Daily Check-In:

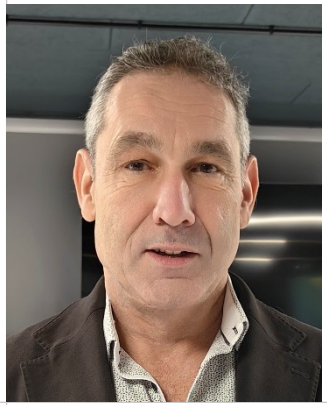
Wednesday

Please take a moment to check in for today's session.

MIRION Connect 26
AMERICAS
Annual Users' Conference

Advancing Radiation Safety.
Empowering Progress.

How digital twin can support the Nuclear industry challenges



Martin
COURCHESNE
Head of Interactive
Simulation Laboratory

Plan

1. CEA Introduction
2. Interactive Multi-physics Simulation and some examples
3. Gobie and Murene use-case description and hilights
4. Toward semi automatic digital twin creation using AI

CEA, a major center for science and technology research

- **One of the France's leading government research organization**
- **Scientific and technical objectives** organized around **four pillars**

Energy transition (nuclear and renewable)

Digital transition

Technologies for **Health**

National **security and Defense**

CEA key figures

700 +
R&D partnerships

260
startups created since 1972

640
priority patent applications

22,100
employees

€6.4 BN
operating budget
(civil and defense)

7,870
active patent families

No.1 research organization in the top 100 global innovators ranking
(Clarivate – March 2025)

No.1 research organization for patents filed
in Europe (OEB – March 2025) and France (INPI – March 2025)

No.5 for patents filed in France
(INPI - March 2025) just behind Stellantis, Safran, L'Oréal et Valeo

One of the CEA's missions is to transfer new technologies developed in our labs to help businesses remain competitive, create jobs, and support economic sovereignty.

CEA organization

- **CEA conducts research and delivers innovative technologies that meet society needs.**
- **It's** organized around **four operational Divisions**

SECURITY
DEFENSE

FUNDAMENTAL
RESEARCH

LOW CARBONE
ENERGIES

TECHNOLOGICAL
RESEARCH

cea list
Smart digital systems

cea leti
Micro & nano-technologies

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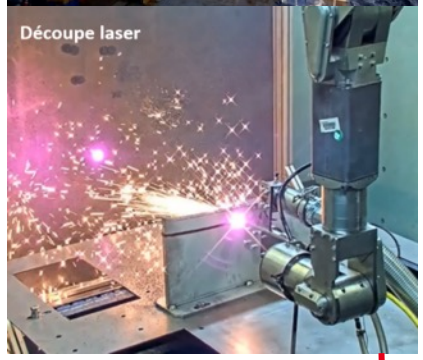
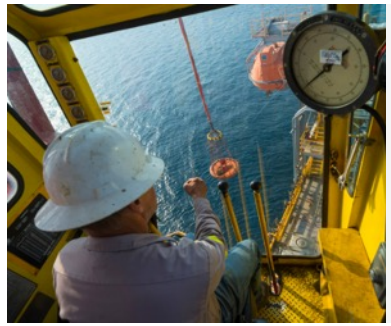
Immersive and Interactive Digital Twin

INTERACTIVE MULTI-PHYSICS SIMULATION

Real



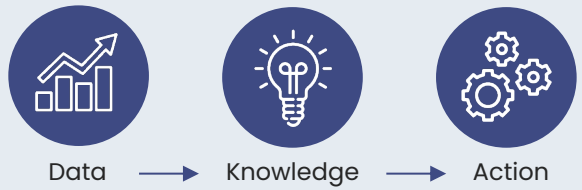


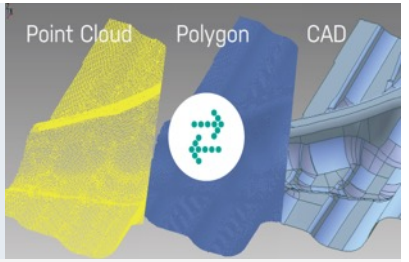
Human in the loop

INTERACTIVE DIGITAL TWIN

Simulation

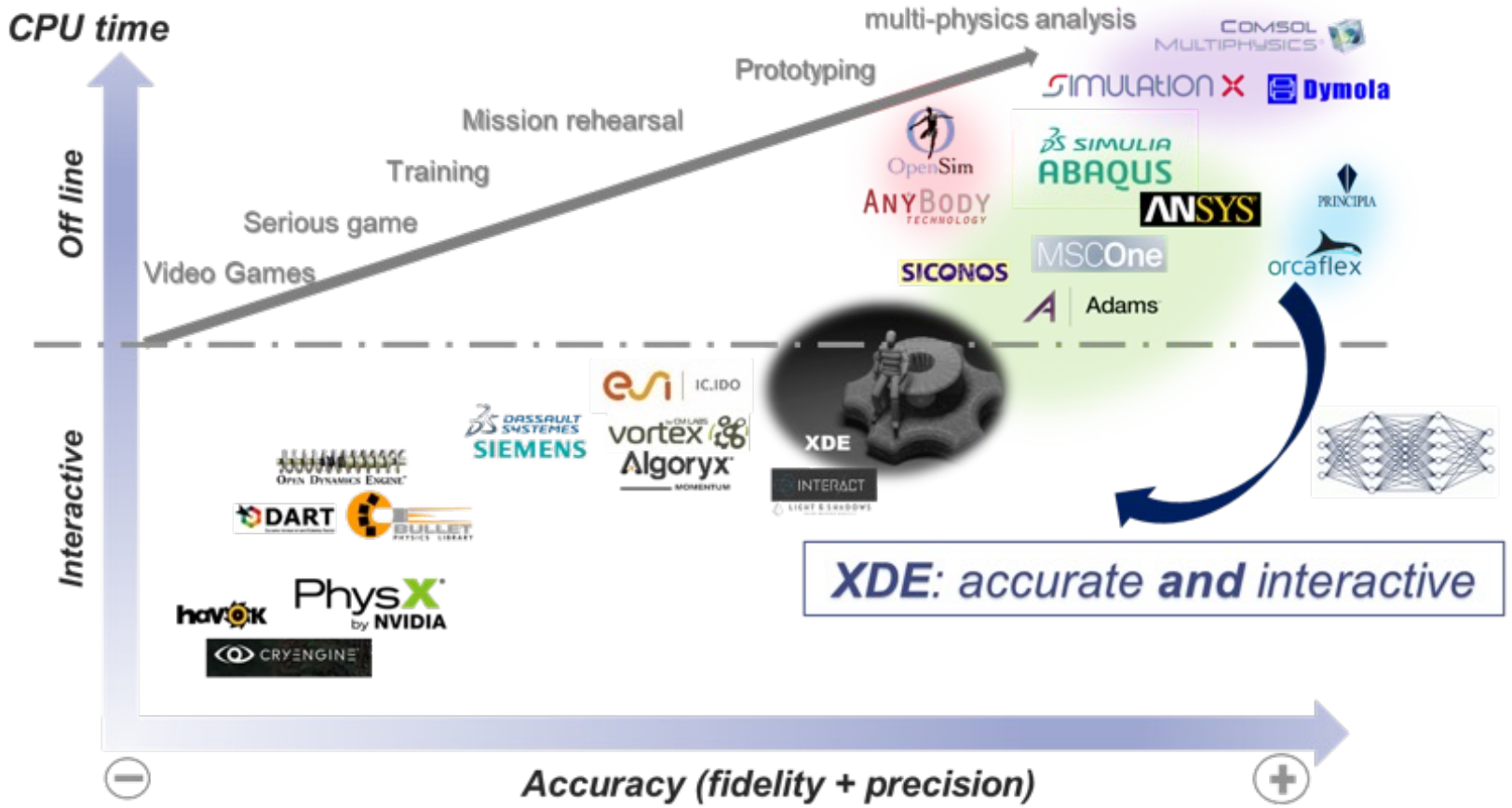
- Problem Identification and resolution from concept
- Risk analysis, complex mission planning
- Know-how capitalisation / Digitalisation, training
- Collaboration between collaborators from different fields





