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PHYSICS-BASED DIGITAL TWINS FOR CO-SIMULATION

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AGENDA

01 Digital Twin concept

02 Industrial grade simulations

03 Developing with NVIDIA Omniverse™

04 Co-simulation

05 Use cases

06 USD-FMI standard

07 Recap

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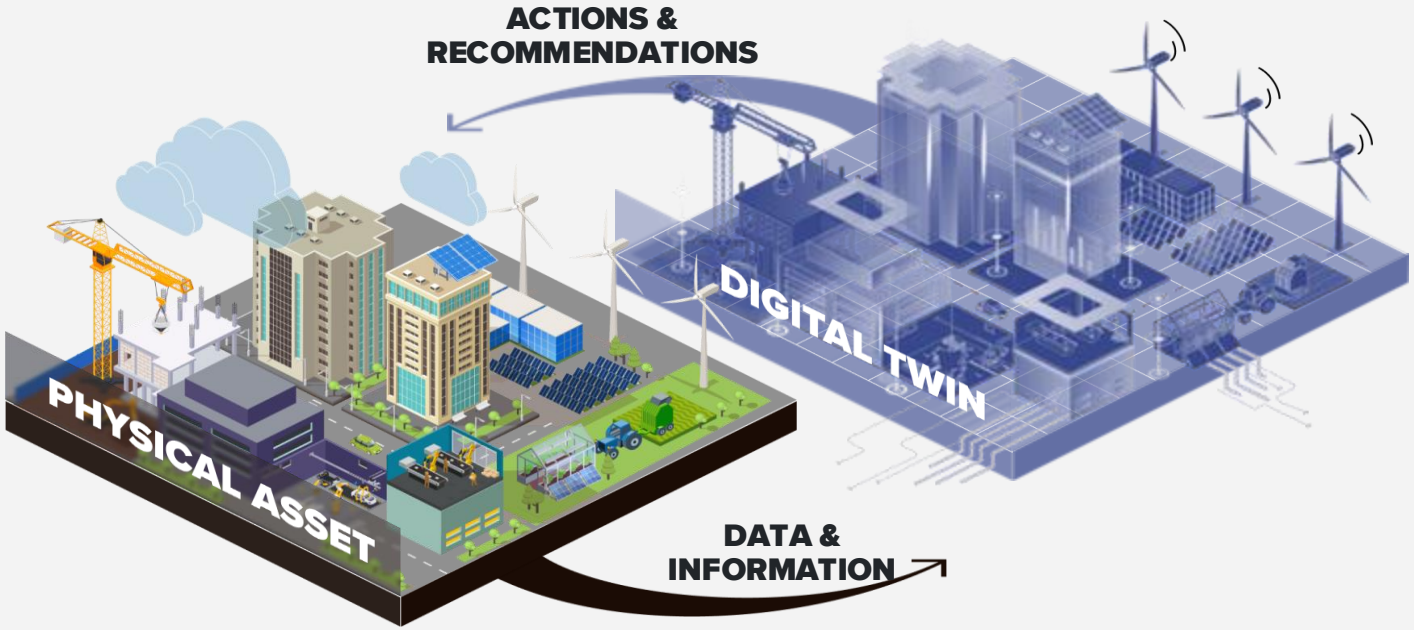
DIGITAL TWIN OBJECTIVES

A digital twin is a virtual representation of a physical system, product, or process that dynamically updates based on real-world data to provide insights and improve operations [SoftServe].

- Support design
- Assess the present
- Revisit the past
- Predict the future



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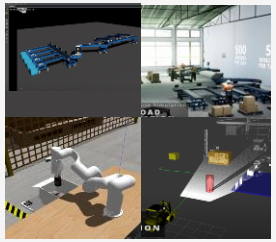
MANUFACTURING DIGITAL TWINS
FOCUS USE CASES

PRODUCT DESIGN

- Collaborative design
- Virtual team collaboration
- Virtual product build-up

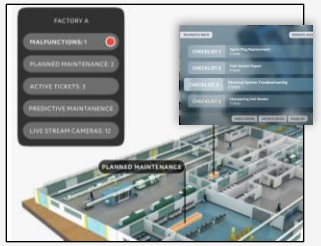


FACTORY DESIGN

- Factory layout design
- Factory/Plant Simulation
- Manufacturing Processes / Production line simulation
- Virtual commissioning
- Virtual team collaboration

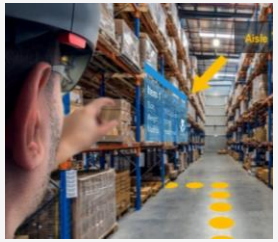
PRODUCTION PLANNING

- What-if scenarios / simulations
- Schedule verification
- Optimize warehouse / inventory design and flow
- Increased OEE, navigate potential bottlenecks & machine failures



PRODUCTION CONTROL

- Shopfloor transparency
- Machine configuration
- Quality Control
- Online Diagnostics
- Predictive Maintenance



WORKER TRAINING & PLANT TOURS

- Virtual training
- Virtual Plant tours

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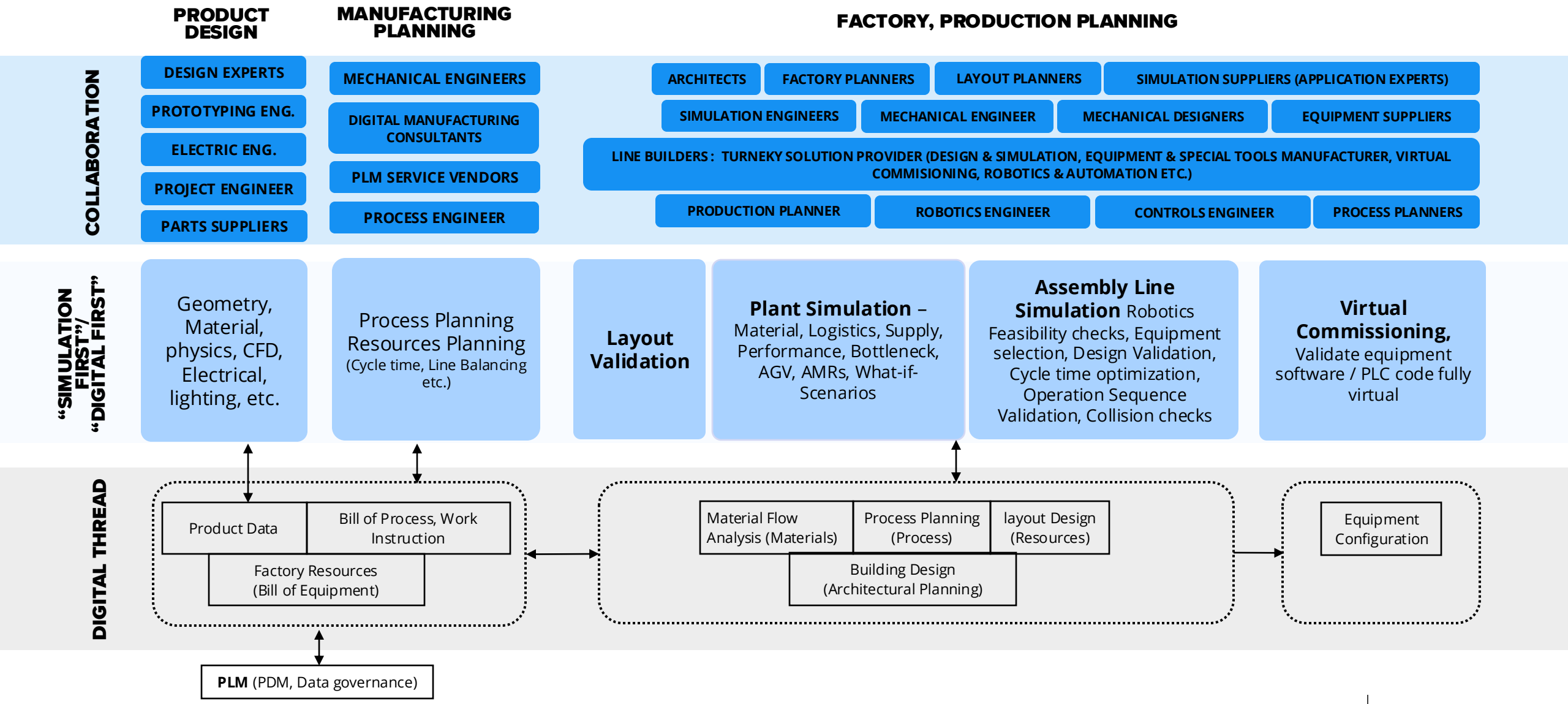
INDUSTRIAL METAVERSE | DIGITAL FIRST



