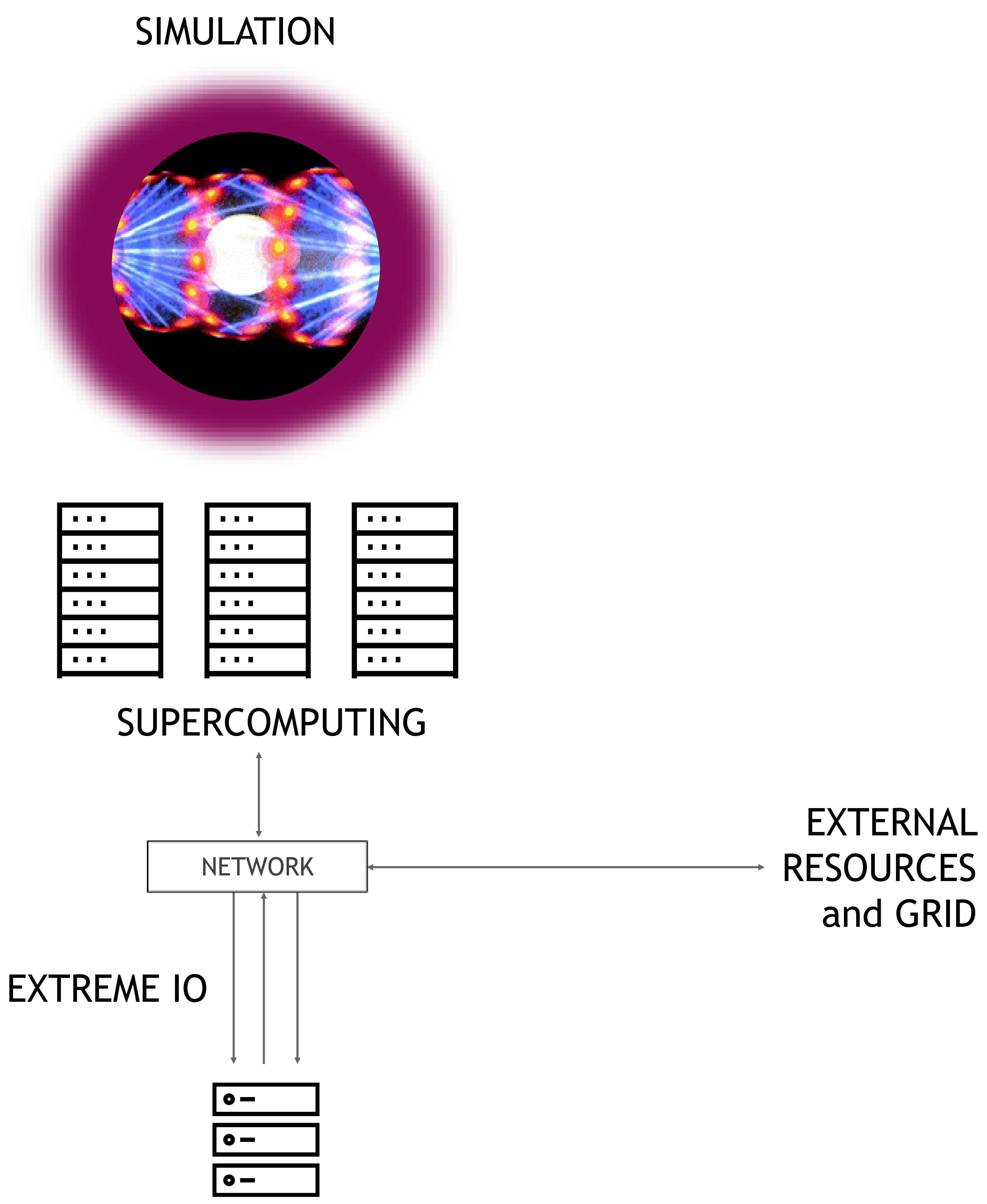
ACCELERATING COMPUTING FROM THE EDGE TO THE DATACENTER IN THE NEXT DECADE

TRADITIONAL HPC WORKLOAD



SIMULATION

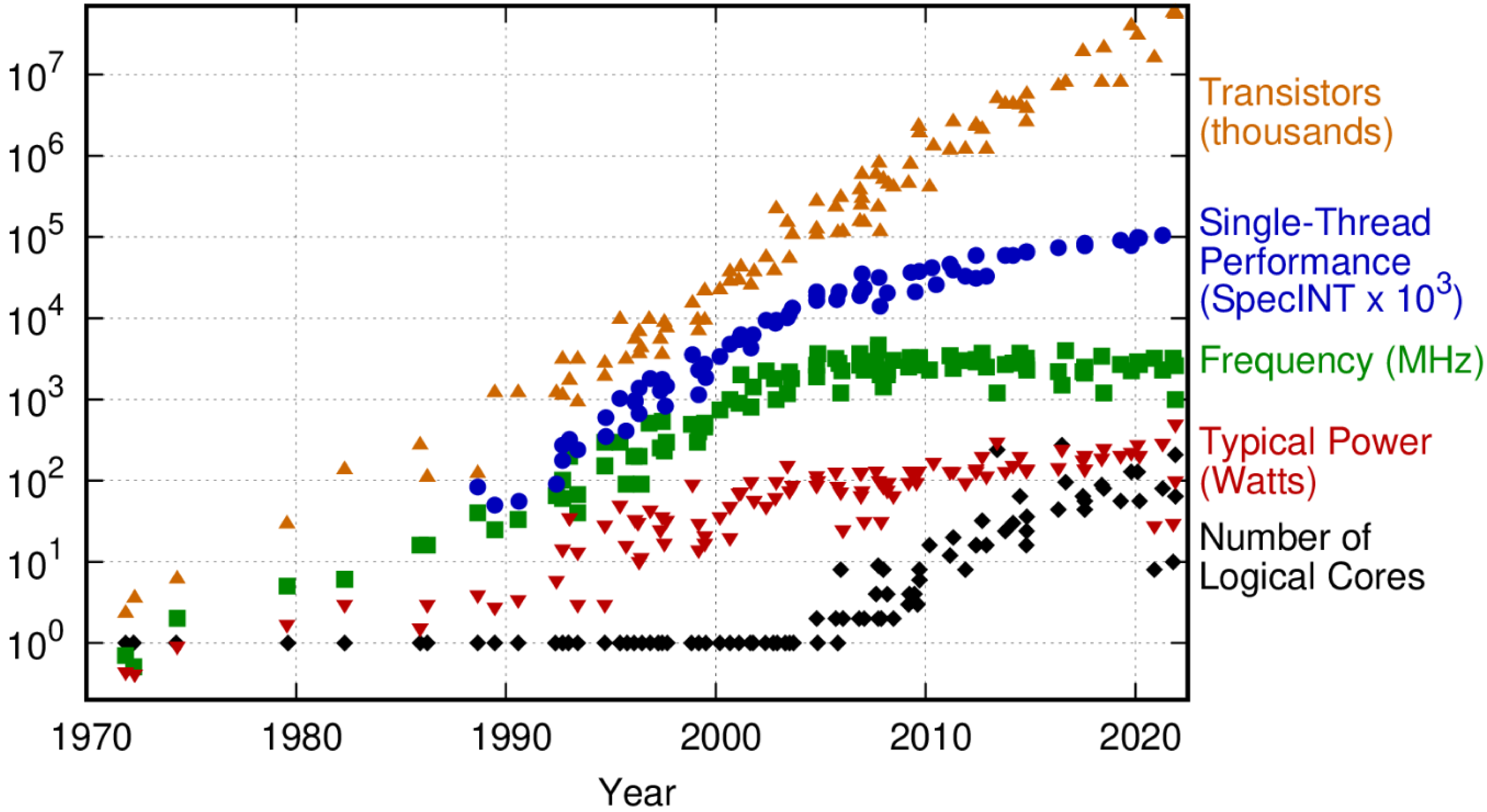