Data

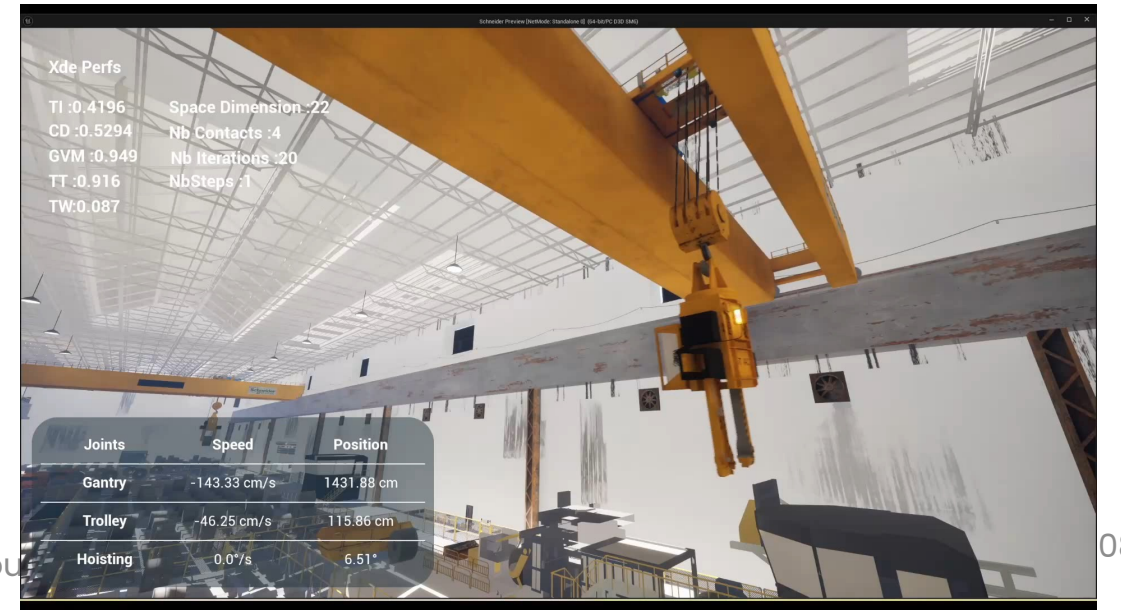
Interactive Multiphysics Simulation/ XDE

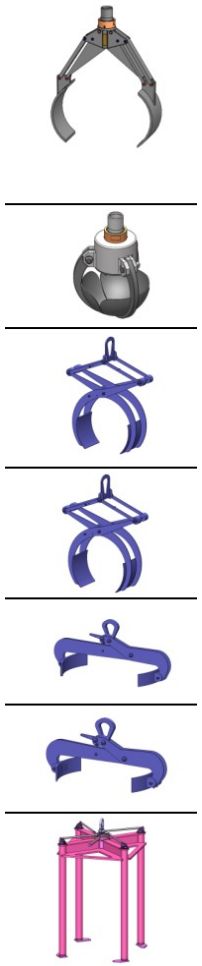


XDE Multi-Physics Solver: multibody dynamics simulation, contact detection, hydrodynamic models, hydraulic simulation, nuclear reactor simulation

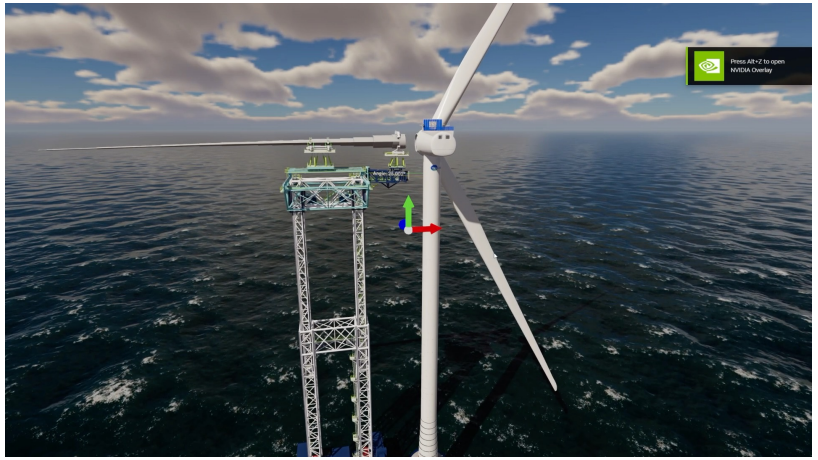
MAKE DECISION BASED ON SIMULATION RESULTS

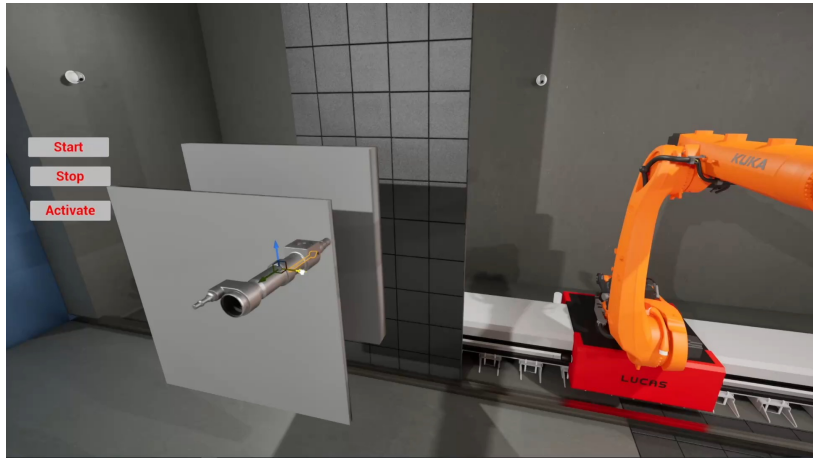
INTERACTIVE MULTI PHYSICS SIMULATION / XDE





INTERACTIVE MULTI PHYSICS SIMULATION / XDE





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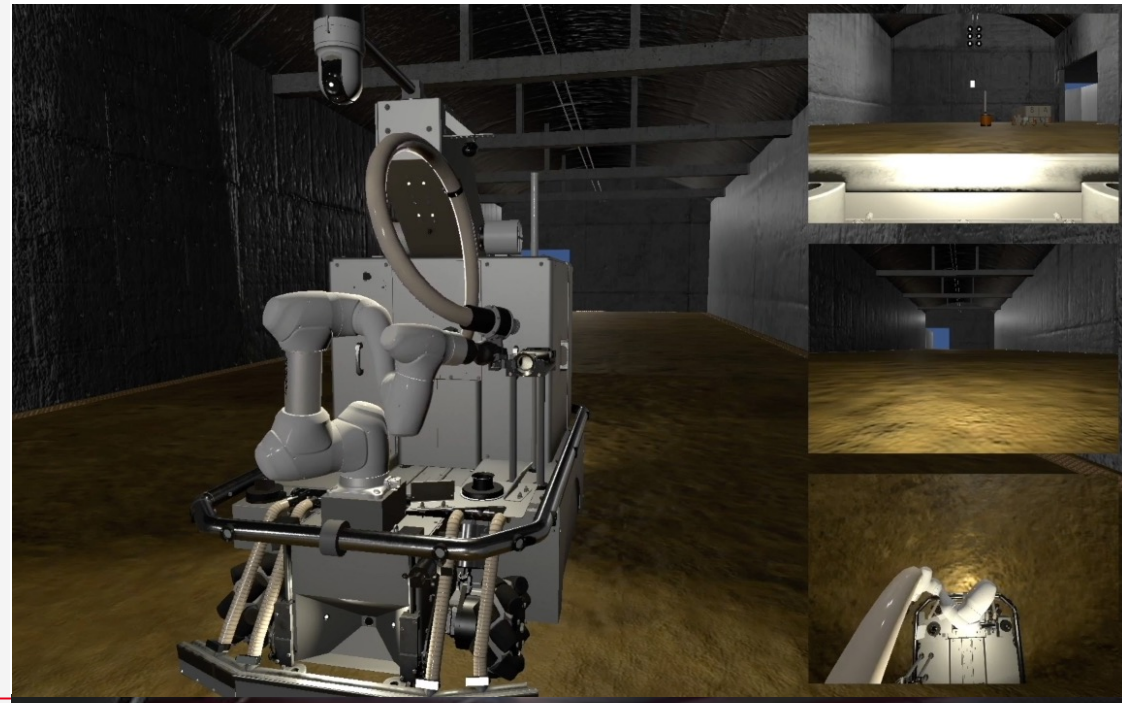
Complex machines Digital Twin in XR

GOBIE - MURENE

Until now, the operations to recover old bitumen drums stored were carried out using trolleys fitted for a nuclear environment.