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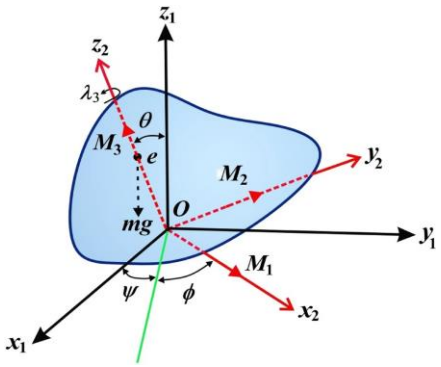
INDUSTRIAL HIGH-FIDELITY SIMULATIONS

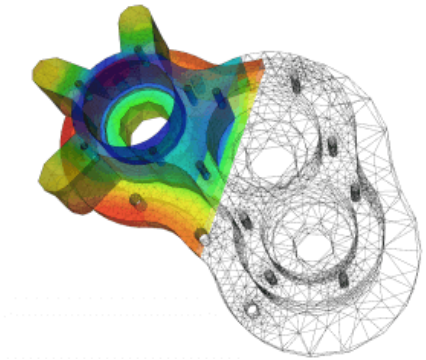
Rigid body dynamics

- body motion
- kinematics
- contains
- collision



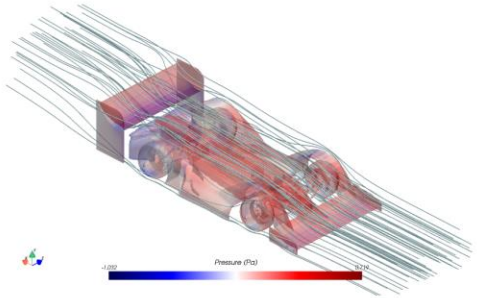
Structural Mechanics

- stress,
- strain,
- materials deformation



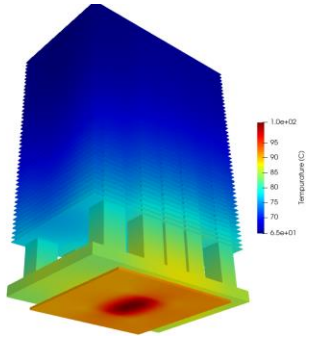
Fluid dynamics

- laminar flow
- turbulent flow
- compressible
- incompressible



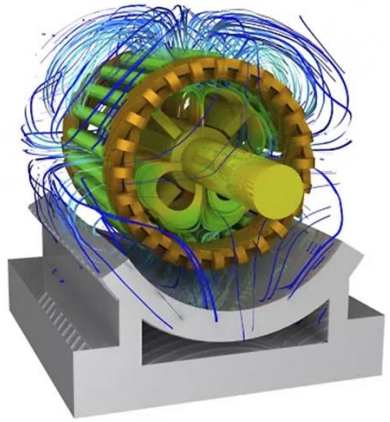
Heat transfer

- conduction
- convection
- radiation



Electromagnetic

- wave propagation
- induction
- eddy currents



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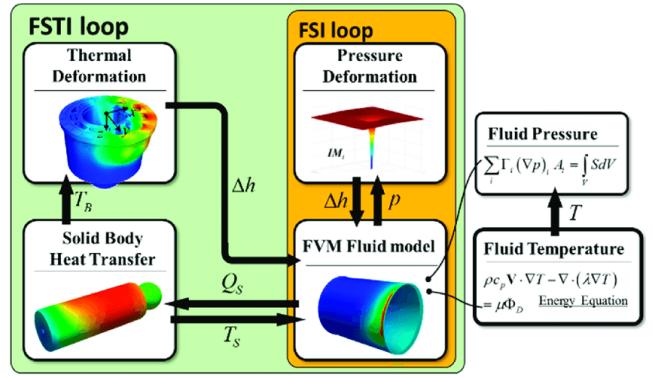
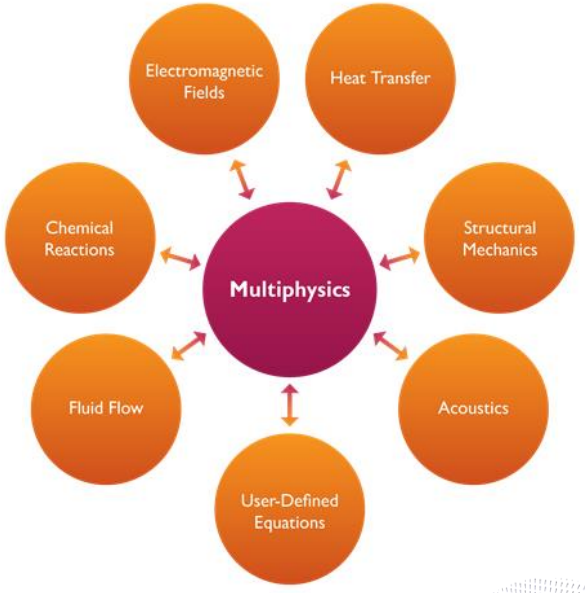
MULTIPHYSICS SIMULATIONS

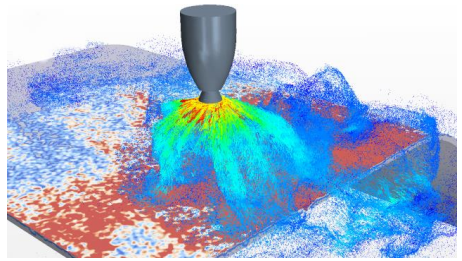
Multiphysics simulations involve the simultaneous modeling of multiple physical phenomena that interact within a system.



FEATURES

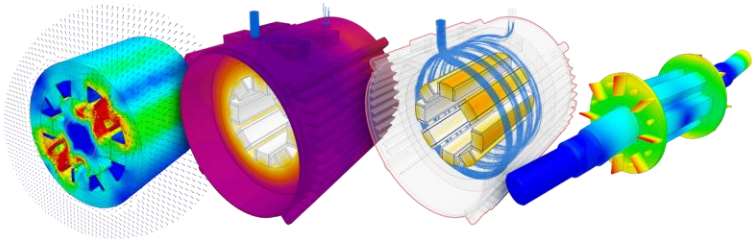
- **Cross-Domain Interactions**
- **High Accuracy**
- **Solver Integration**
- **Scalability**





CHALLENGES

- Computational Intensity
- Solver Coupling
- Mesh Generation and Adaptivity
- Time Synchronization
- Boundary Conditions
- Data Management
- Accuracy and Validation
- Interdisciplinary Knowledge
- Software Interoperability



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UNIVERSAL SCENE DESCRIPTION (OpenUSD)

WHAT IS OpenUSD?

Extensible software ecosystem for constructing, packaging, assembling, simulating and collaborating on 3D projects

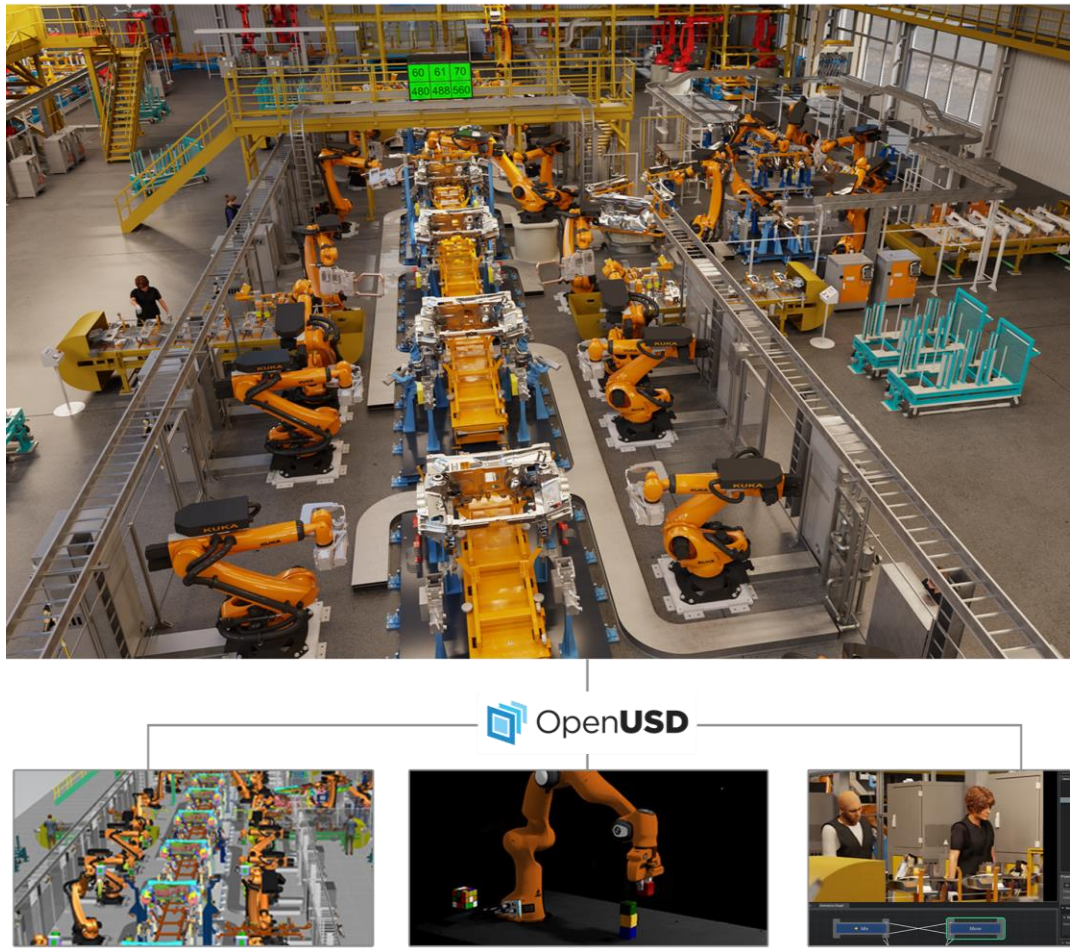
Robust interchange with its expanding set of schemas and standardized core APIs