SUPERCOMPUTING

NETWORK

EXTERNAL
RESOURCES
and GRID

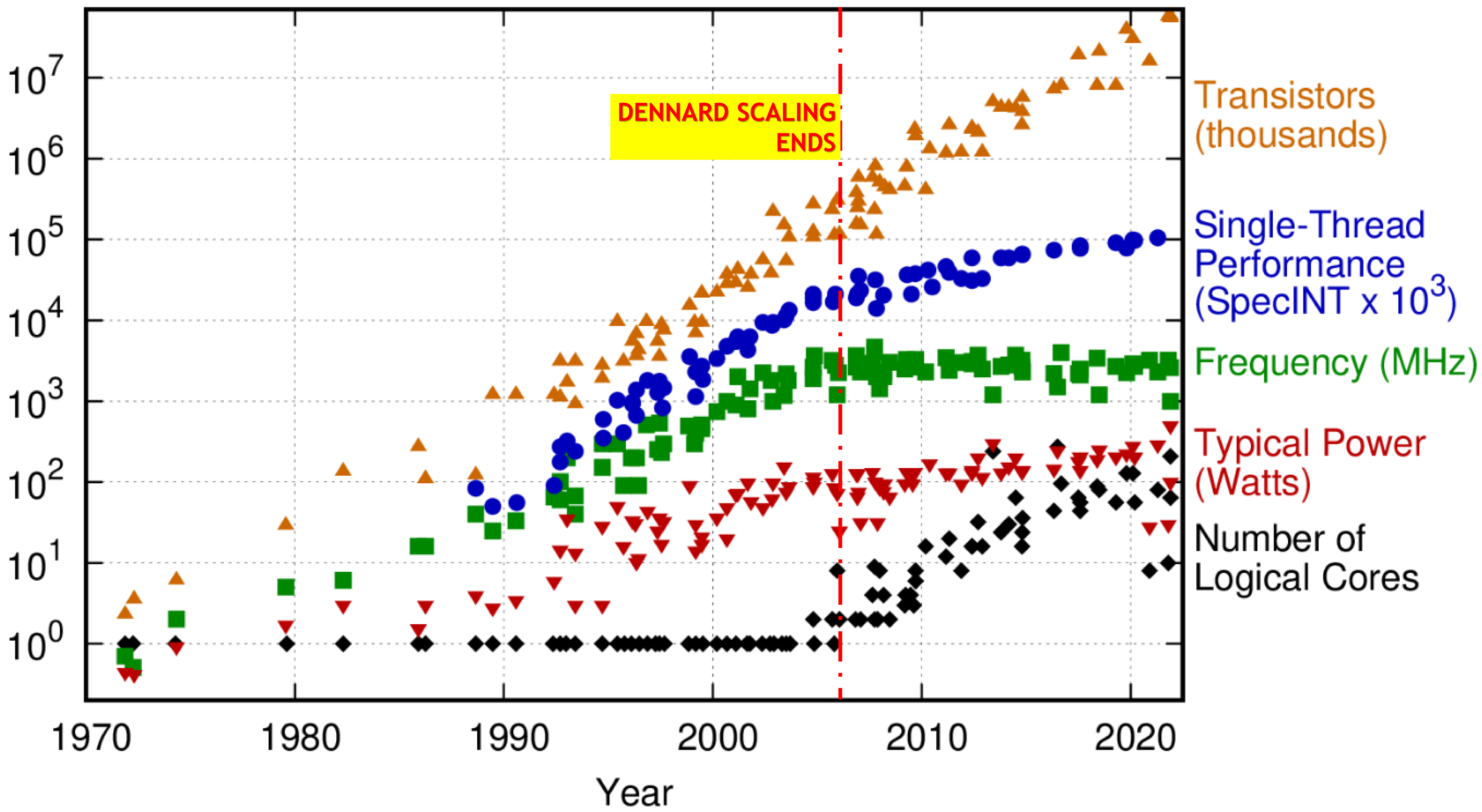
EXTREME IO

50 Years of Microprocessor Trend Data

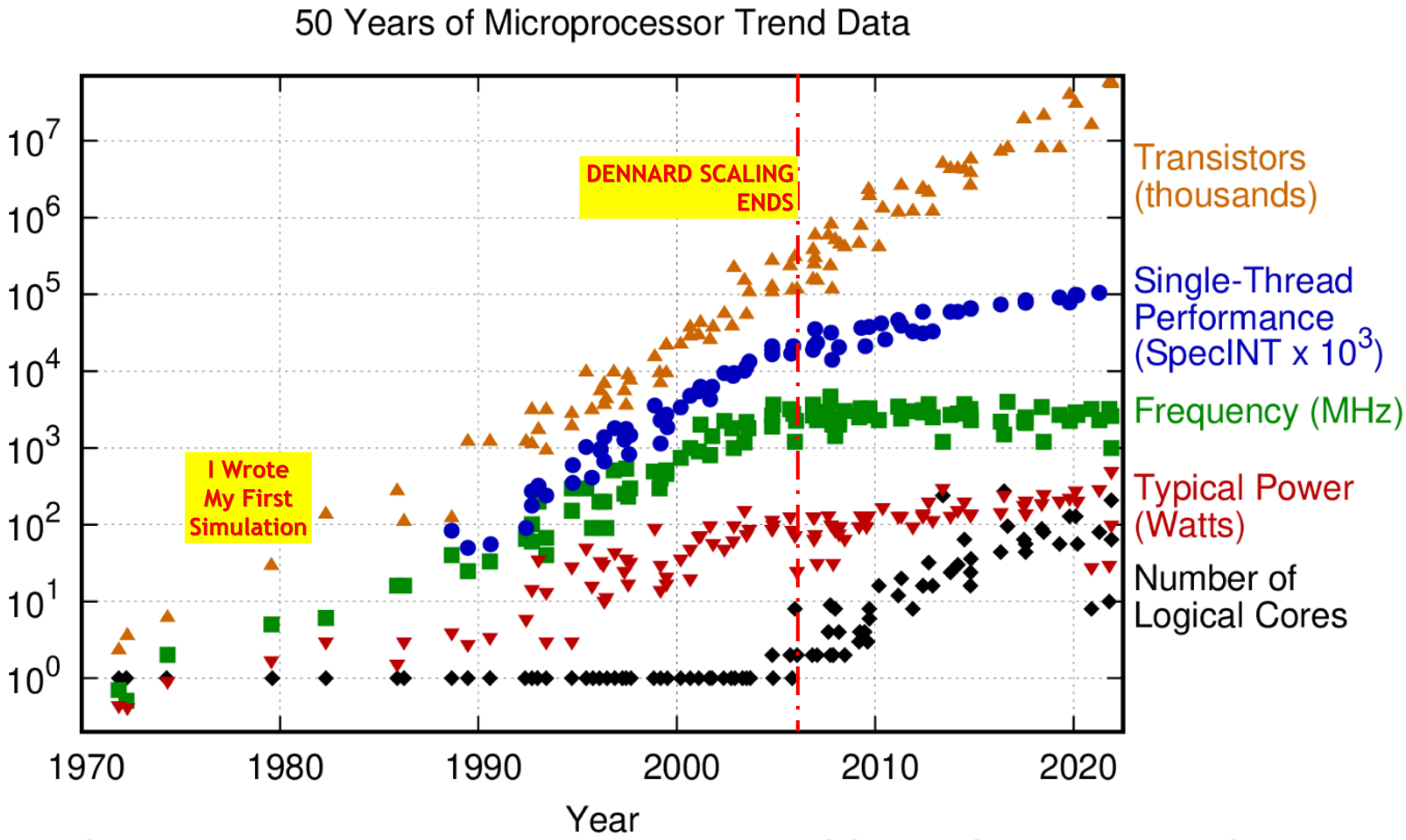


Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2021 by K. Rupp

50 Years of Microprocessor Trend Data



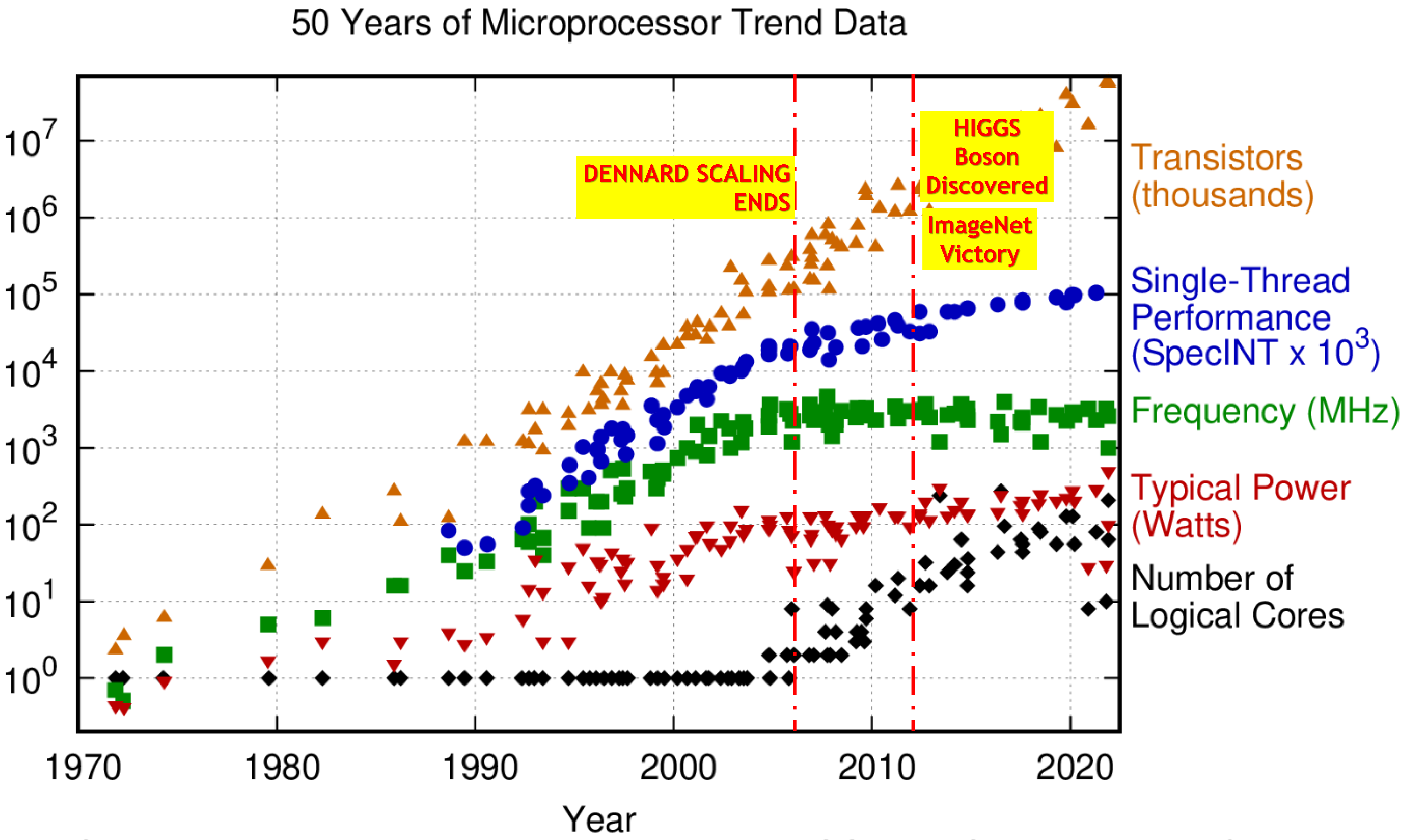
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2021 by K. Rupp



