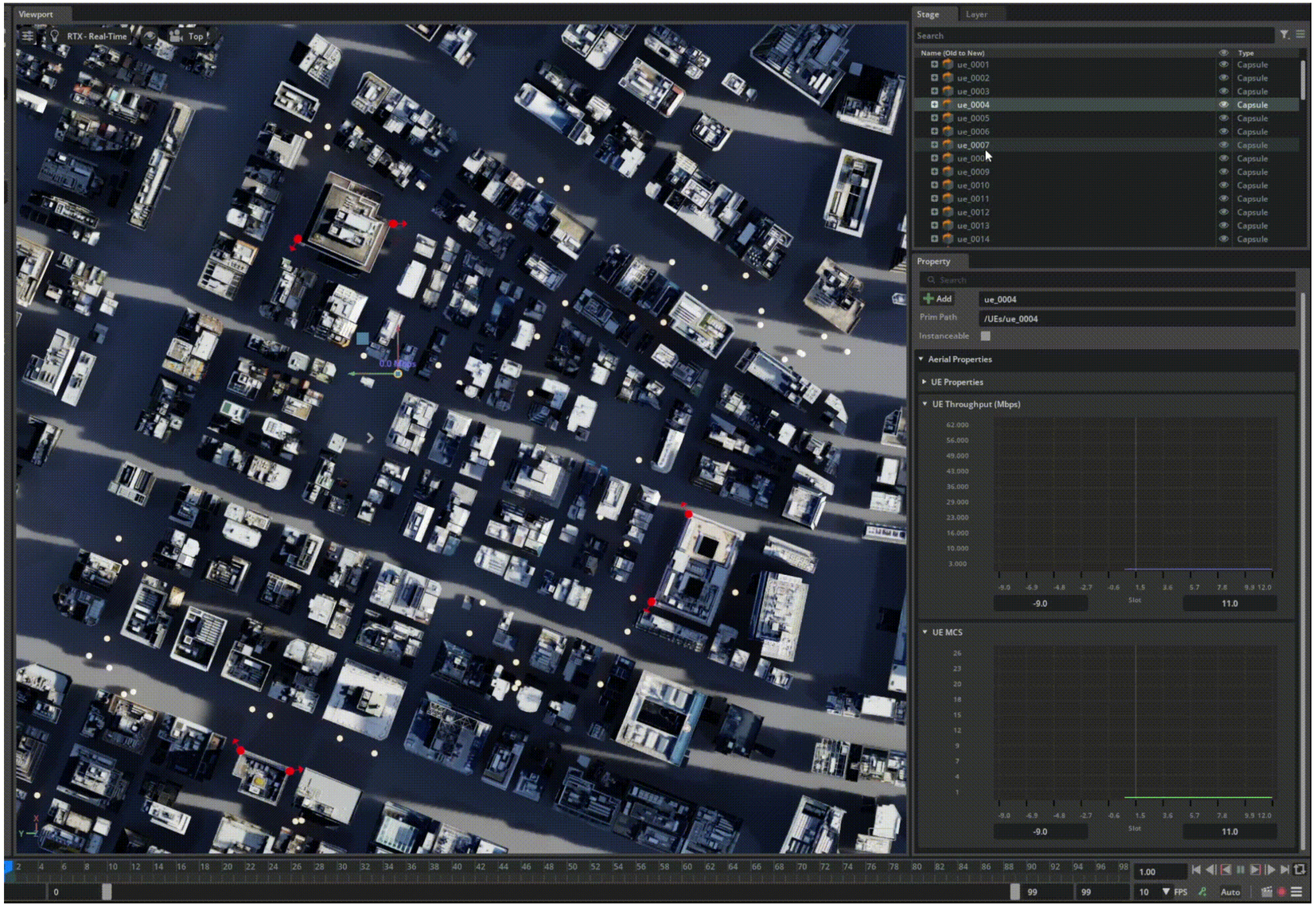
Aerial Omniverse Digital Twin – PHY/MAC

Simulation of downlink for 6 RU, 60 UE, 100 slots



- **Aerial Digital Twin is based on NVIDIA cuPHY:**
  - SW-defined and real-time
    - PxSCH with HARQ
    - SRS*
    - SSB*
    - PRACH*
    - PxCCH*
  - API*
    - Component level
    - Pipeline level

- **Aerial Digital Twin is based on NVIDIA cuMAC:**
  - SW-defined real-time
    - allocation spatial layers
    - allocation of PRBs
    - modulation and coding scheme
    - UE pairing*
  - API*