Geometry **Shading** **Lighting** **Physics**

Combine assets into larger assemblies and enable collaborative workflows

ALLIANCE FOR OpenUSD (AOUSD)

Open, non-profit organization dedicated to promoting the interoperability of 3D content through OpenUSD



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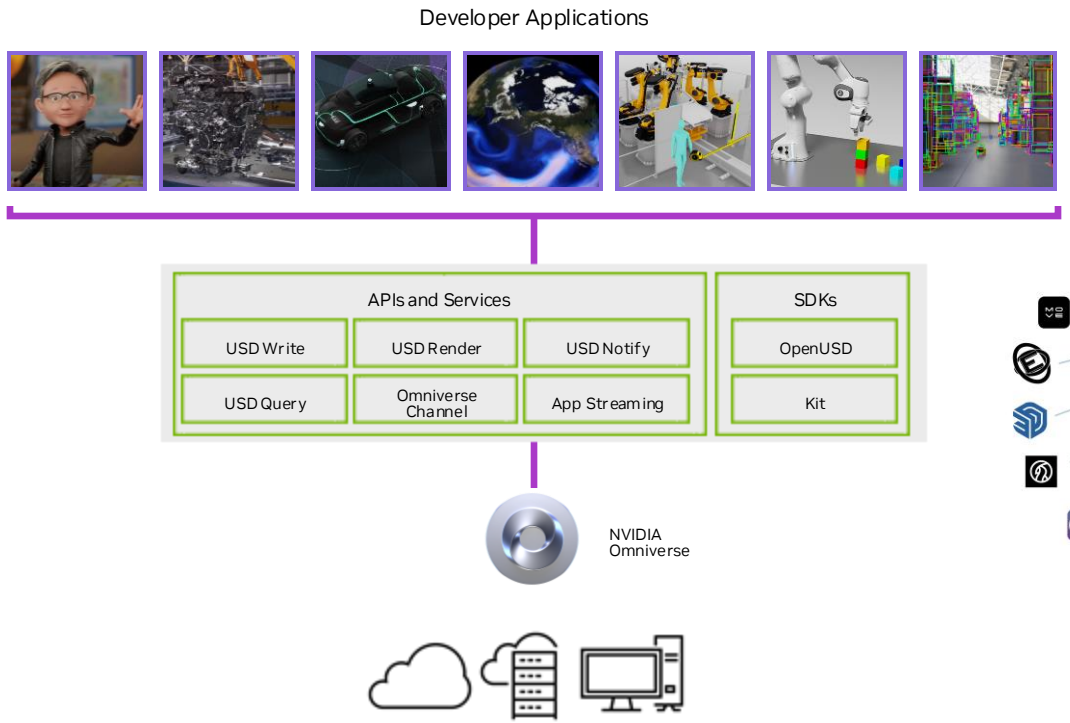
NVIDIA OMNIVERSE

Platform to Develop OpenUSD-Based Industrial Digitalization Applications

NVIDIA Omniverse™ is a platform of APIs, SDKs, and services that enable developers to integrate OpenUSD, NVIDIA RTX™ rendering technologies, and generative physical AI into existing software tools and simulation workflows for industrial and robotic use cases.



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NVIDIA OMNIVERSE

Industrial Digitalization Applications and Use Cases

Developers across industries are building physical AI and industrial simulation applications with OpenUSD, Omniverse SDKs and APIs.

VIRTUAL FACILITY INTEGRATION

Develop physically accurate Digital Twins of massive facility layouts, simulations, automation systems and operations.

SIMULATION FOR PHYSICAL AI

Provide physically accurate world simulation, sensor simulation that scales for Auto AV, AMRs, Manipulators and smart spaces.

GENERATIVE AI FOR DESIGN

Leverage Generative AI for Design and Configurators

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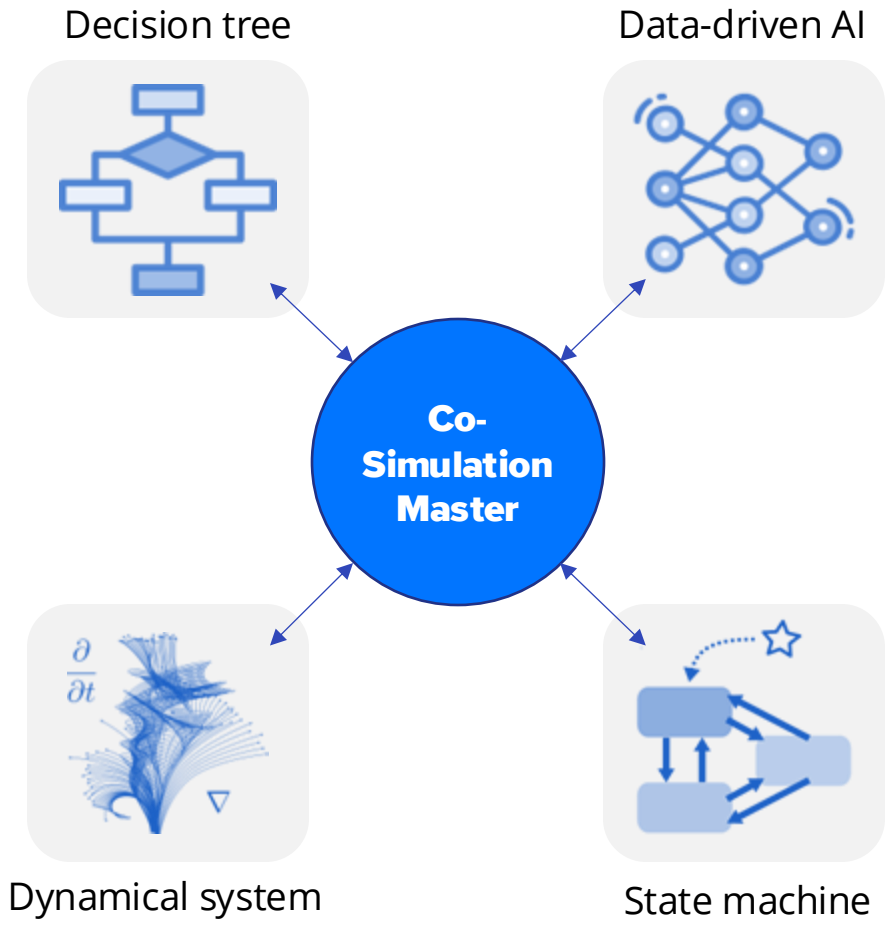
CO-SIMULATION IN NUTSHELL

Co-simulation is a method where different simulation models work together to analyze complex or multi-domain systems in a coordinated way.

- Hybrid simulation (**mixed time- & event-driven)**
- Simulation of **heterogeneous systems**
- **Distributed simulation**
- Common simulation **standards (**FMI, DCP, SSP)
- **Unified models**
- **Flexible solvers**
- **Scalable infrastructure**



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FMI/FMU STANDARD

The Functional Mock-up Interface (FMI) is a free standard that defines a container and an interface to exchange dynamic models using a combination of XML files, binaries and C code, distributed as a ZIP file.