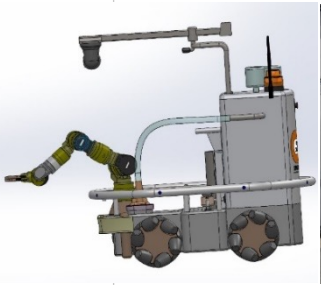
These trolleys have **many disadvantages :**

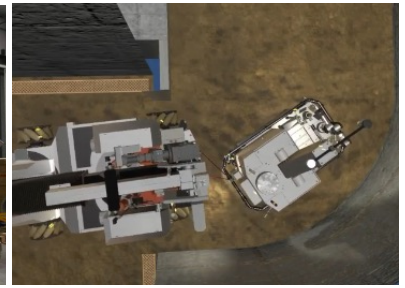
- the presence of an obligatory driver
- heavy equipment (19 t), a cart that is difficult to maneuver
- restricted visibility and limited production time

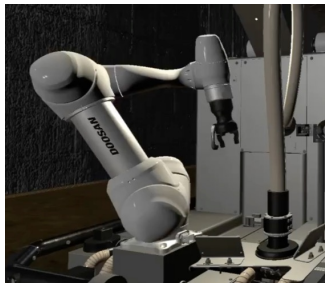


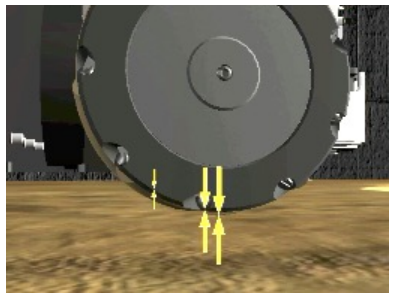
GOBIE and MURENE
are innovative remote-controlled equipment for clean-up and dismantling sites

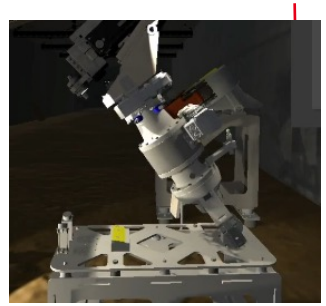
Complex machine Digital Twin in XR : Development time line











2021

DT Gobie
- Training

2022

DT Murène
- Training

2023

DT Murène
- Dimensioning expertise
- New scenes (Towing, more drums, …)

2024

DT Murène
- JN-battery coupling
- Specific cave scenarii
- Front of drums
- Changing tools
- Semi-auto pilot validation

DT Gobie
- Validation Doosan arm

2025

DT Murène
- DT-battery coupling
- New specific scenarii
- New HMI
- Scene configuration tool

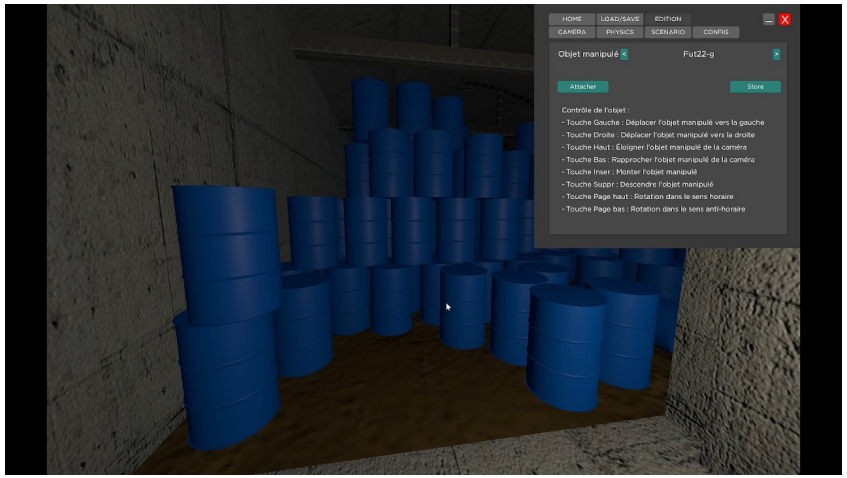
2026

DT Murène
- Machine breakdown analysis
- Use DT for third person view during operation

Typical scenario examples

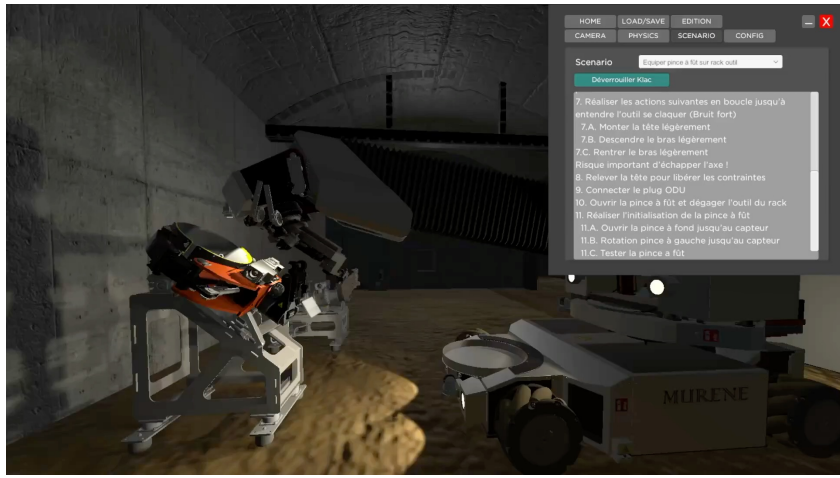
Simulator is teleoperated using original consol.
Digital twin simulates all sensors, cameras