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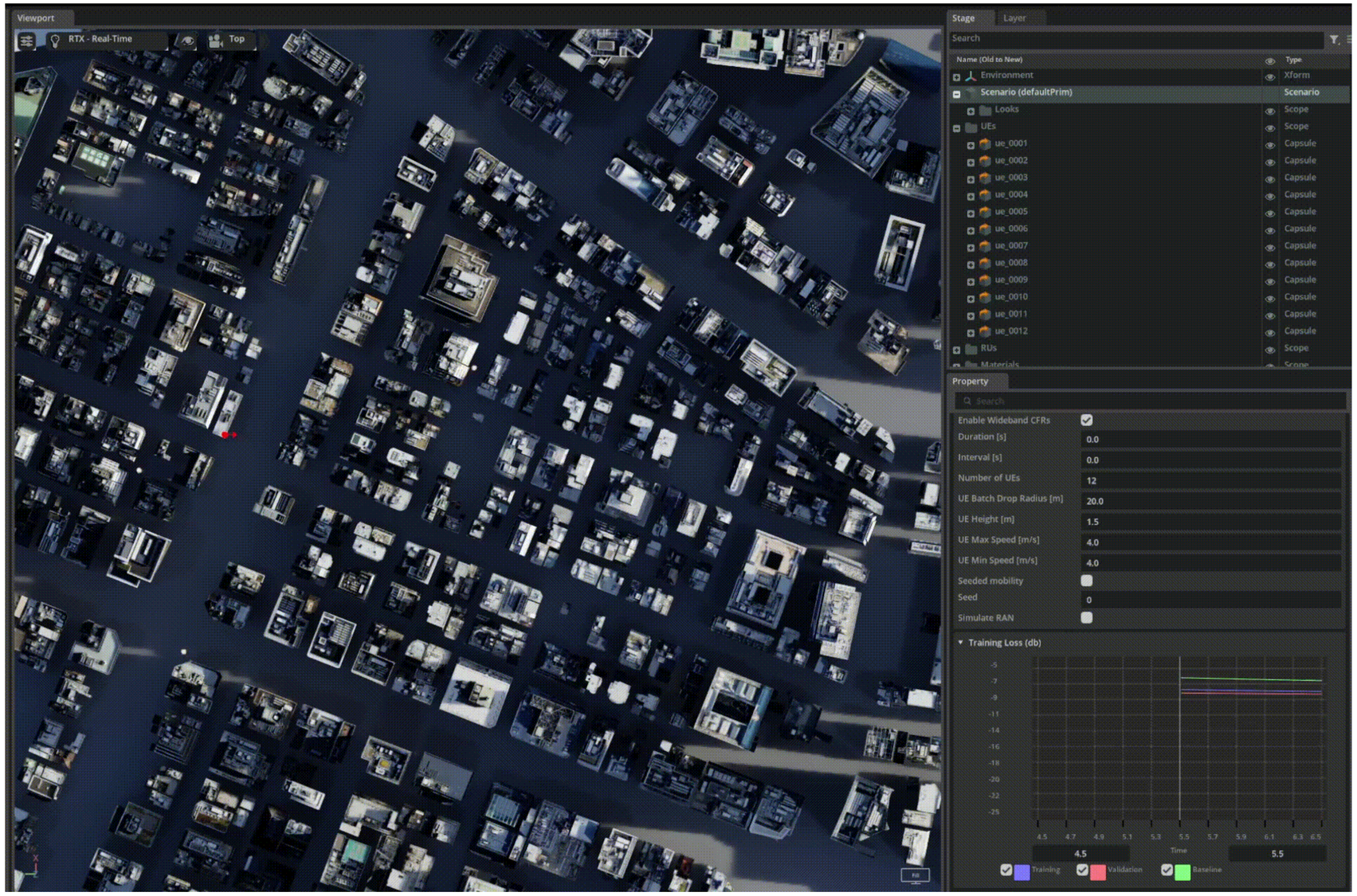
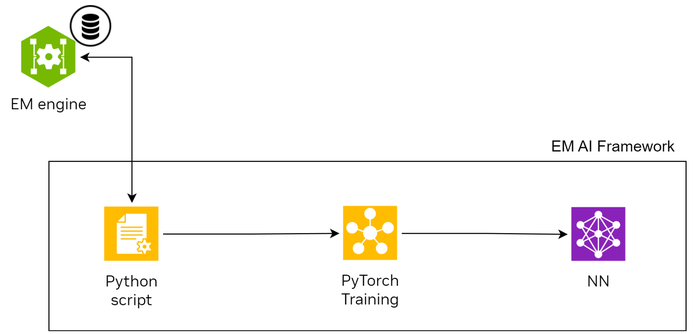
Aerial Omniverse Digital Twin – AI Framework

Online training of future channel prediction NN vs MMSE (baseline)



- Aerial Digital Twin
  - data to train and exercise ML algorithms offline
  - fully integrated with PyTorch for online training
  - API for PHY/MAC training/inference*



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Conclusions

- **Aerial Omniverse Digital Twin delivers the possibility of conducting**
  - site-specific
  - large-scale
  - highly accurate

  RAN simulations

- **By doing so, it offers new opportunities for**
  - tackling the design of the 6G air interface
  - studying the effect of AI on the data and control plane of 5G/6G cellular networks
  - deploying cost-effective RAN infrastructure

- **Aerial Omniverse Digital Twin will be available for download in April 2024**