- Tool-independent standard making submodels binary compatible
- Functional Mock-Up Unit (FMU)
- The FMI standard specifies the APIs
- Supported by more than 200+ tools
- Maintained as a Modelica Association Project (MAP FMI)
- Releases on *github.com/modelica/fmi-standard*

fmi Functional Mock-up Interface

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CO-SIMULATION IN NVIDIA OMNIVERSE

PROBLEM

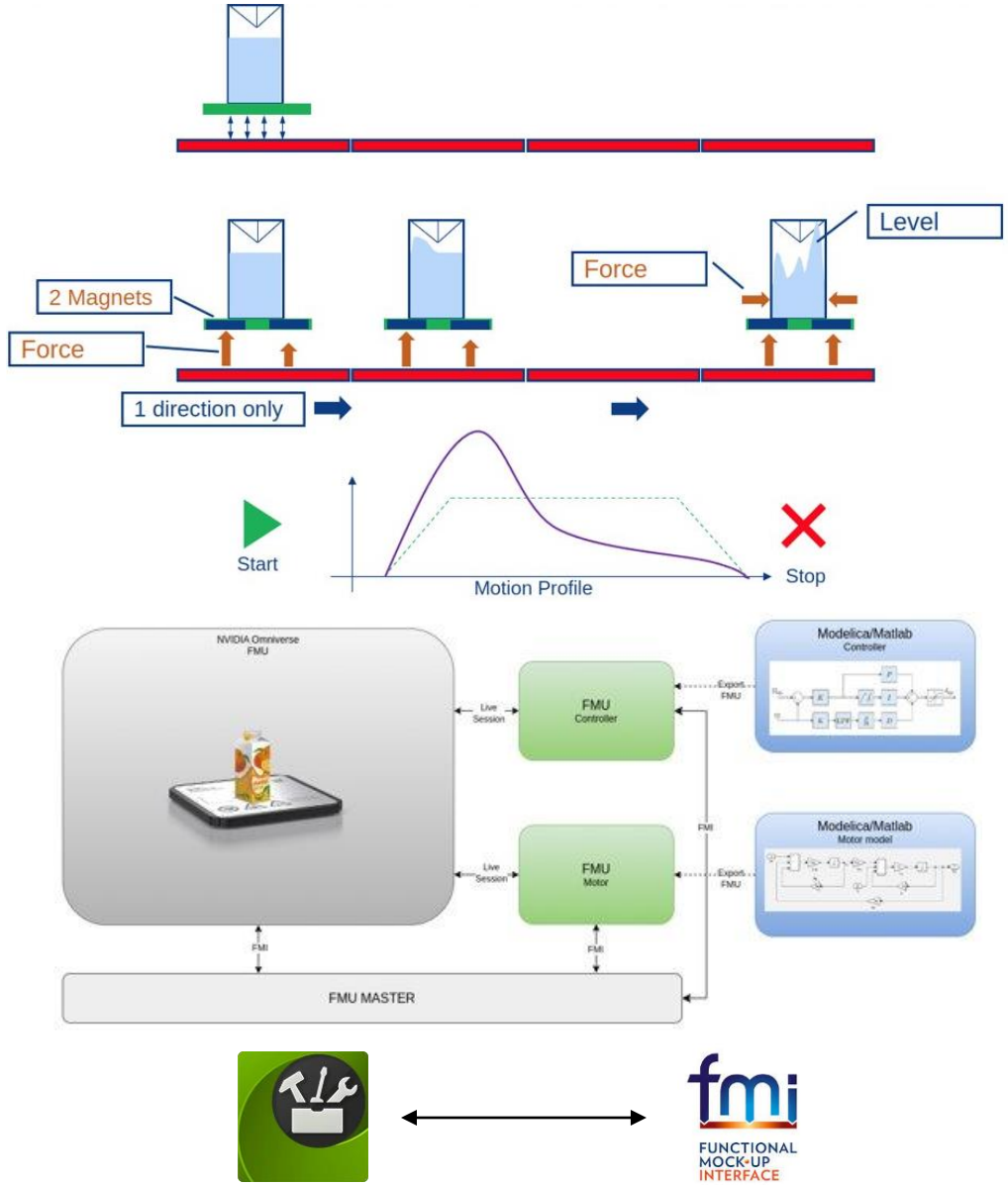
- Replicating the real-world processes in real-time
- Observe and evaluate the system under various conditions
- Leverage the integrative power of the NVIDIA Omniverse ecosystem
- Enable improved multi-disciplinary collaboration across different engineering teams

SOLUTION

- Introduce **FMI/FMU** standard to NVIDIA Omniverse ecosystem
- Develop co-simulation scenario of the 1DOF levitating plate with payload
- Combine soft-RT **rigid-body** (PhysX) and **fluid** (Particles) simulation with **control**
- Develop models in **Python** and **OpenModelica**
- Develop **NVIDIA Omniverse KIT extension** with **UI** interface
- Compare results of fluid simulation with **OpenFOAM CFD**

IMPACT

- **Accelerating engineering teams**
- **Process optimization**
- **Adaptation to business goals on the design stage**



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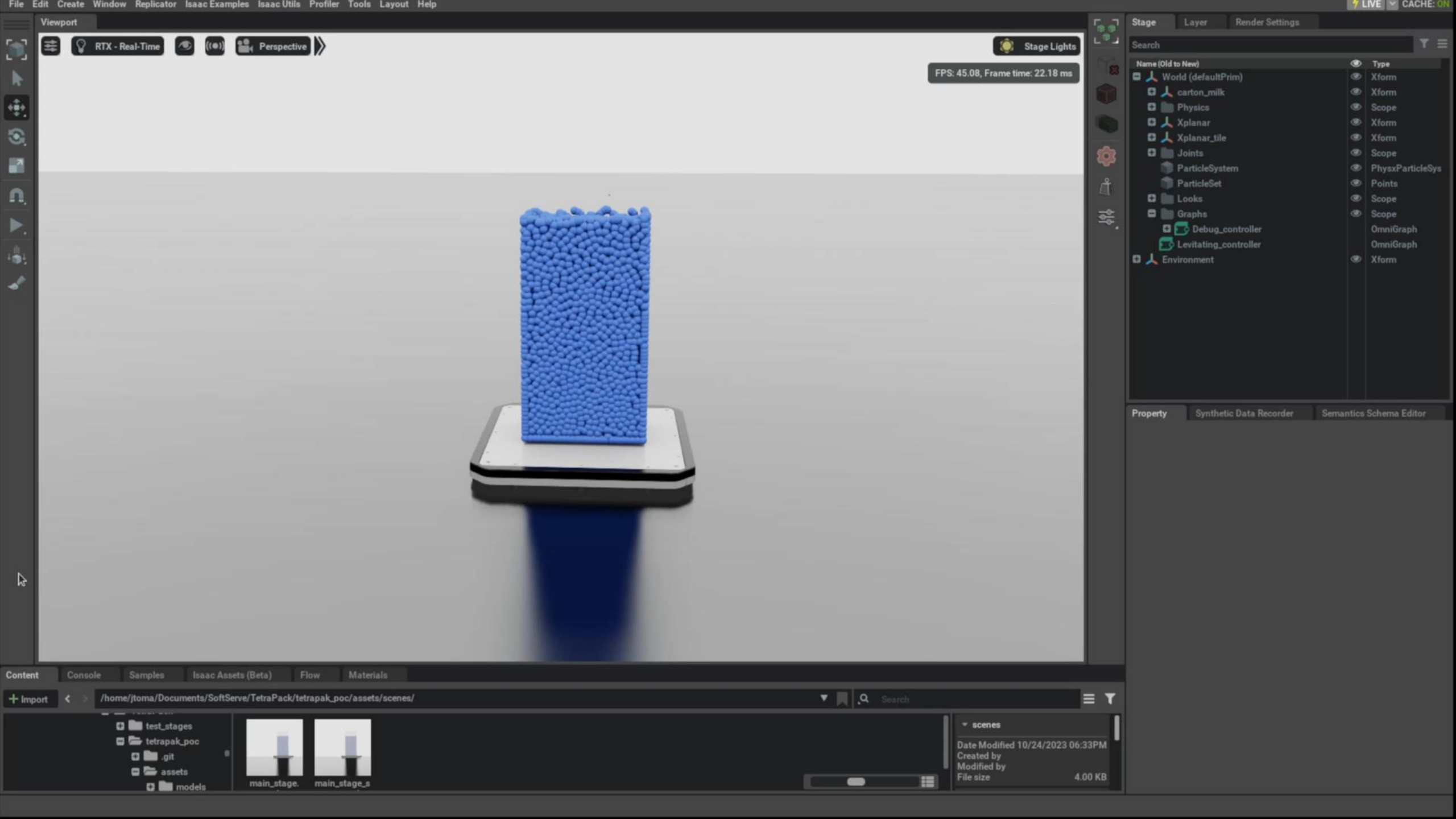
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Physics
Scope
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Joints
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Looks
Scope
Graphs
Scope
Debug_controller
OmniGraph
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Environment
Xform
Property
Synthetic Data Recorder
Semantics Schema Editor
Content
Console
Samples
Isaac Assets (Beta)
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HIGH FIEDELITY CO-SIMULATION IN NVIDIA OMNIVERSE