Interactive scene configuration tool



Operation in constrained space

Tool change opreation

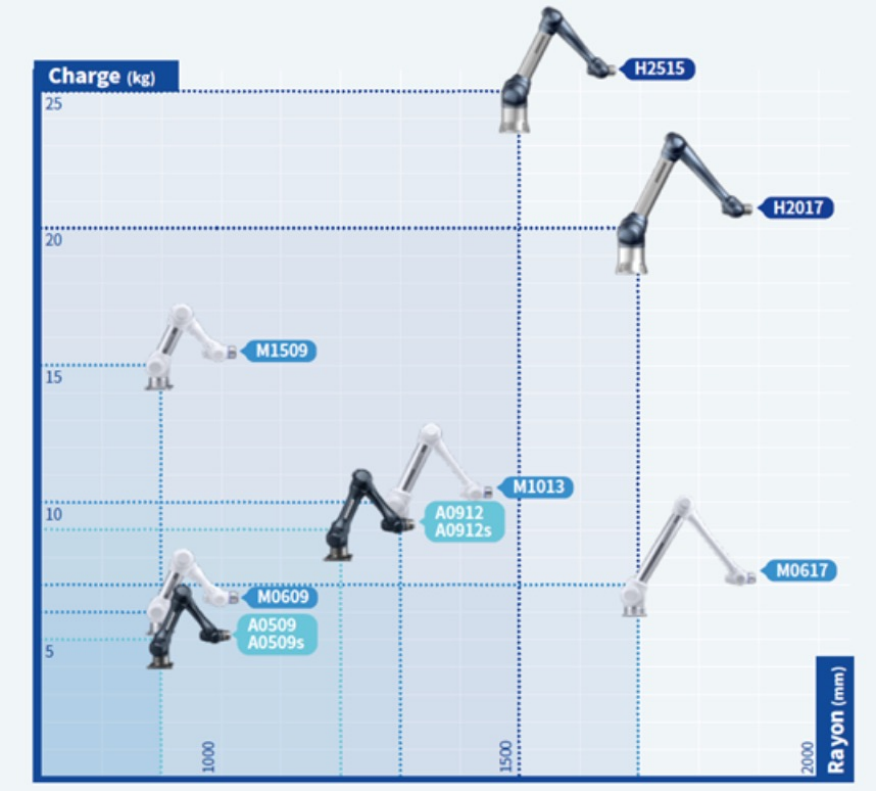


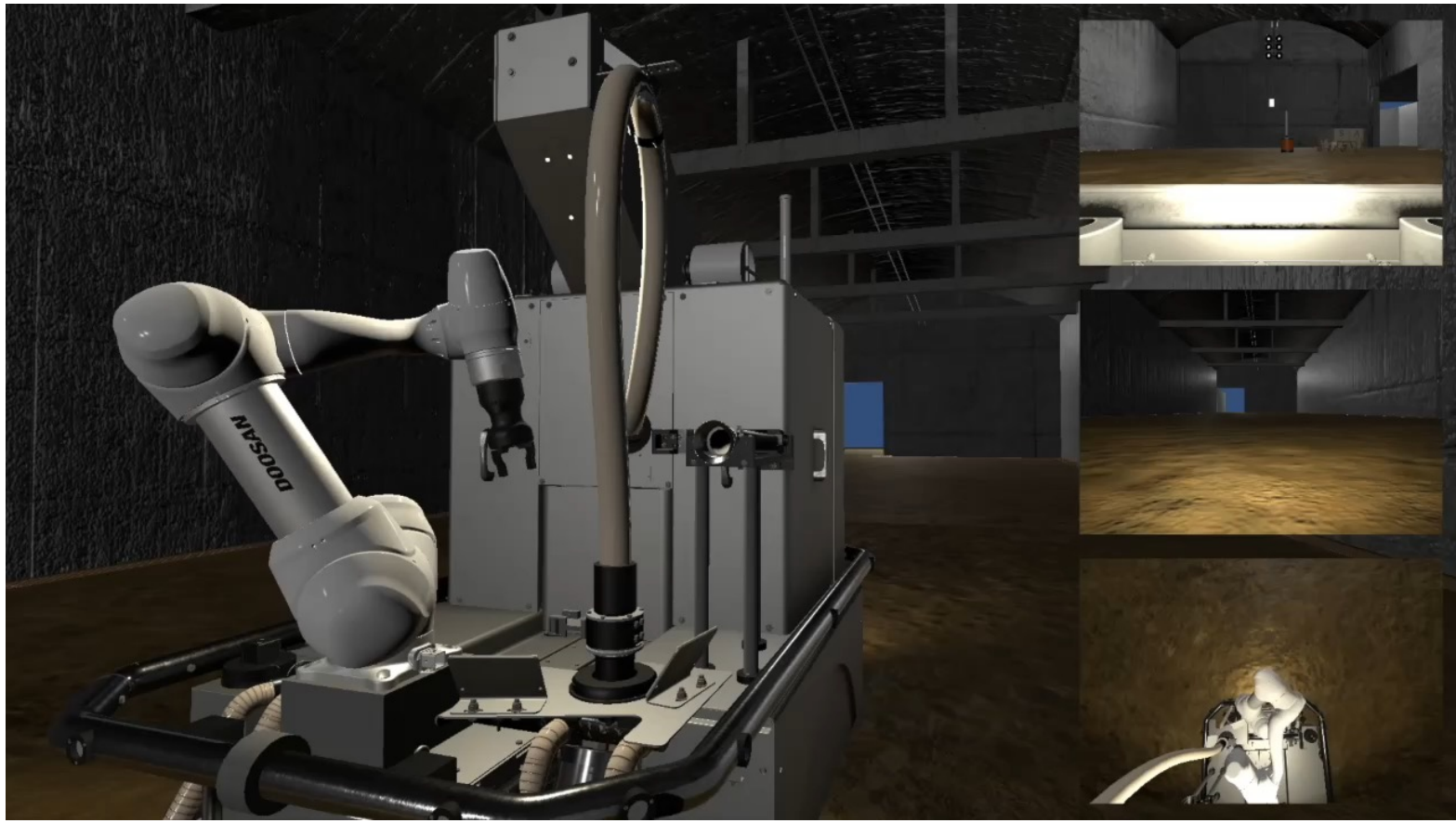
Towing scenario

Emergency procedure validation in case of machine breakdown

Study for robotic arm replacment

Accessibility tests, for different actions with different robotic arm models





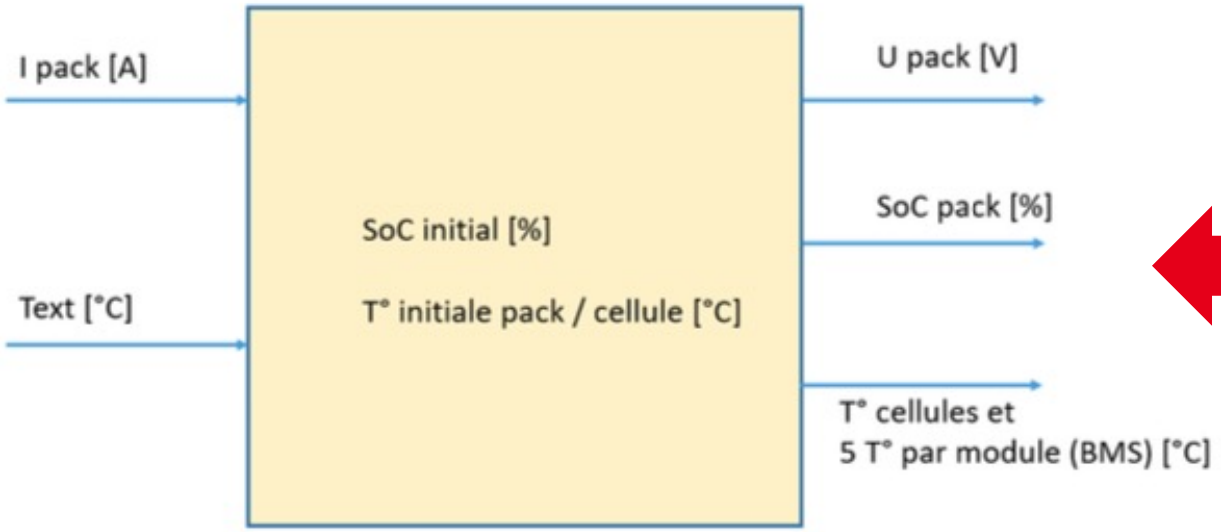
Coupling DT with battery simulator

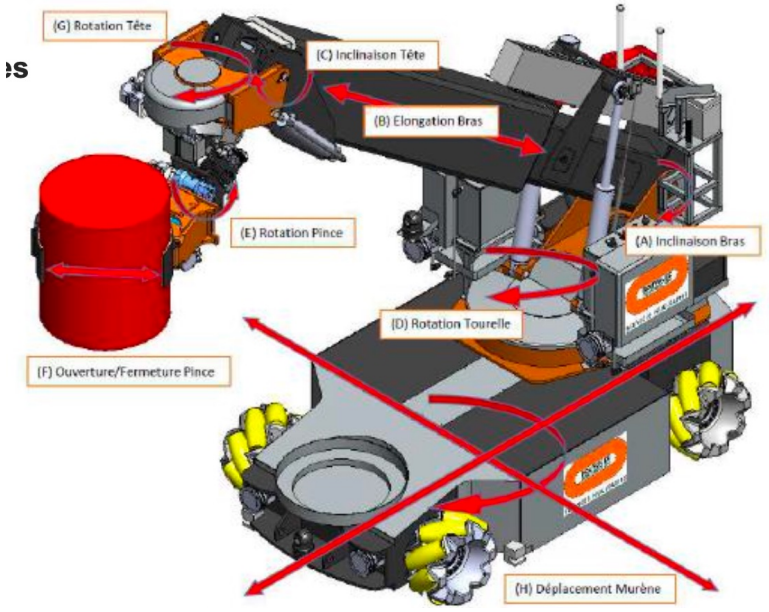
Objective: Predict the energy consumption of the Murene in real time during DT operation.

Prediction Models : **Hydraulic axes: semi-empirical models**

Electric axes: physical models

Coupling to the battery simulator via Simulink.

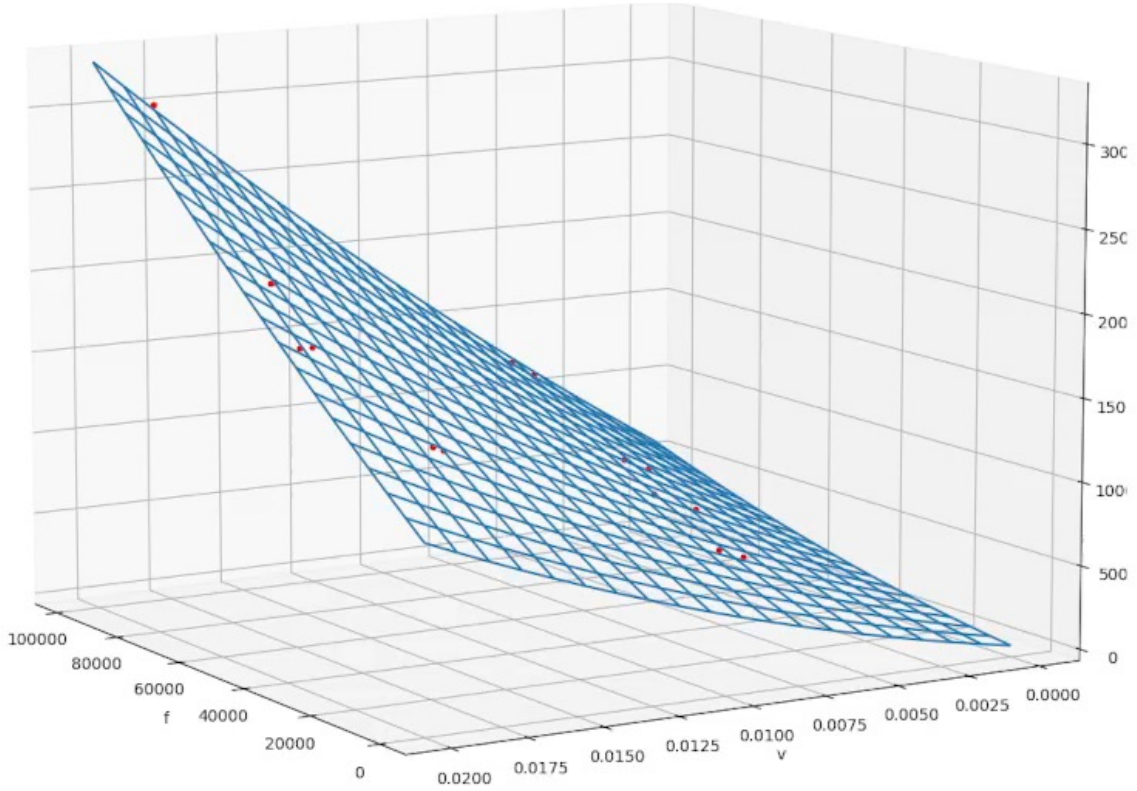




Energy consumption Prediction Models

Hydraulic axes: Semi-empirical models

Fit two-variables polynomial formulae



Electrical axes: Physical models

Power consumption model $P(\omega,\Gamma)$

$$\boldsymbol{P(\omega,\Gamma) = \eta_{variator}^{-1}\,\eta_{motor}^{-1}\,\eta_{gearbox\,1}^{-1}\eta_{gearbox\,2}^{-1}(\omega,\Gamma)\,|\omega\,\Gamma|}$$