DENNARD SCALING ENDS

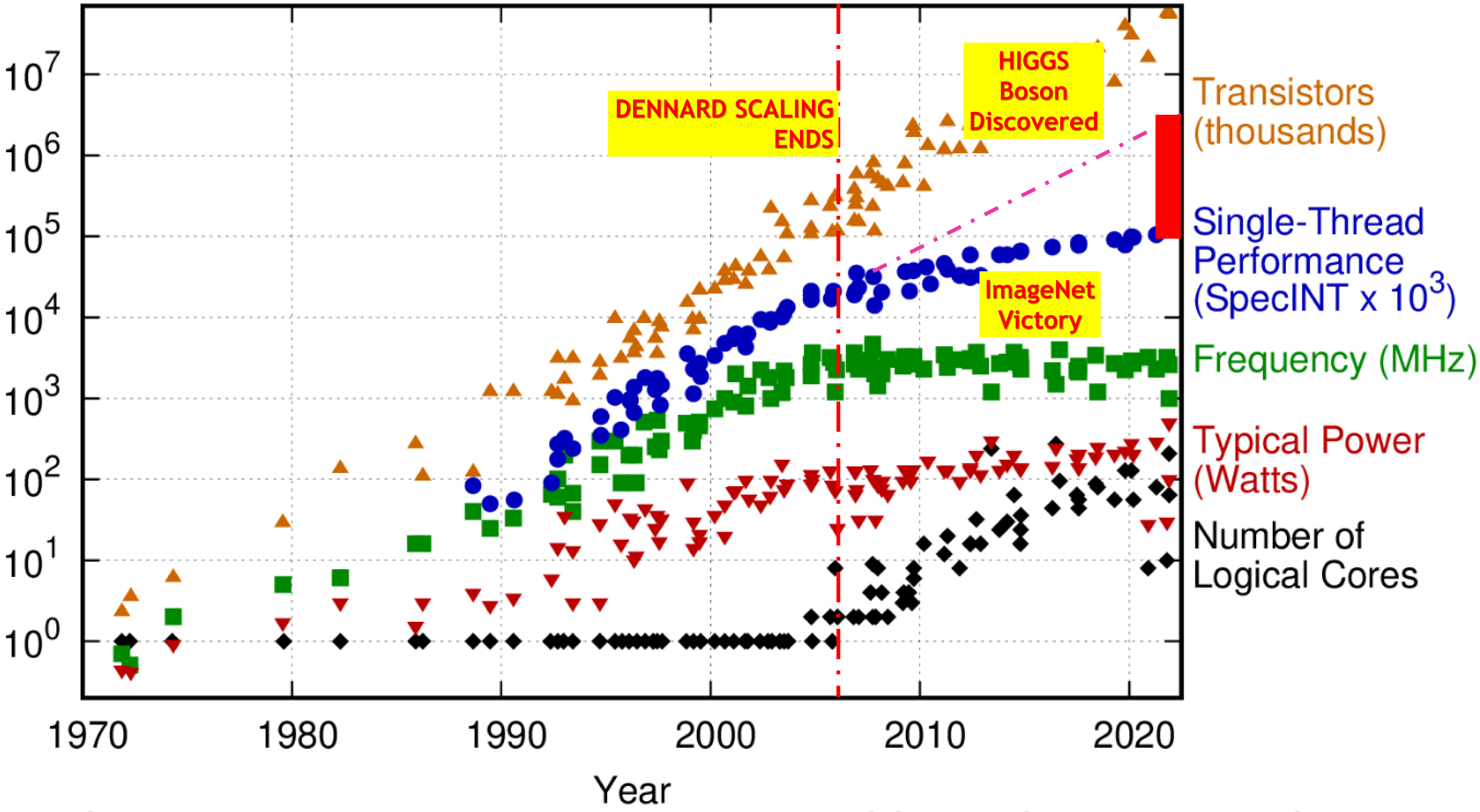
I Wrote My First Simulation

Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2021 by K. Rupp



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2021 by K. Rupp

50 Years of Microprocessor Trend Data



DENNARD SCALING ENDS

HIGGS Boson Discovered

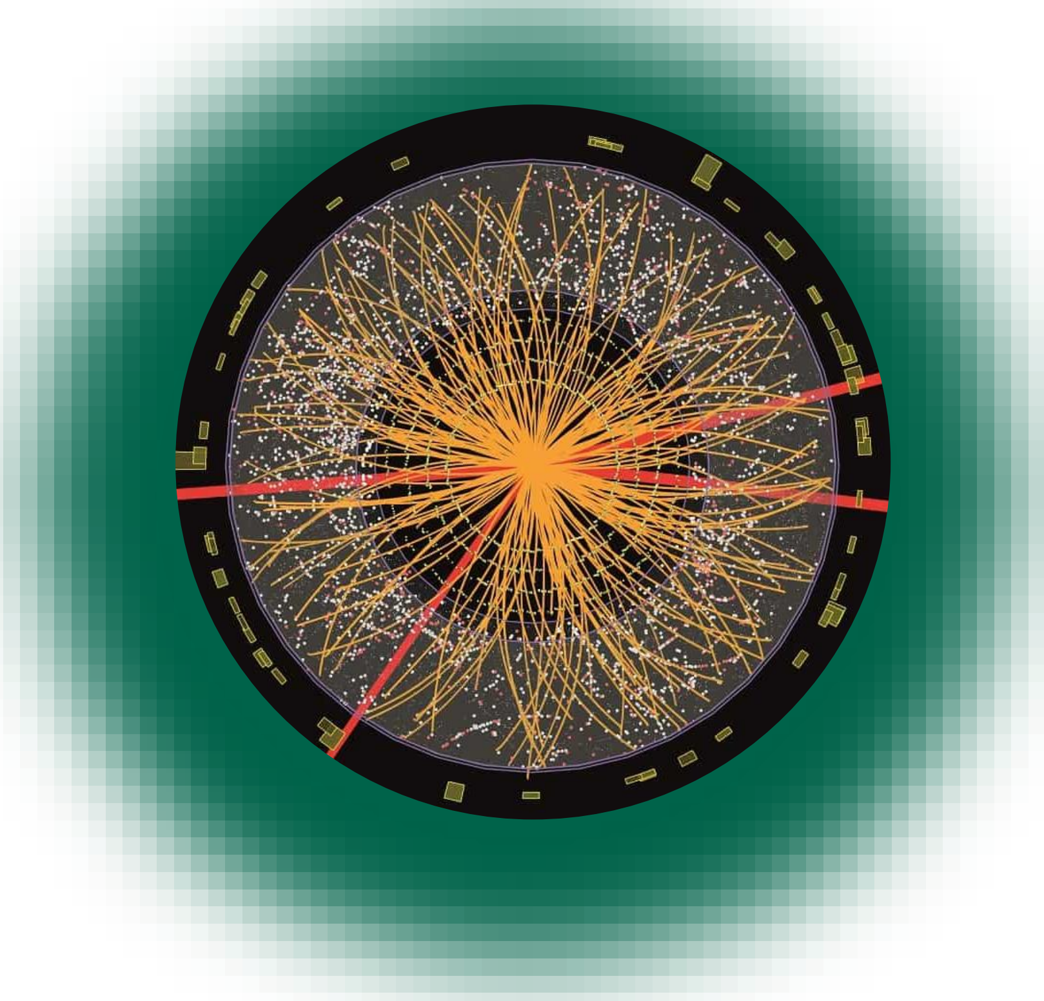
ImageNet Victory

Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2021 by K. Rupp

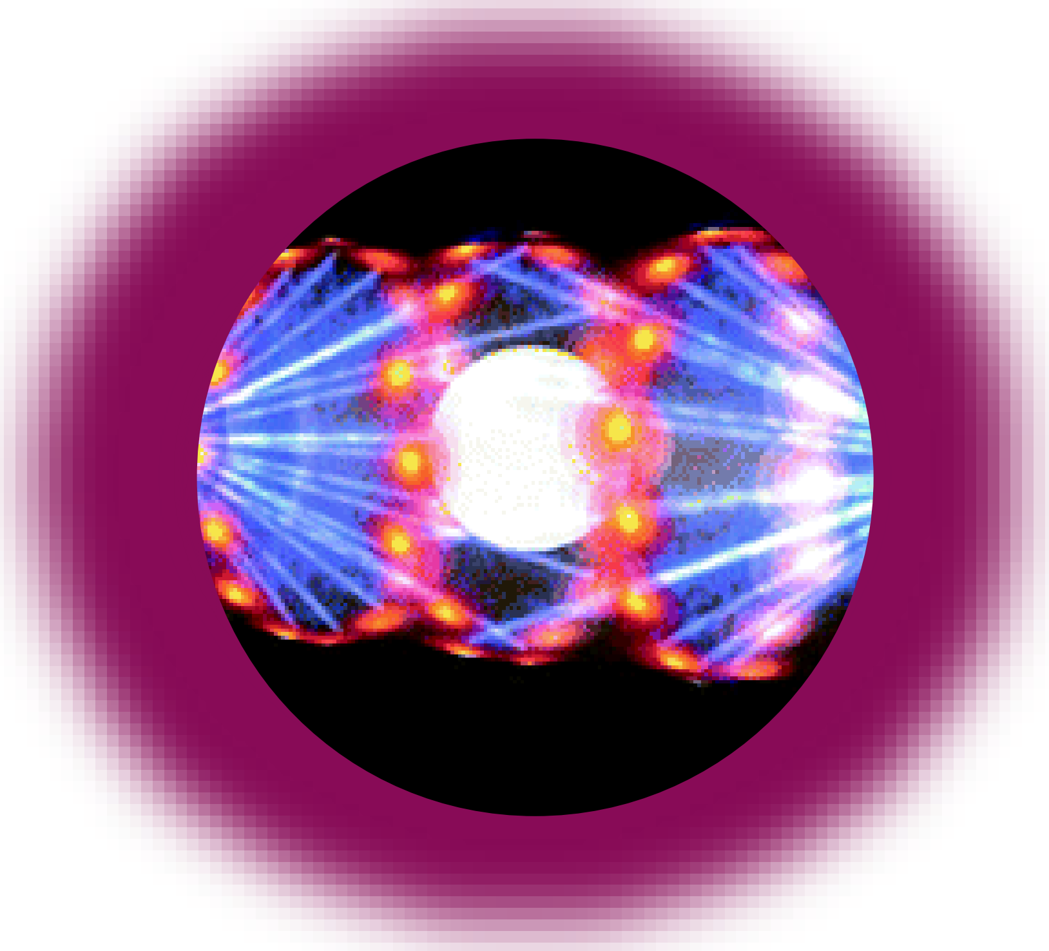
EXPANDING UNIVERSE OF THE NEW AGE OF HPC