PROBLEM

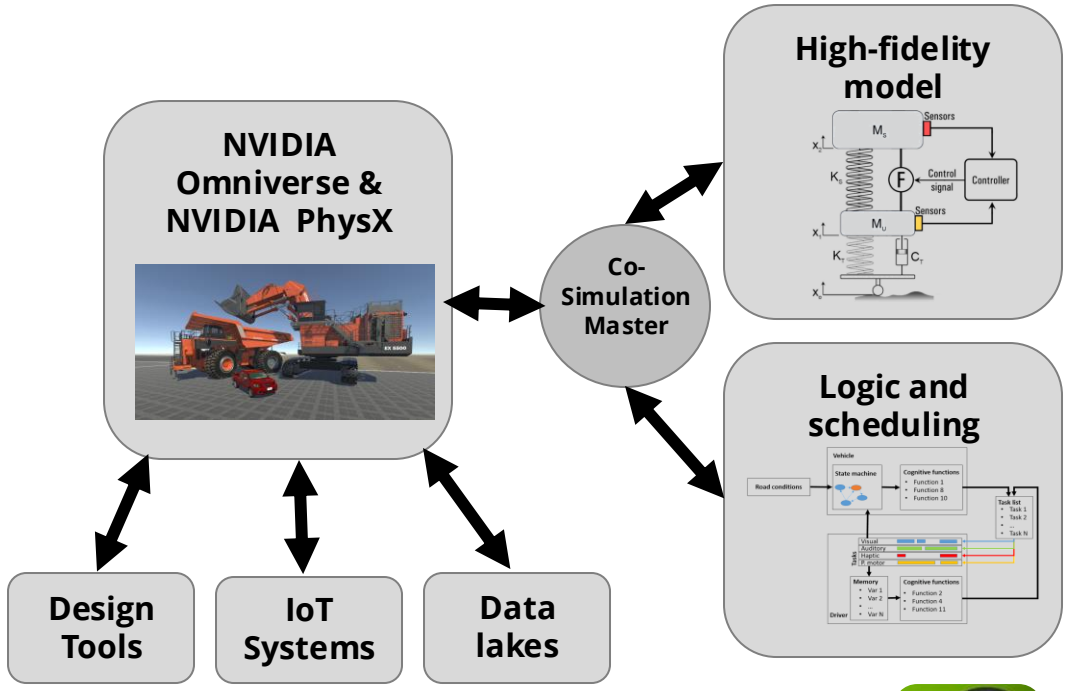
- Create a foundation for a Digital Twin of the industrial machines
- Monitor, control and tune the device via set of control parameters
- Include high-fidelity simulations of selected assembly processes
- Enable fine-tuning of the process control parameters.

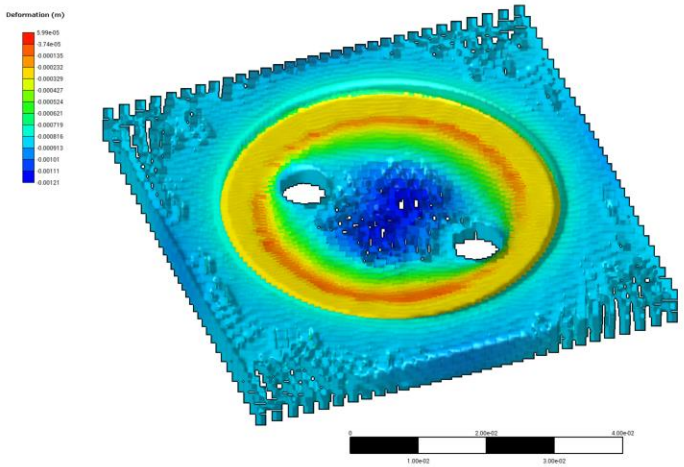
SOLUTION

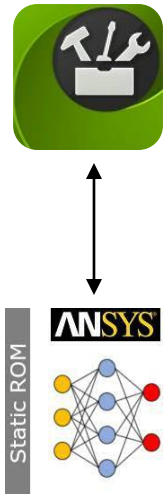
- Introduce ANSYS **ROMs** to **NVIDIA Omniverse** ecosystem.
- Combine simulation of **rigid-body** (PhysX), **soft-body (Ansys ROM)** with **control**
- Develop **Simulation Twin** of the press machine
- Develop models in **Python** and **Ansys Twin Builder**
- Develop **nonlinear static simulation** of element under press in Ansys
- Develop **NVIDIA Omniverse KIT** extension with **UI** interface
- Integrate **Simulation Twin** with **AWS IoT Twin Maker**

IMPACT

- **Accelerating engineering teams**
- **Process optimization**
- **Adaptation to business goals on the design stage**







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OCEAN UUV DIGITAL TWIN

BUSINESS OVERVIEW

Develop digital twin of the UUV to meet the following business needs:

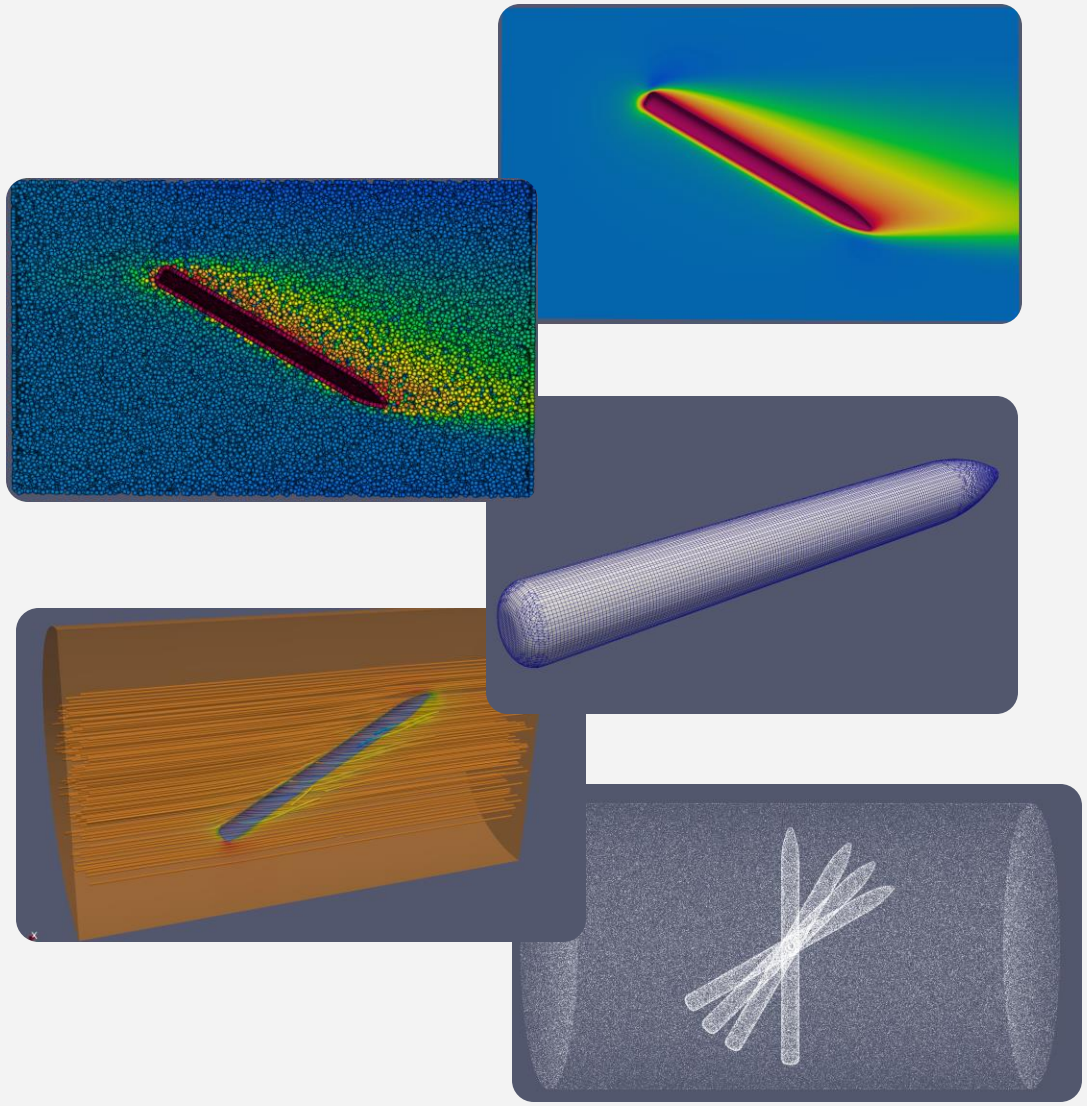
- Decrease time-to-market for the UUV solution
- Increase end-user satisfaction by increasing solution quality
- Increase solution effectivity by developing a high-fidelity model

SOLUTION HIGHLIGHTS

- Simulate AOR (Area of Responsibility) focusing on littoral depths 50’ to 250’ deep.
- Develop a one-way coupled CFD set of models
- Develop equivalent PINNs model of fluid flow around UUV
- Track preplanned UUV trajectory
- Estimate battery consumption
- Visualize simulations with Nvidia Isaac Sim

TECHNOLOGIES

NVIDIA Omniverse, NVIDIA Modulus, OpenFOAM, PINNS, CFD, Numerical methods, Modeling, Motion planning, Control