Parameters	Value	Estimation method
$\eta_{variator}$	0,9	Manufacturer spec
η_{motor}	0,9	Manufacturer spec
$\eta_{gearbox\,1}$	0,9	Plausible value
r_1	21 mm	Approx. from 3D models
r_2	155 mm	Approx. from 3D models
z_2	80	Plausible value
μ	0,2	Fit from monitoring data
$\Gamma_{friction}$	**996 N.m**	Fit from monitoring data

Energy consumption Prediction Models

Hydraulic axes: Semi-empirical models

Hydraulic axes: Physical models

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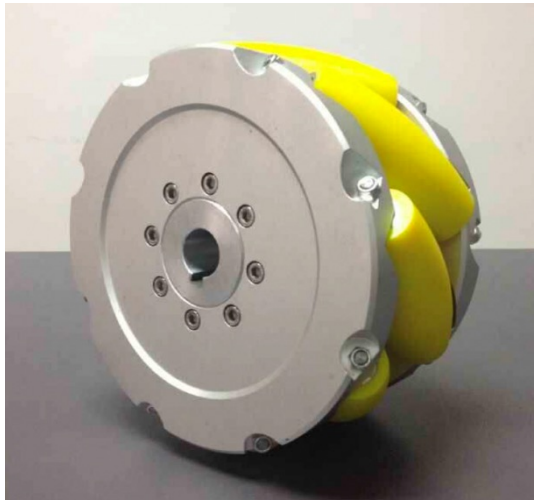
$\Gamma_{friction}$	**996 N.m**	Fit from monitoring data

Results highlights the cause of excessive energy consumption

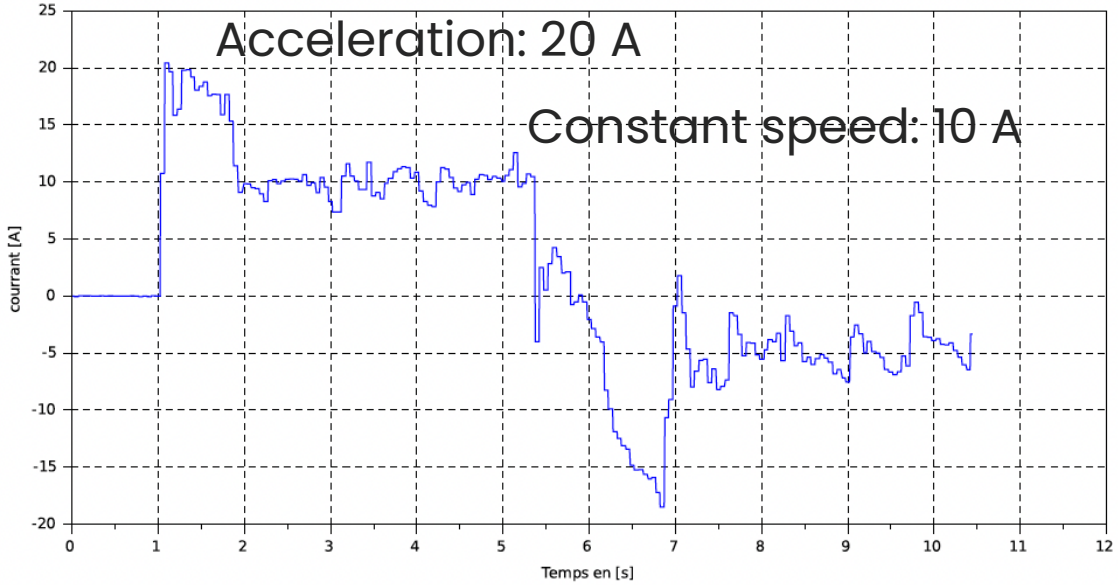
Energy consumption Prediction Models

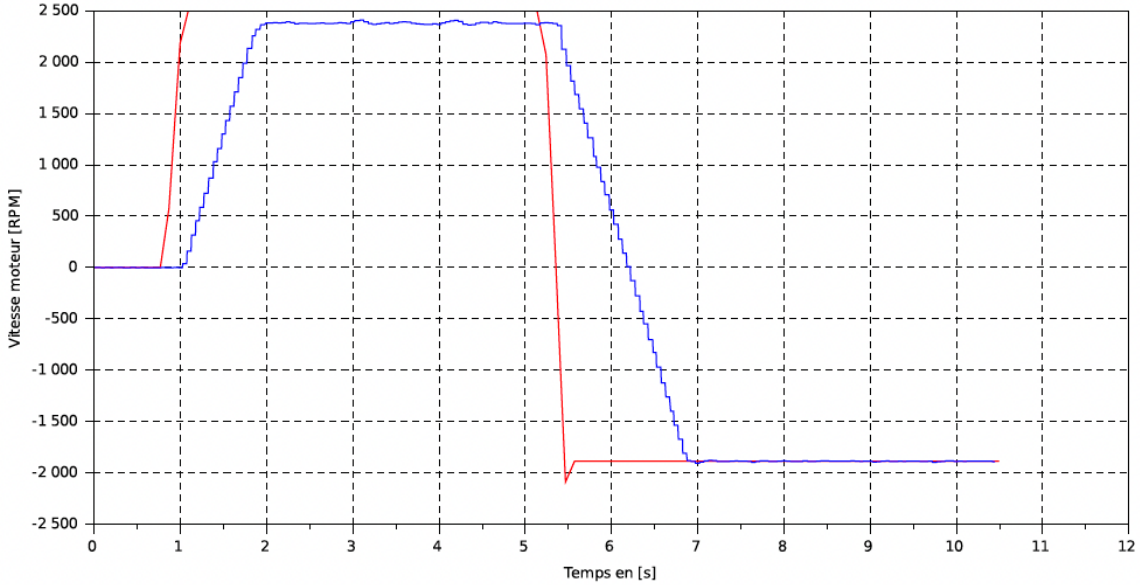
Wheels ground interaction with mecanum wheels

- Locomotion consumes large portion of the energy
- Consumption depends on the type of ground, difficult to categorize
- Real-time tuning of the rolling resistance model can be achieved via wheels motor's electrical current intensity monitoring



While the energy consumption is higher in the acceleration phase, the locomotion still consumes a non negligible amount of energy, even at constant speed due to rolling resistance.





Energy consumption Prediction Models

Digital twin usefulness recap

Until now, the recovery operations of old stored bitumen drums were carried out using trolleys adapted to a nuclear environment. These trams have many disadvantages: the presence of a mandatory driver Heavy equipment (19 t), a trolley that is difficult to maneuver Restricted visibility and limit Production time.

The CEA has designed the Gobie and the Murène, two remote-controlled mobile robots designed to enable these complex operations in a more efficient and safe way. The digital twins of these machines were initially aimed at the training needs of operators.
Quickly, users of the simulator realized that the digital twin could have other uses:

- Today, missions are validated via the digital twin evolving in faithful reproductions of the casemates: for difficult or congested access, stacks of barrels high up near the ceilings, etc.
- Validation of emergency operations (towing in case of breakdown)
- Validation of the replacement of the Gobie's robotic arm
- Study of the cause of premature wear of a vehicle part
- Study of energy consumption and battery usage
- Increased operator console with a 3rd person view for more efficient control.
- Testing and validation of pilot assistance functions
- …

Perspectives

- Using the digital twin for improving situational awareness of the vehicle its its actual configuration and its environment. This will complement the limited vision from the cameras, lidar and sensors.

- Use the digital twin vs monitoring data during operation to detect disparities for predictive maintenance.