EDGE

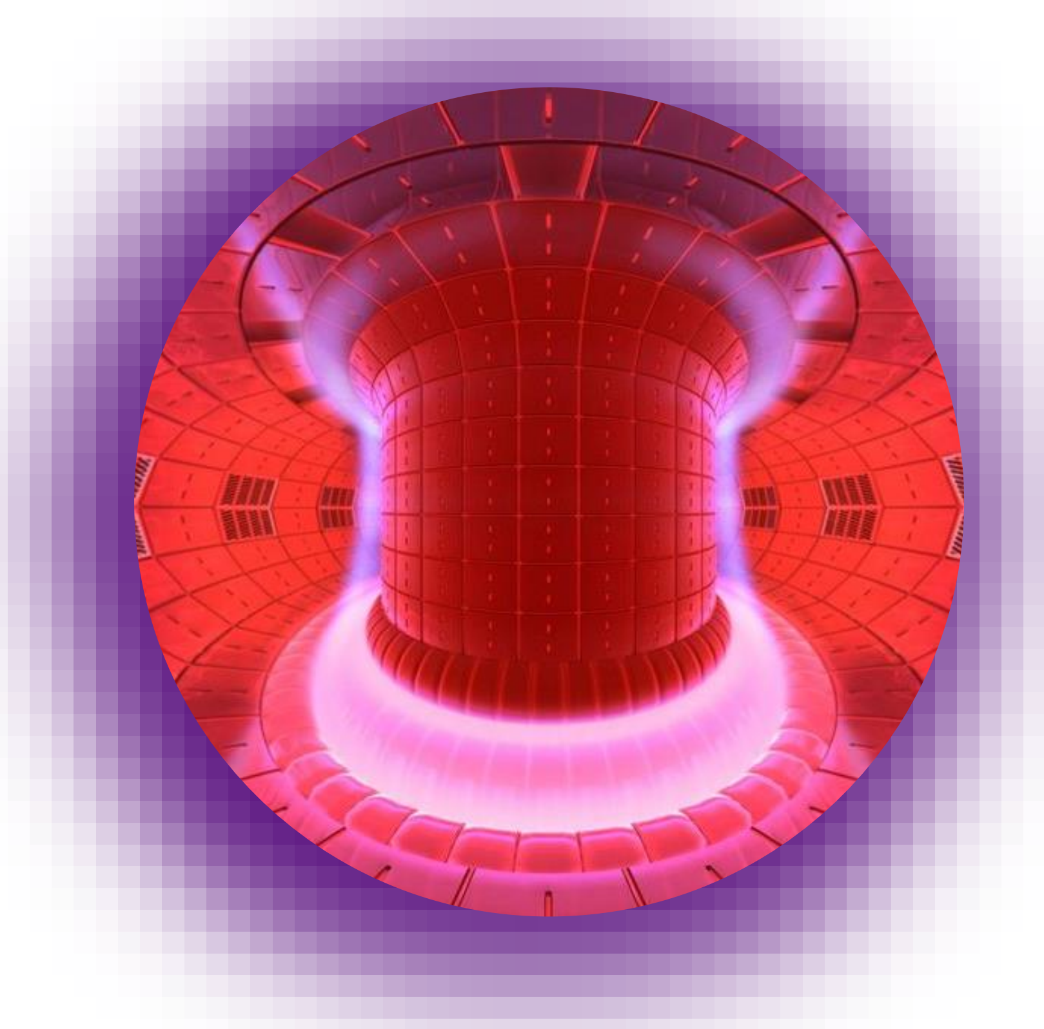
HPC * AI



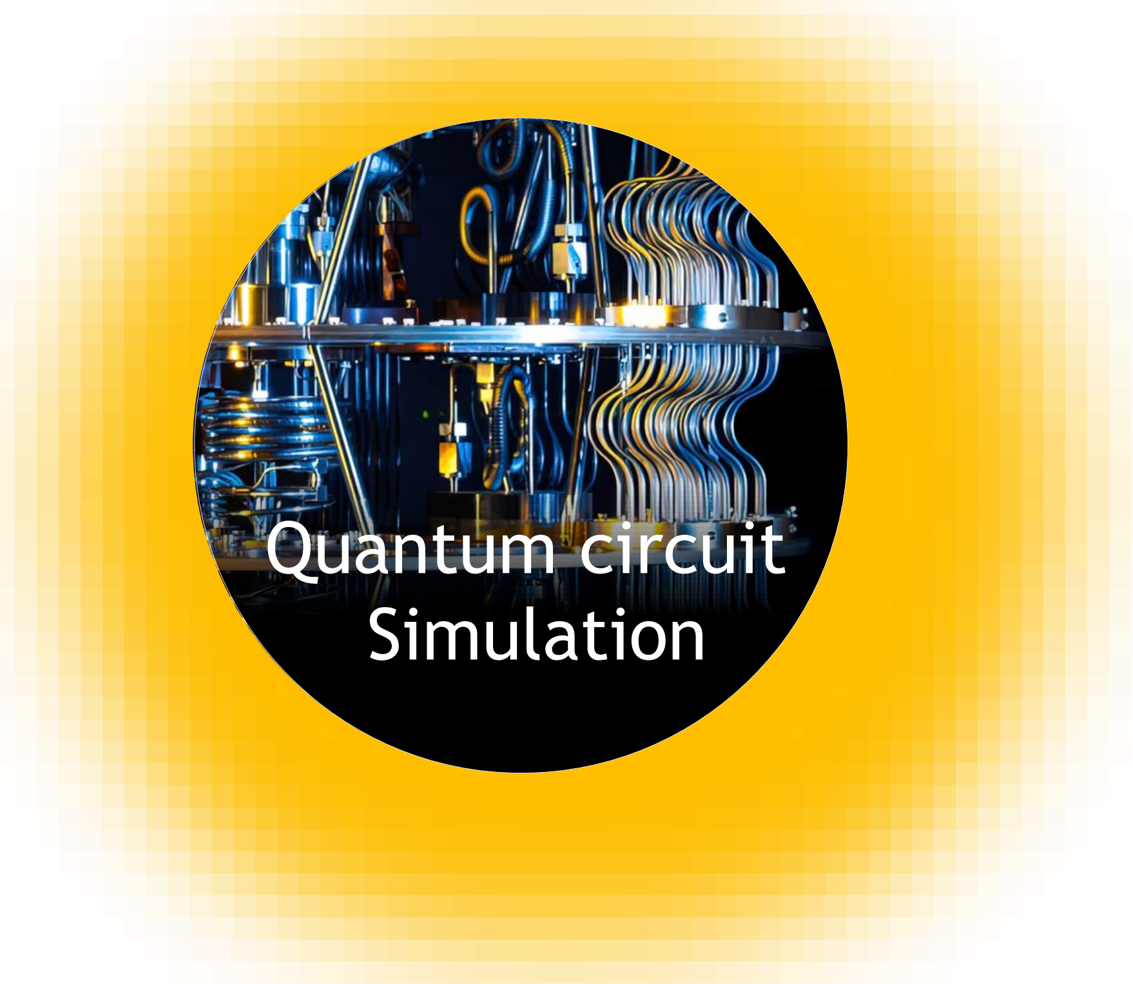
SIMULATION

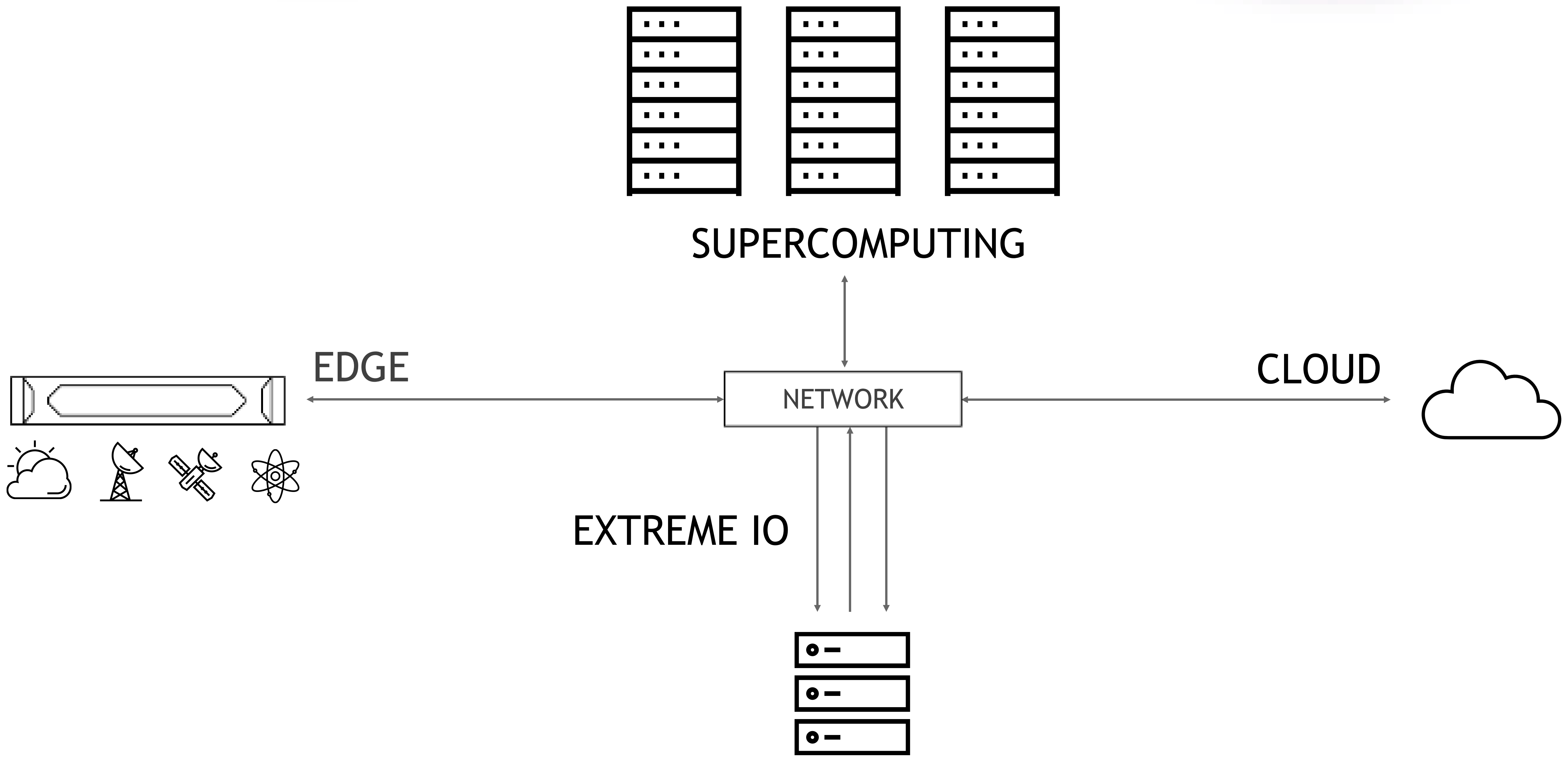


DIGITAL TWIN



QUANTUM COMPUTING





SUPERCOMPUTING

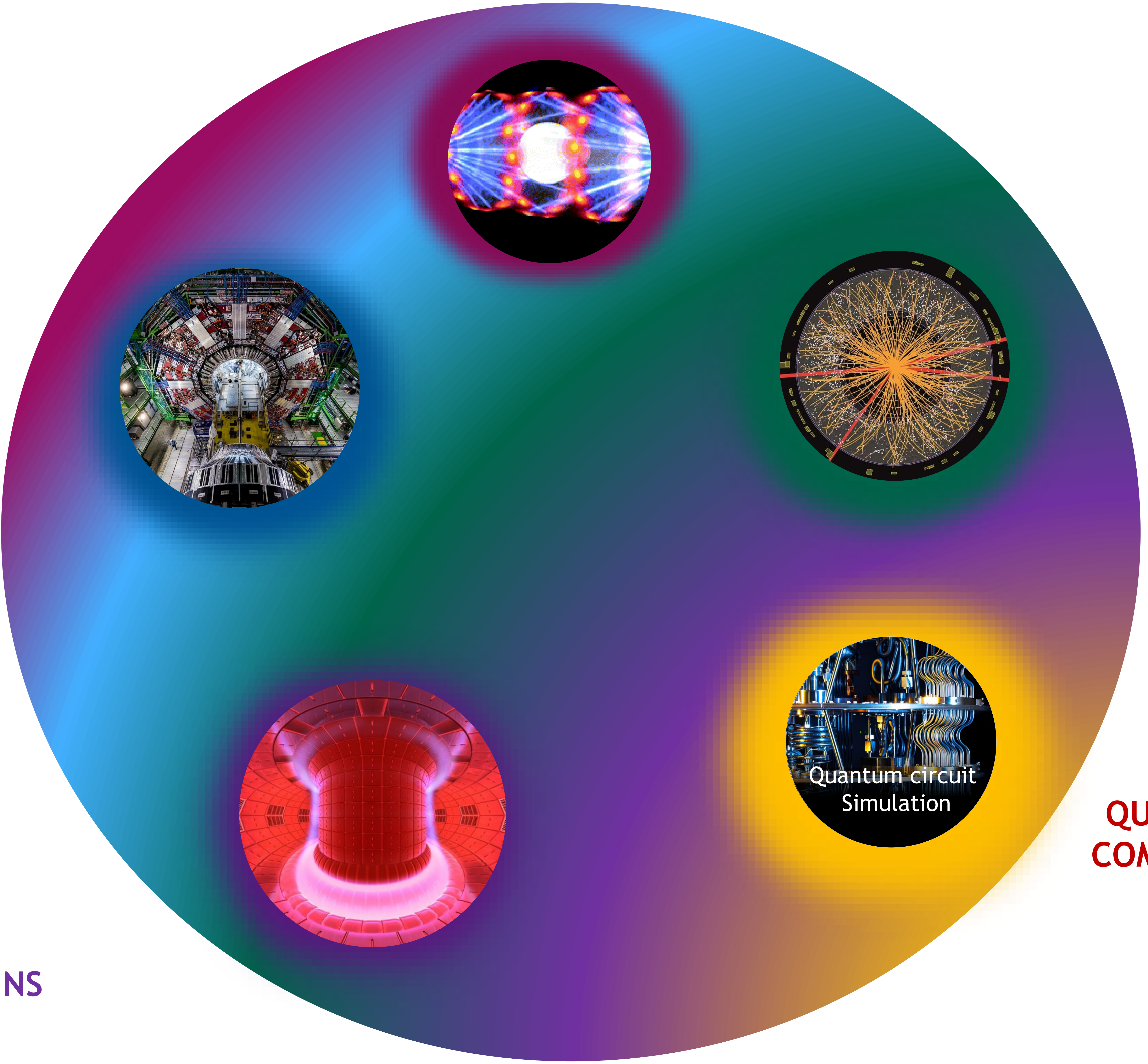
EDGE

NETWORK

CLOUD

EXTREME IO

NEW WORKFLOWS EMERGING TO SOLVE GRAND CHALLENGES



SIMULATION

HPC*AI

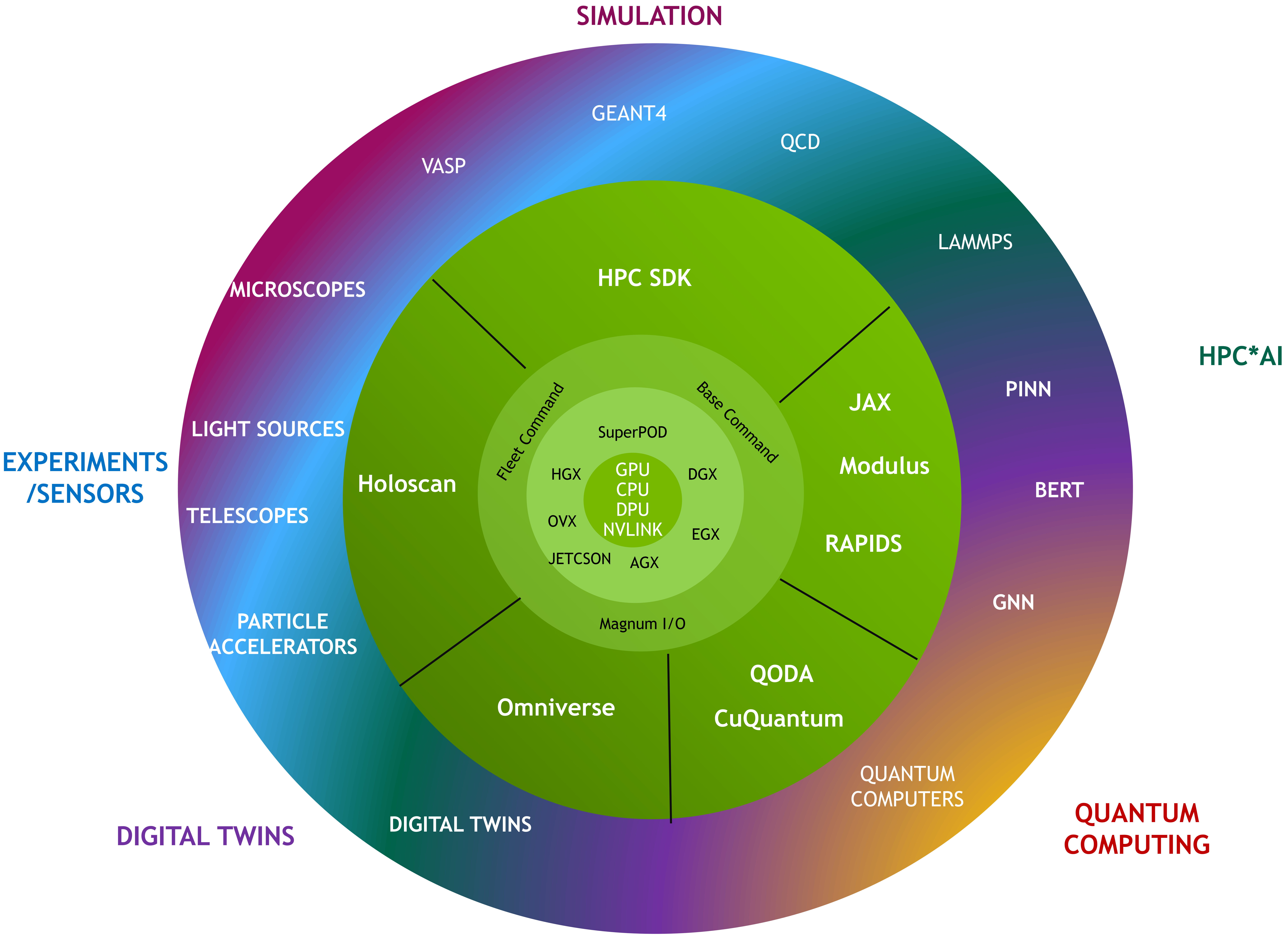
EXPERIMENTS
/SENSORS

Quantum circuit
Simulation

QUANTUM
COMPUTING

DIGITAL TWINS

NVIDIA ROADMAP EVOLVING TO MEET THE CHALLENGE



SIMULATION

GEANT4

QCD

VASP

LAMMPS

MICROSCOPES

HPC*AI

PINN

BERT

GNN

EXPERIMENTS
/SENSORS

LIGHT SOURCES