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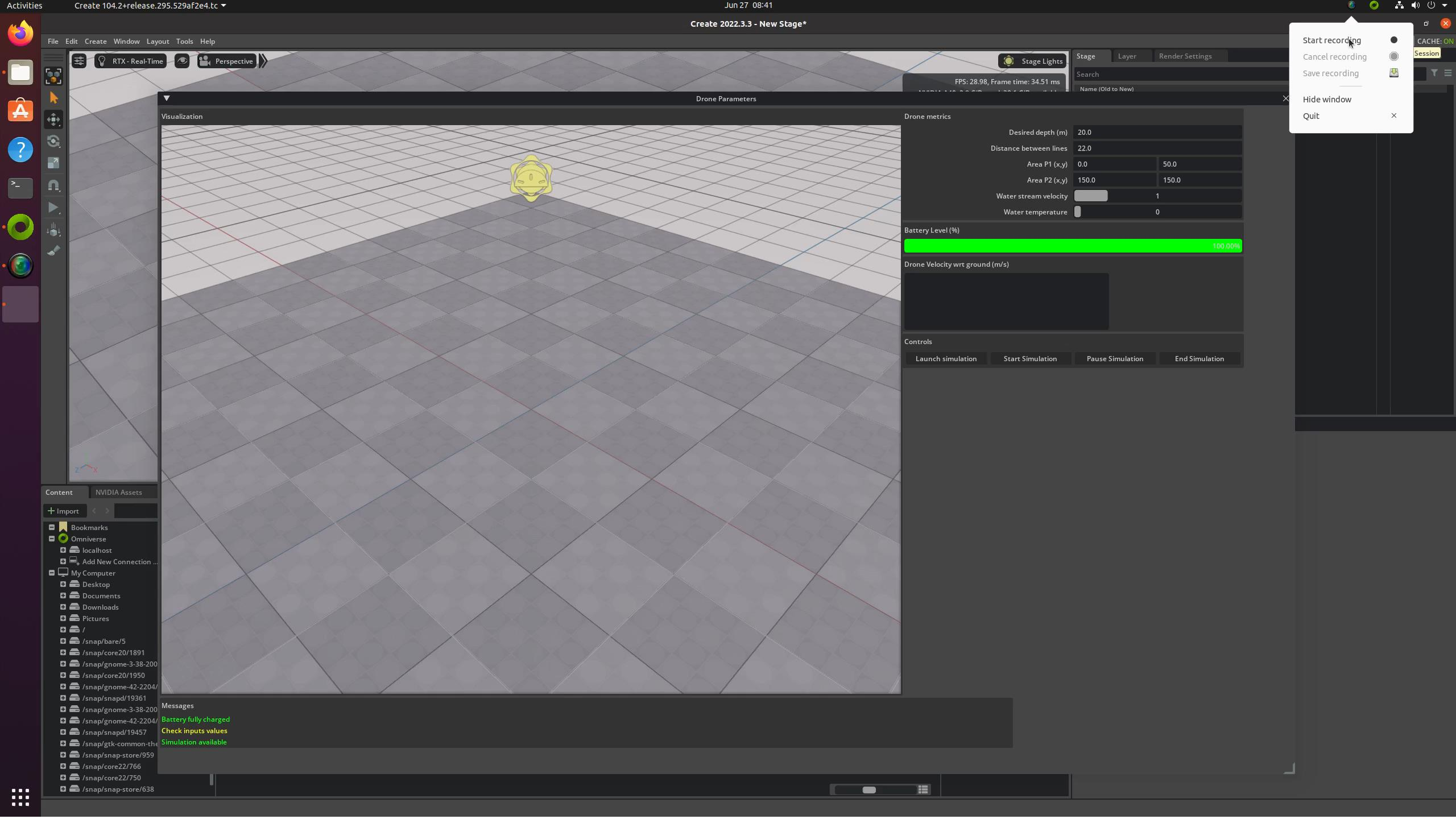
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Create 2022.3.3 - New Stage*
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RTX - Real-Time
Perspective
Stage Lights
FPS: 28.98, Frame time: 34.51 ms
Stage
Layer
Render Settings
Search
Name (Old to New)
Start recording
Cancel recording
Save recording
Hide window
Quit
CACHE: ON
Session
Drone Parameters
Visualization
Drone metrics
Desired depth (m) 20.0
Distance between lines 22.0
Area P1 (x,y) 0.0 50.0
Area P2 (x,y) 150.0 150.0
Water stream velocity 1
Water temperature 0
Battery Level (%)
100.00%
Drone Velocity wrt ground (m/s)
Controls
Launch simulation
Start Simulation
Pause Simulation
End Simulation
Messages
Battery fully charged
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/snap/core20/1891
/snap/gnome-3-38-200
/snap/core20/1950
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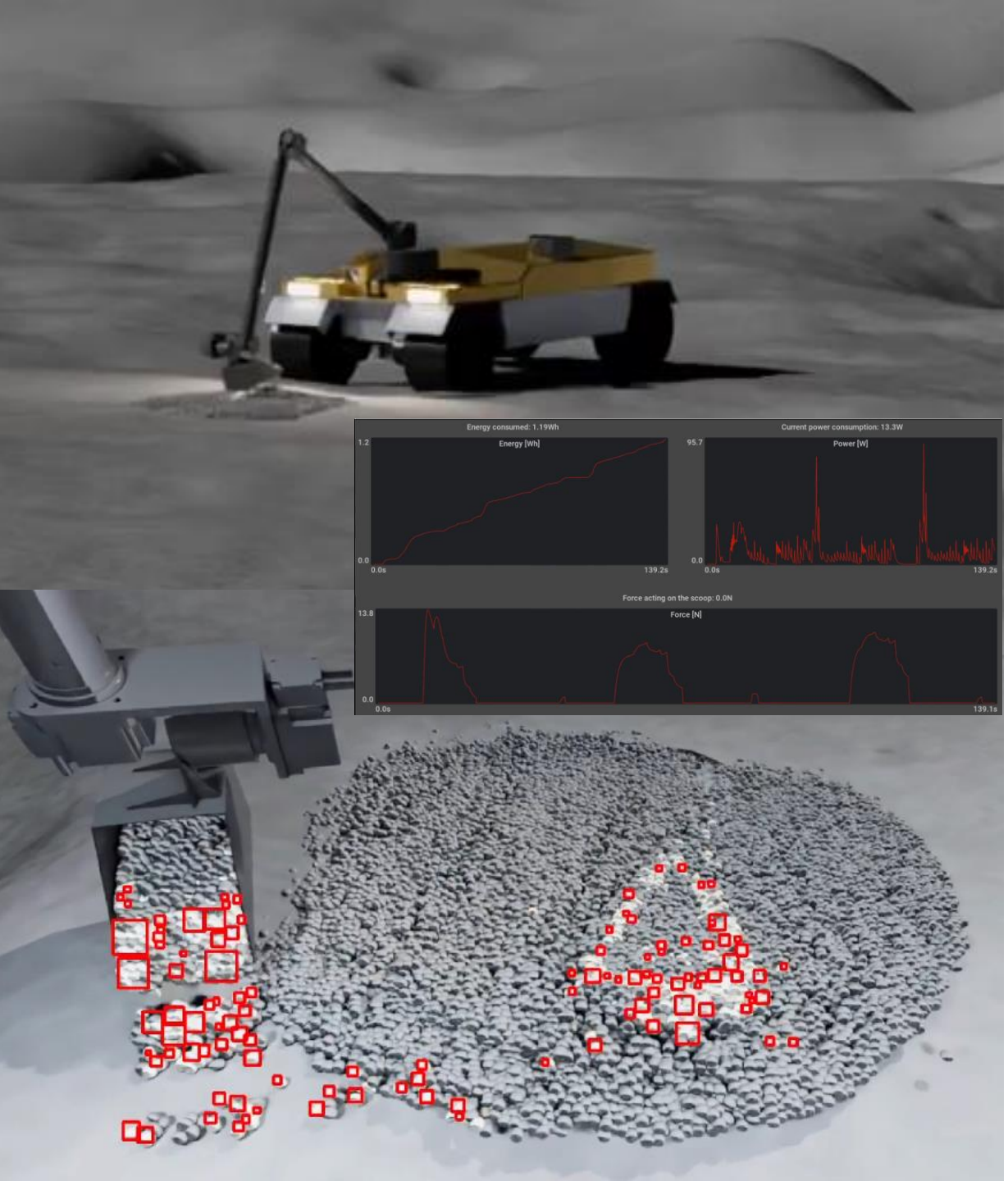

MOON SCOOPING

BUSINESS OVERVIEW

- Developed a solution of a mobile platform equipped with a robotics arm to scoop the regolith searching for ice deposits on the Moon
- Scoop the Moon regolith for exploration or construction
- Detect ice deposits while scooping
- Enable energy efficient operations