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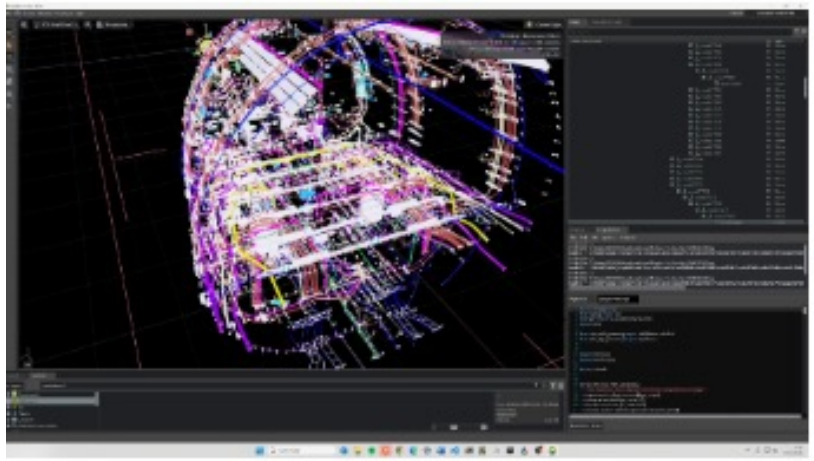
4. **Toward semi automatic digital twin creation using AI**

DIGITAL TWIN CREATION

- Maximizing Digital Twin Return On Investment
- Toward automatic Digital Twin creation using :
  - Available data: CAD, Point clouds, Pictures, Movies, …
  - Artificial intelligence and generative AI, algorithmic geometry, …

CAD MODELS



POINT CLOUDS

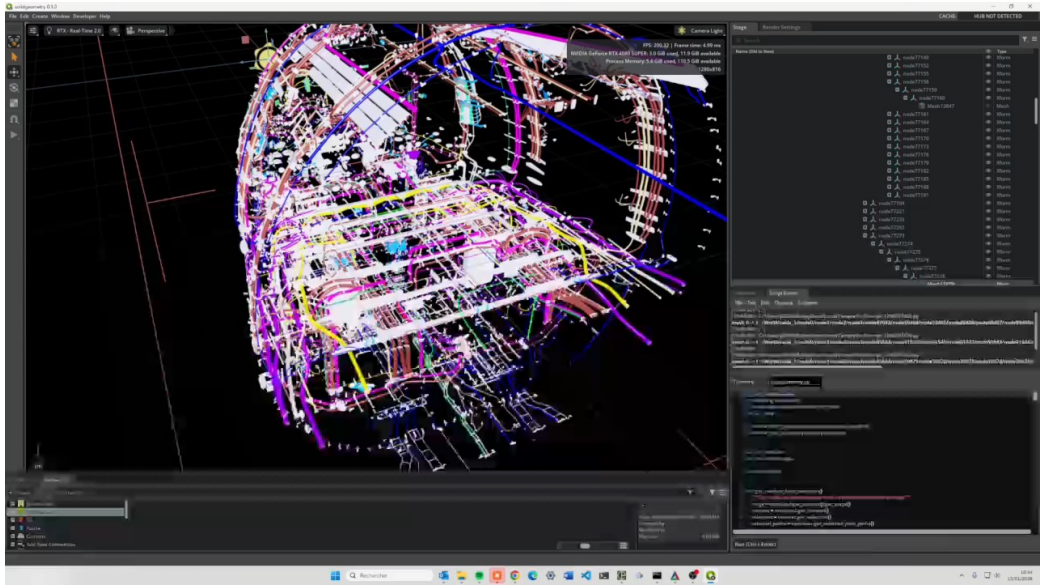
3DGS

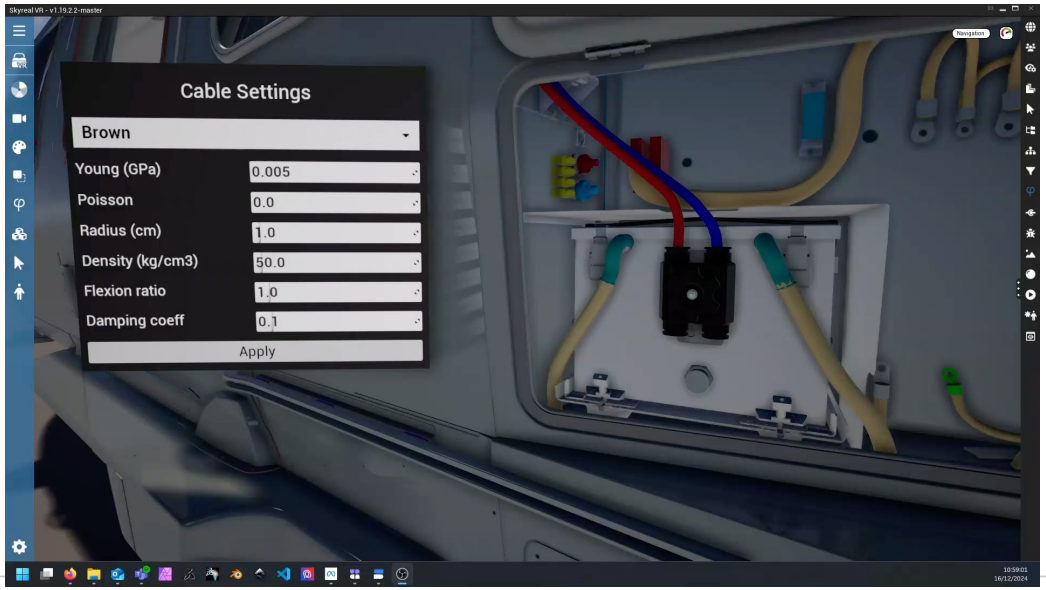
DATA PREP FROM CAD MODELS

- **Digital twin generation from cad models**
  - Automatic physics generation of rigid bodies and cable generation
  - Automatic kinematic constraint positioning
  - No-code scenarisation

- **Interactive multi-physics application**
  - Training, mission rehearsal
  - Virtual prototyping
  - Accessibility, ergomony
  - Training, ...

- **Interaction in collaborative VR**





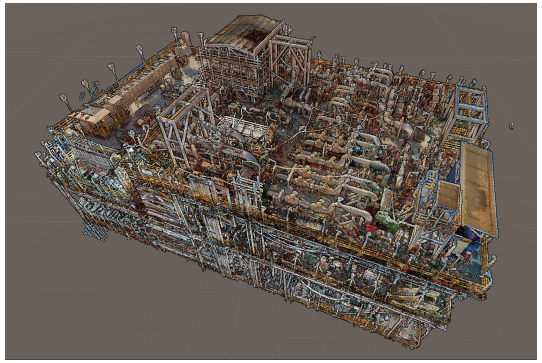
DATA PREP FROM POINT CLOUD

- **Digital twin generation from point cloud**
  - Automatic data base generation for AI
  - Automatic search for CAD elements from a dictionary
  - Reconstruction of object hierarchies

    CAD models like -> simulation ready

- **Accessibility study**
  - Accessibility
  - Path planning
  - …

- **Visualisation in VR**
  - Annotation, mesurements
  - Interactive selection tools



DATA PREP FROM SCAN (3DGS)

- **Digital twin generation from 3DGS Scans**
  - Scene segmentation and reconstruction
  - Reconstruction of object hierarchies
    CAD models like -> simulation ready

- **Accessibility study**
  - Accessibility
  - Path planning
  - …

- **Visualisation in VR**
  - Photorealistic results
  - Annotation, mesurements
  - Interactive selection tools

Visual inspections in complex environments

Tokamak WEST

XDE Physics: Simulation and interaction with massive 3DGS models

cea list cea irfm

CONTEXT

- Training operators in complex environment using drones
- Efficient photorealistic Digital Twin creation of complex environment

CHALLENGES

- Provide photorealistic digital twin of **massive environment**, with tools, machine, devices, sensors etc.
- Provide outputs for evaluating the quality of the operation: coverage, distance thresholds, Swept volume, collisions, ... \

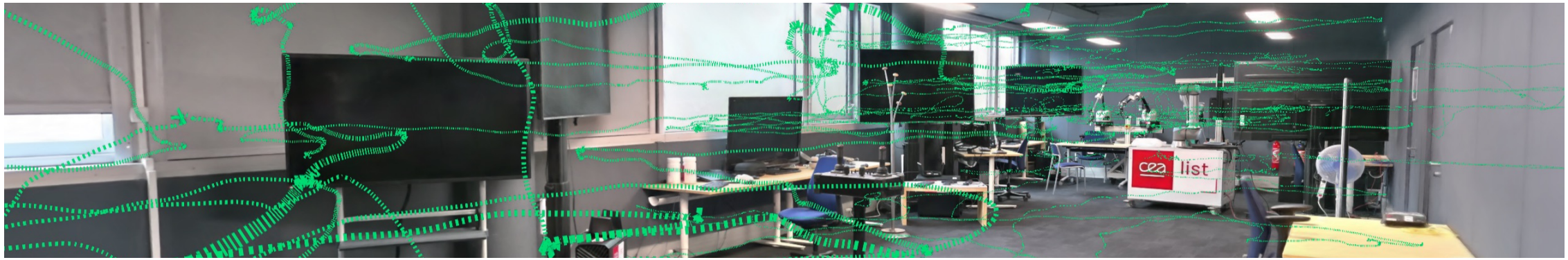
SOLUTION

- Use XDE Physics to capture and simulate interaction with massive 3DGS models.