TELESCOPES

PARTICLE
ACCELERATORS

DIGITAL TWINS

DIGITAL TWINS

QUANTUM
COMPUTERS

QUANTUM
COMPUTING

HPC SDK

JAX

Modulus

RAPIDS

QODA

CuQuantum

Omniverse

Holoscan

Fleet Command

Base Command

Magnum I/O

SuperPOD

HGX

DGX

OVX

EGX

JETCSON

AGX

GPU
CPU
DPU
NVLINK

SIMULATION & EXPERIMENT INTEGRATED WITH ML & AI

Simulation
Trained Model or Surrogate
Align, Annotate, Denoise, Extract, Filter, Segment, Transform, Transpose, Interactive visualization
Motion detect, Reconstruct, Register, Segment
Classify, Control, Detect, Measure, Human vis
Real time Steering & Control
Sensor / Experiment
Data Acquisition
Inference
Data Analytics Post Process
Results

Integrated workflow with real-time analysis, steering and visualization for human in the loop

WORKFLOW TO WORKSTREAMS

Workflow between Datacenter & Experiment

Simulation

Trained Model or Surrogate

Control System for Experiment

Sensor/Instrument

Data Acquisition

Inference

Data Analytics Post Process

Results

Workstreams

Instrument to Edge ↔ Data Transmission ↔ Sim + DM/A + AI

Optimize and bring the best solution to that create the integrated workflow

WORKFLOW TO WORKSTREAMS

Workflow between Datacenter & Experiment

Simulation

Trained Model or Surrogate

Control System for Experiment

Sensor/Instrument