SOLUTION

- Design of hardware components of the robot
- Design a vibratory mechanism to ensure energy effective scooping
- Apply simulation-first approach for efficient scooping
- Utilize robotics perception for ice deposit detection
- Implement high-fidelity terramechanics approach (**NVIDIA Warp**)
- Enable real-time energy consumption tracking

IMPACT

- Increase mission duration with energy efficient scooping
- Enable real-time ice deposit detection
- Validate complex robotics solution in simulation

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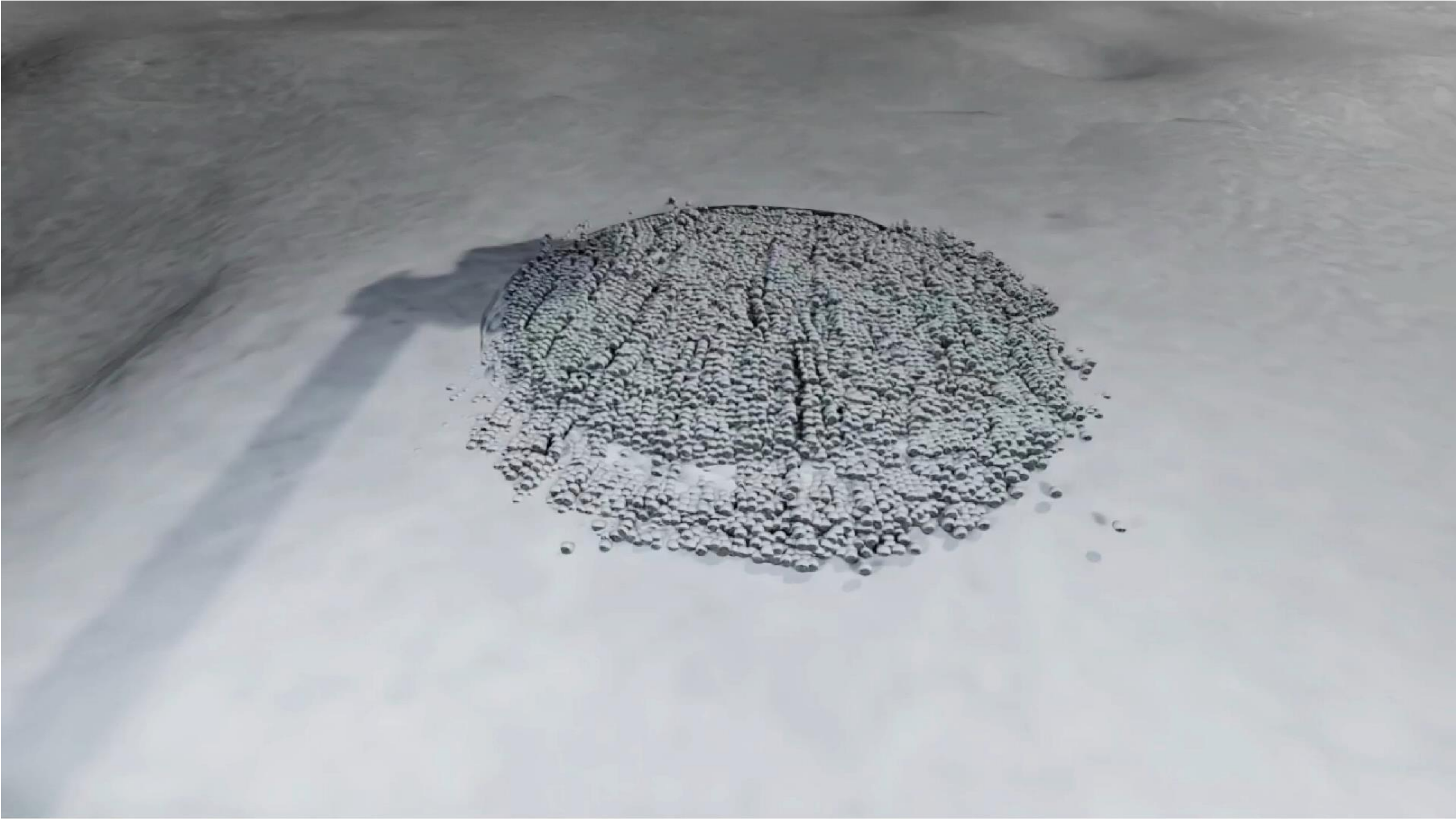

OUR VISION - USD + FMI

Completely Define 3D Model and Simulation Behavior for Digital Twins

3D DIGITAL TWINS AND PHYSICAL AI

OpenUSD

Geometry, shading, lighting, and physics

+

FMI

Self contained simulation behavior

- **MVP** – Standardizing FMU integration in USD for co-simulation
  - Single FMU ⟷ OpenUSD
  - POC Shared as an open-sourced sample initially
  - Merging the consensus standard and normative guidelines into OpenUSD
- Bring USD and FMI ecosystem partners into further discussions
  - Identify industrial use cases and expand the integration standard/implementation
  - Improve performance and usability

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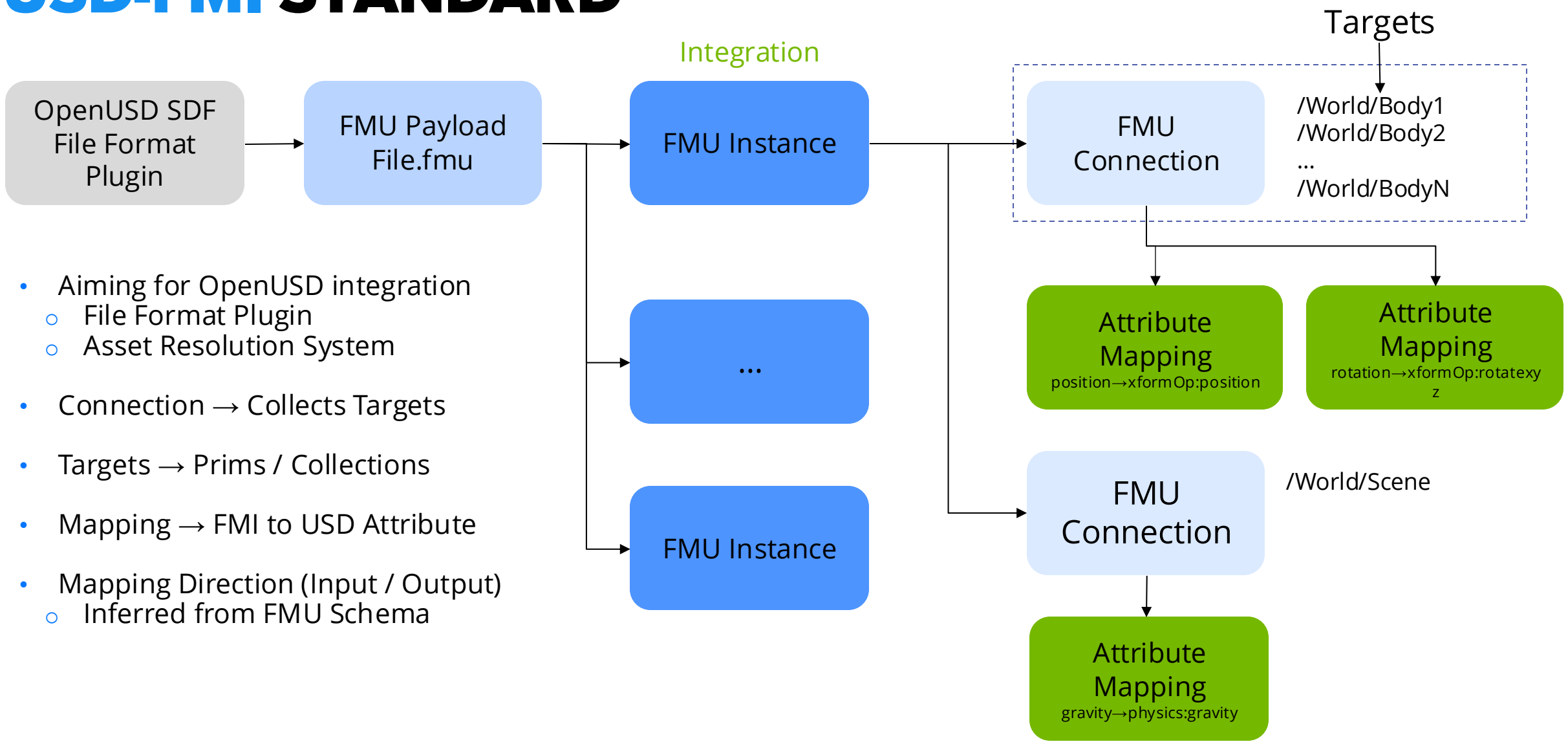
USD-FMI STANDARD