Key benefits for clients/

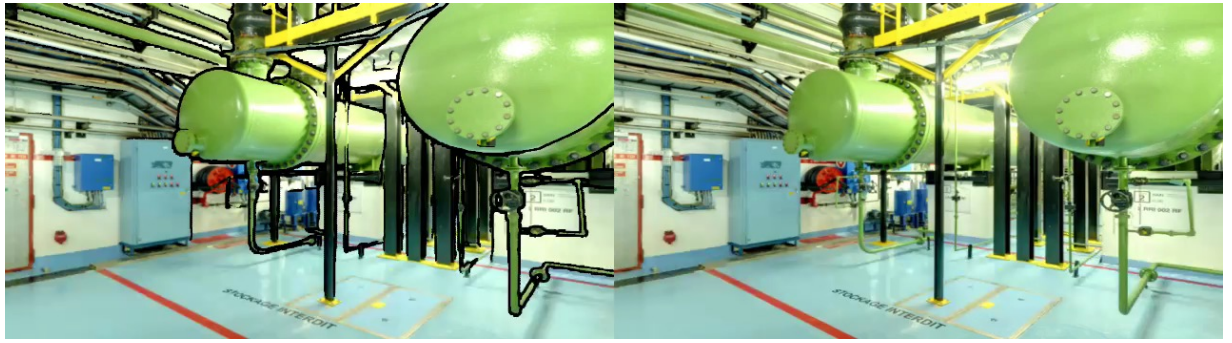
- Fast and inexpensive capture of massive environment
- Photorealistic quality of the result
- Automatic DT creation from scan
- XR compatible

Capture 3D gaussian Splatting with LOD

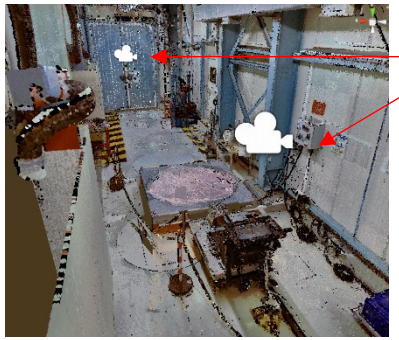


DATA PREP FROM SCAN (3DGS)

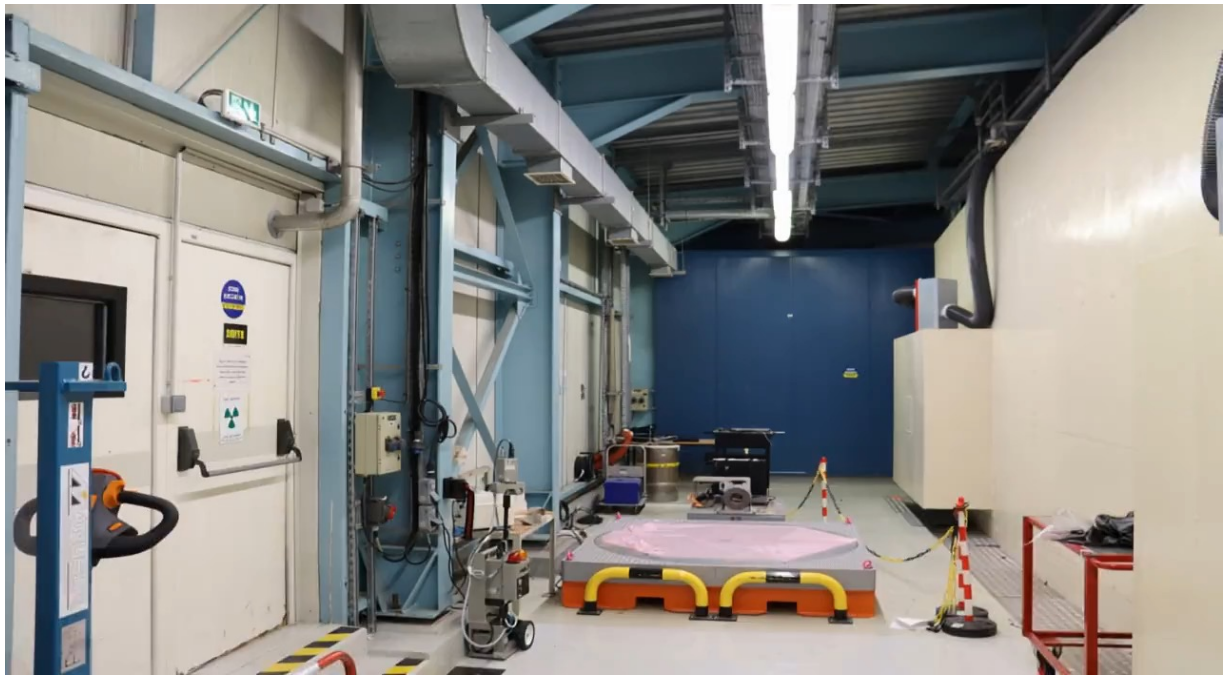
- Photorealist 3D scene reconstruction from point clouds and limited images