- Aiming for OpenUSD integration
  - File Format Plugin
  - Asset Resolution System
- Connection → Collects Targets
- Targets → Prims / Collections
- Mapping → FMI to USD Attribute
- Mapping Direction (Input / Output)
  - Inferred from FMU Schema

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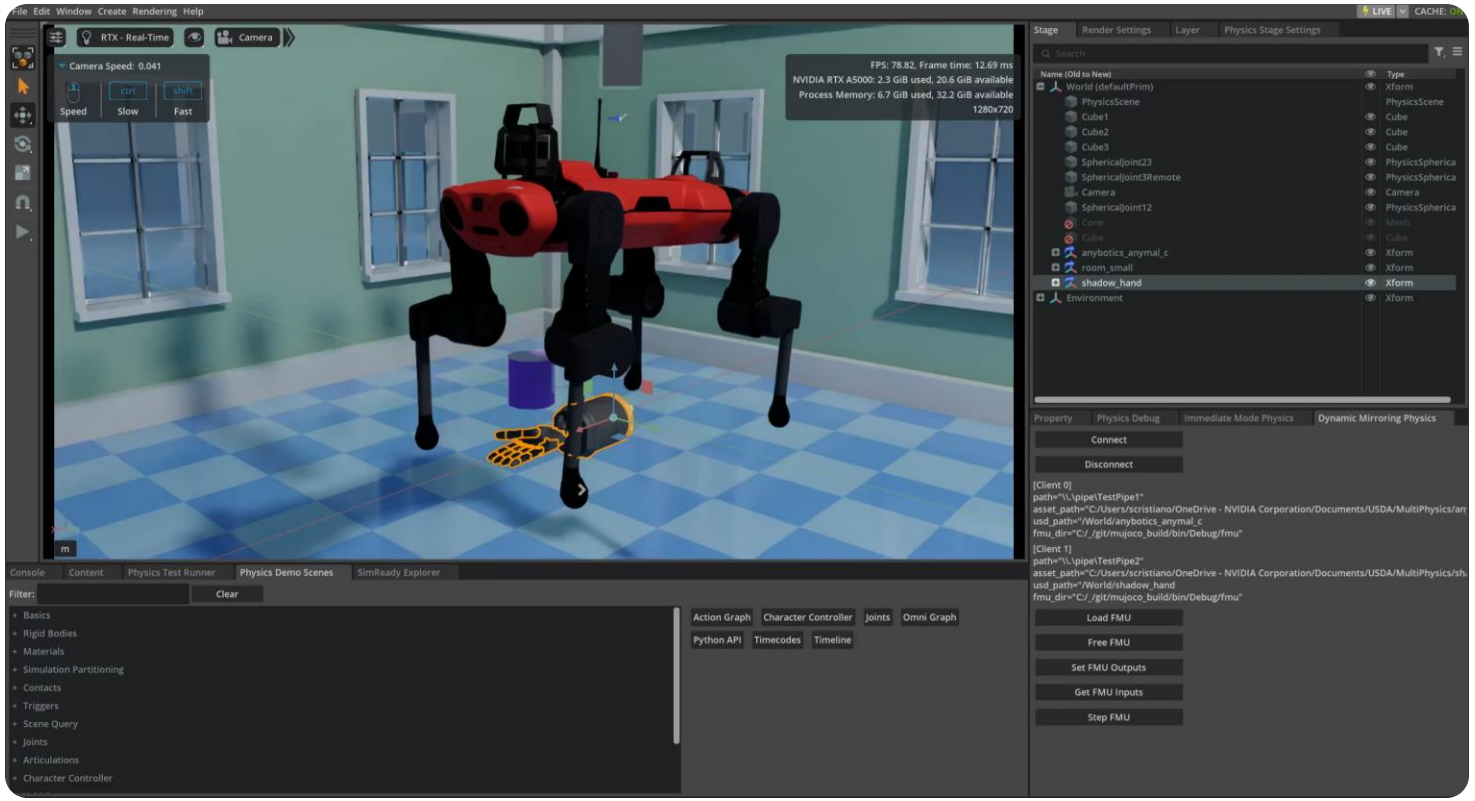
USD-FMI STANDARD

Demo: MultiBody Physics standard

- FMU Wraps MuJoCo Physics Engine
- Mirror Physics Data to USD Stage
- Enables MultiBody Physics interaction

  Collision interaction with host Physics Engine
- Joint Interaction with host Physics Engine

  In Progress implementation of FMI-USD Standard



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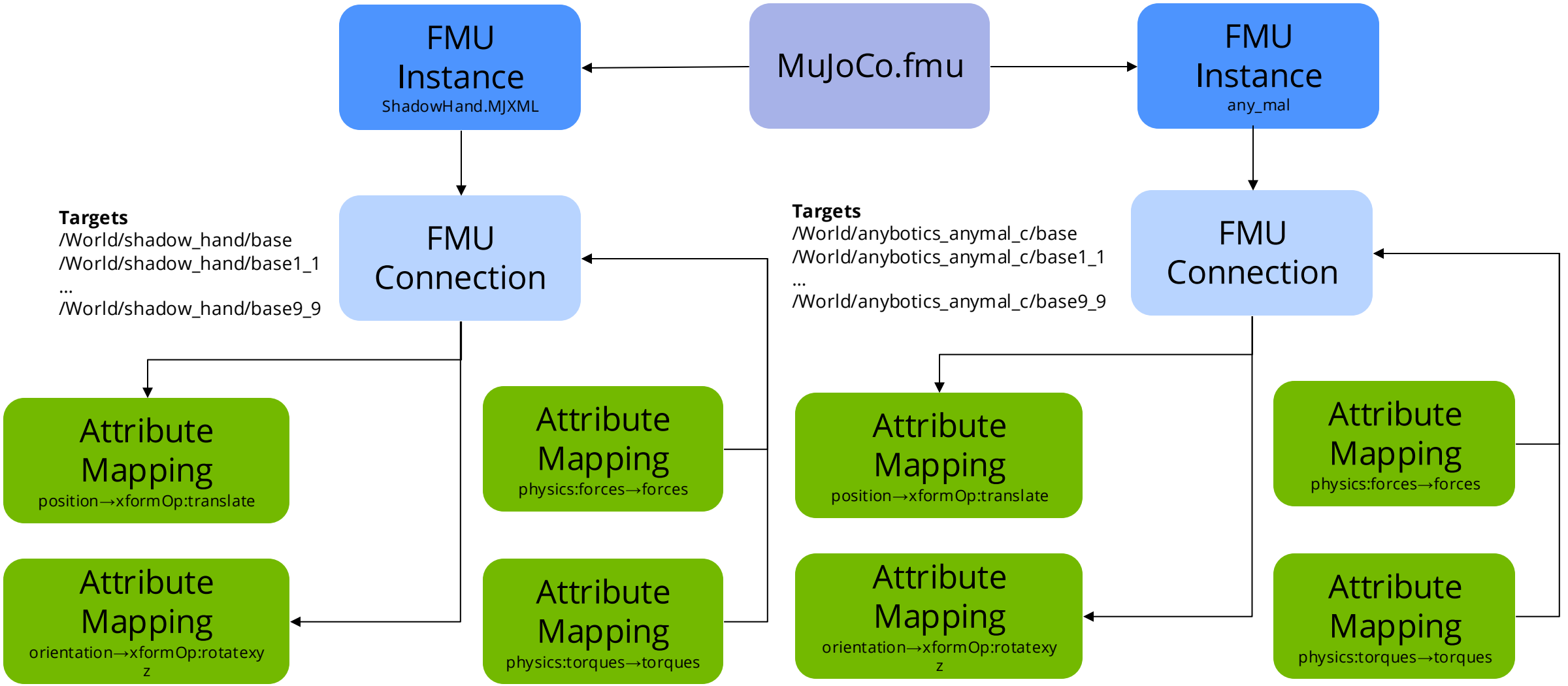
USD-FMI STANDARD

Example: MultiBody Physics standard



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FUTURE OF USD + FMI

What NVIDIA brings to the table

BRIDGE AND BRING THE FMI AND ALLIANCE FOR OPEN USD (AOUSD) STANDARDS GROUPS AND ECOSYSTEMS

- Identify industrial use cases and expand the integration standard
- Create a working group for USD + FMI with stakeholders

WITH NVIDIA'S UNIQUE COMPETENCIES, FURTHER USD+FMI OPPORTUNITIES IN

- Hardware acceleration of FMUs within USD
- Define 'Simready' specifications using USD + FMI --> 3D asset data + coupled behavior
- Neural physics and machine learning models using FMUs

APPLICATION WORKSTREAMS

- Robotics simulations, testing/validation and reinforcement learning pipelines
- Autonomous Vehicles (AV Sim)
- HIL, SIL, PLC control simulations
- Virtual Factory Integration

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RECAP

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THANK YOU!

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ANY QUESTIONS?
LET'S TALK

FOR THE FUTURE