Point cloud



Input images

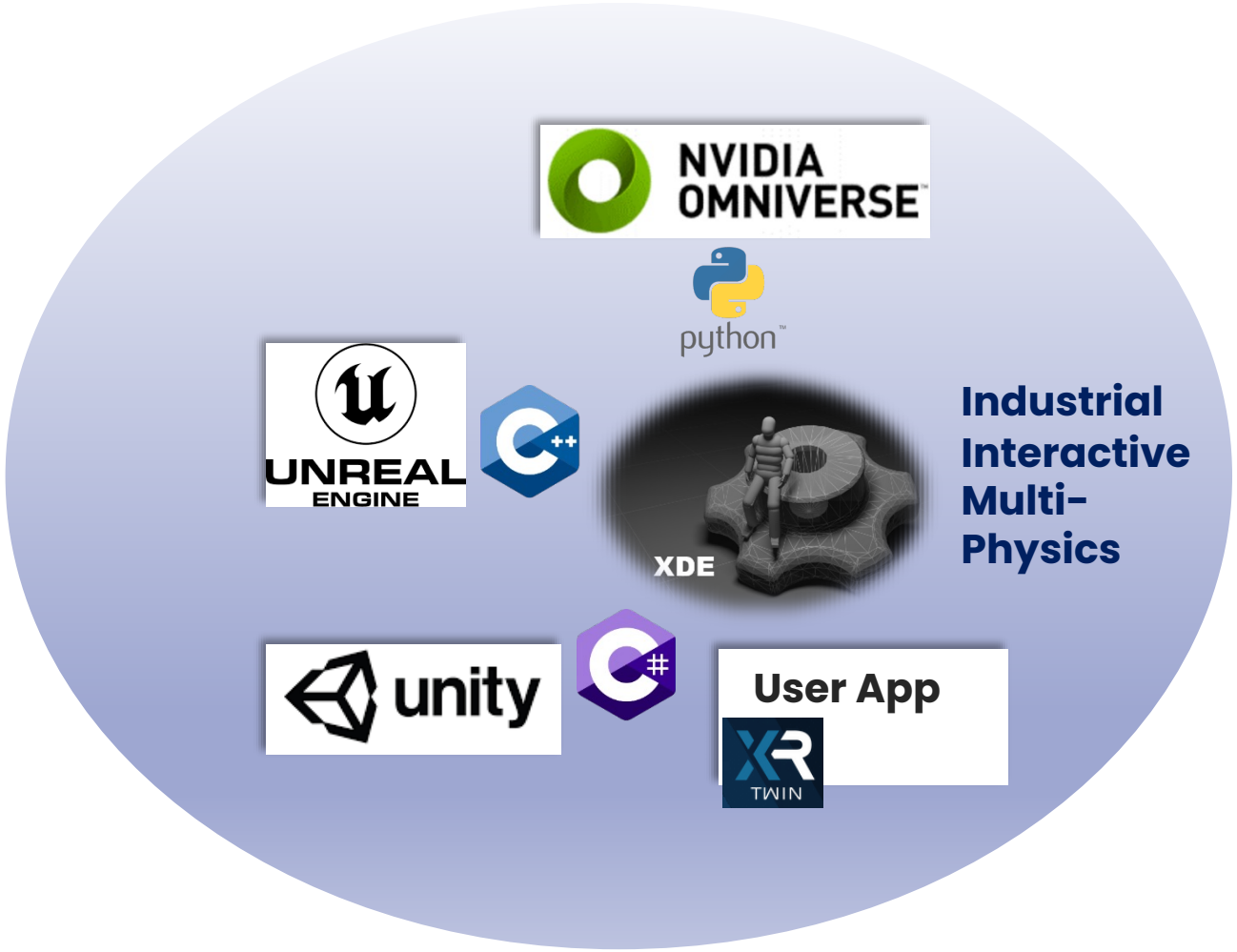


Reconstructed 3D Scene

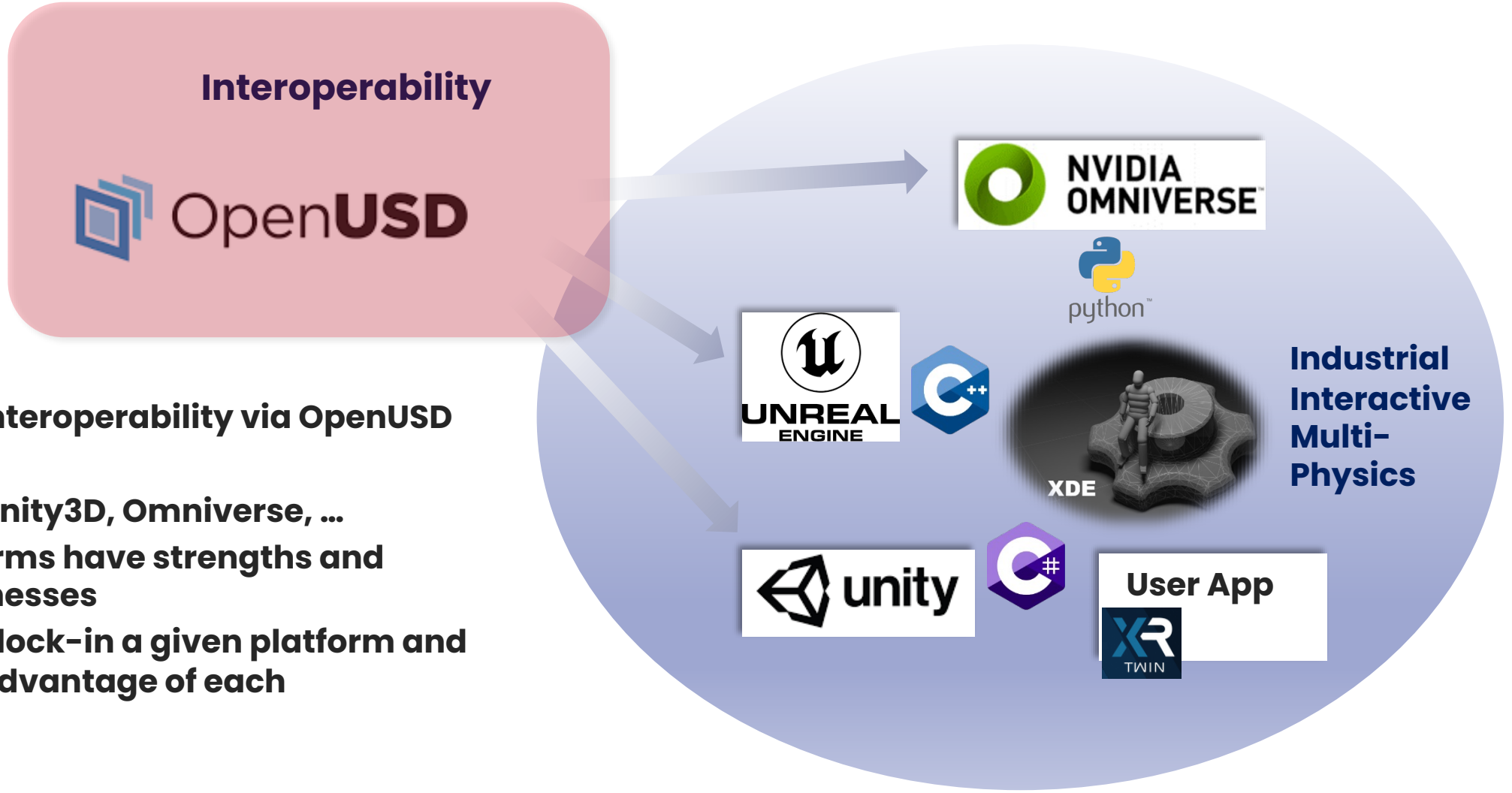
Industrial Grade Multi-Physics simulation

XDE Physics:

- **Built for integration into any 3D application.**
- **Integration with Unreal, Unity and Omniverse already provided**



Industrial Grade Multi-Physics simulation



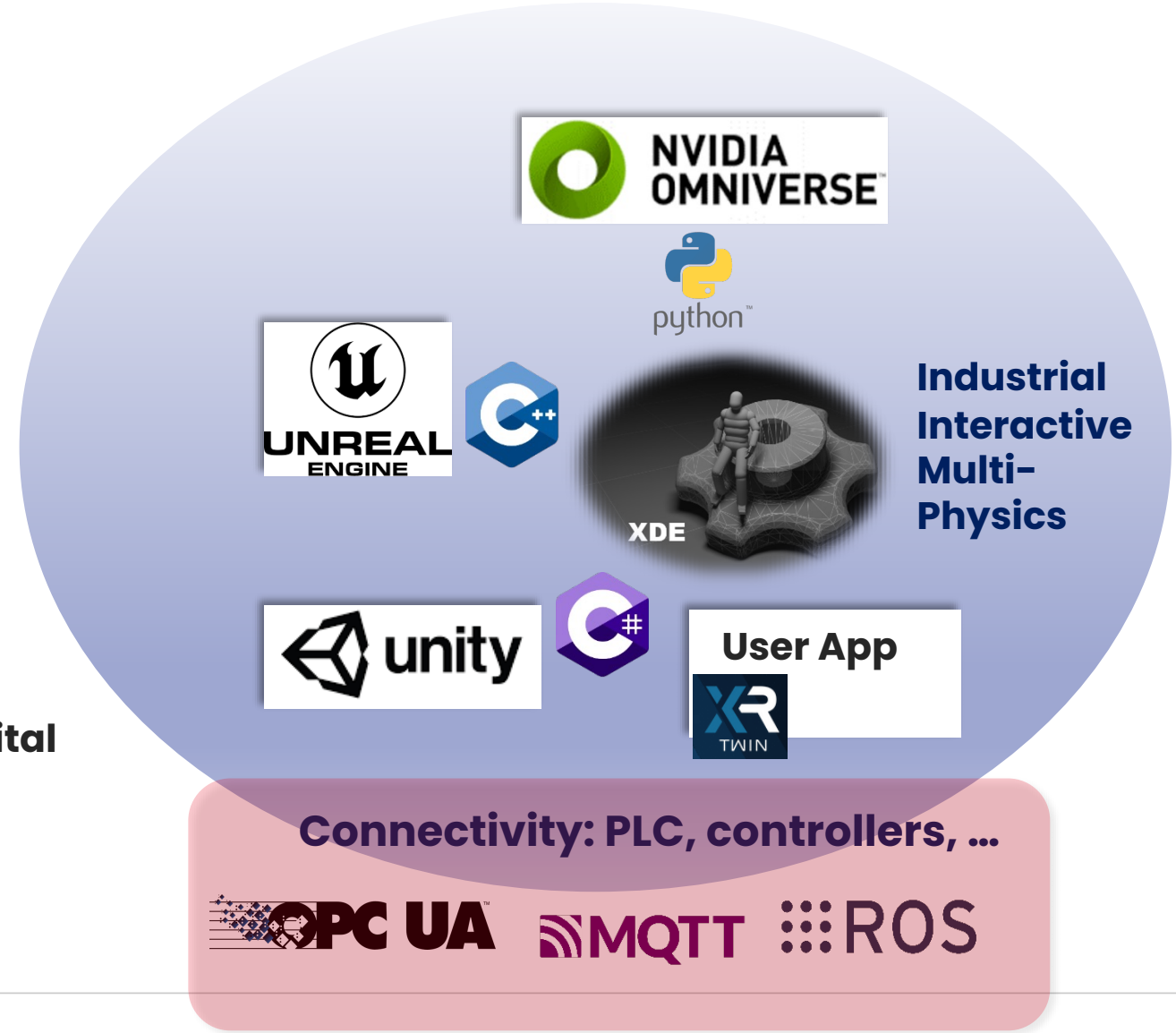
Platform Interoperability via OpenUSD

- **Unreal, Unity3D, Omniverse, …**
  - **Platforms have strengths and weaknesses**
  - **Avoid lock-in a given platform and take advantage of each**

Industrial Grade Multi-Physics simulation

Connectivity:

- **Easy communication between the Digital Twin and other hardware, controllers**
- **Co-simulation with other software (Simulink, …)**



Thank you for your attention

Survey for:

Research & Technology Forum

Please take a moment to fill out a short survey on this session.

MIRION Connect 26 AMERICAS
Annual Users' Conference

Advancing Radiation Safety. Empowering Progress.