Data Acquisition

Inference

Data Analytics Post Process

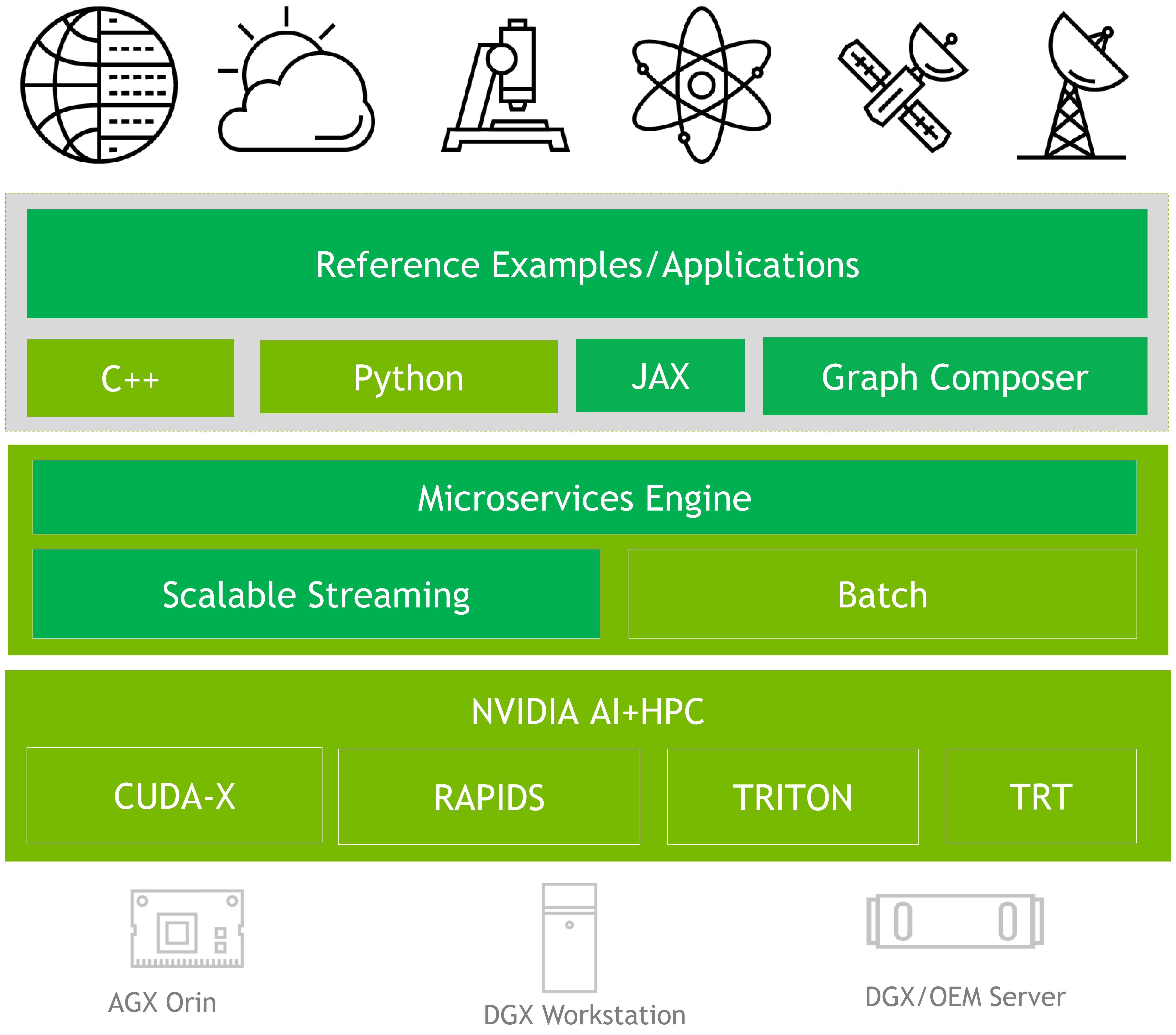
Results

Workstreams: Instrument to Edge ⟷ Data Transmission ⟷ Sim + DM/A + AI

Optimize and bring the best solution to that create the integrated workflow

NV SW	RAPIDS Triton/TensorRT Holoscan, Morpheus, Issac, UCF	Aerial DOCA Morpheus	HPC SDK, RAPIDS, DL FW, Omniverse, Modulus, UC
NV HW	Jetson, AGX,EGX DGX Station/Server	DPU MetroX	DGX Server/SuperPOD HGX

HOLOSCAN SDK : INTEGRATING DATA STREAMING FROM THE EDGE TO THE DATACENTER



Reference Examples/Applications

C++ | Python | JAX | Graph Composer

Microservices Engine

Scalable Streaming | Batch

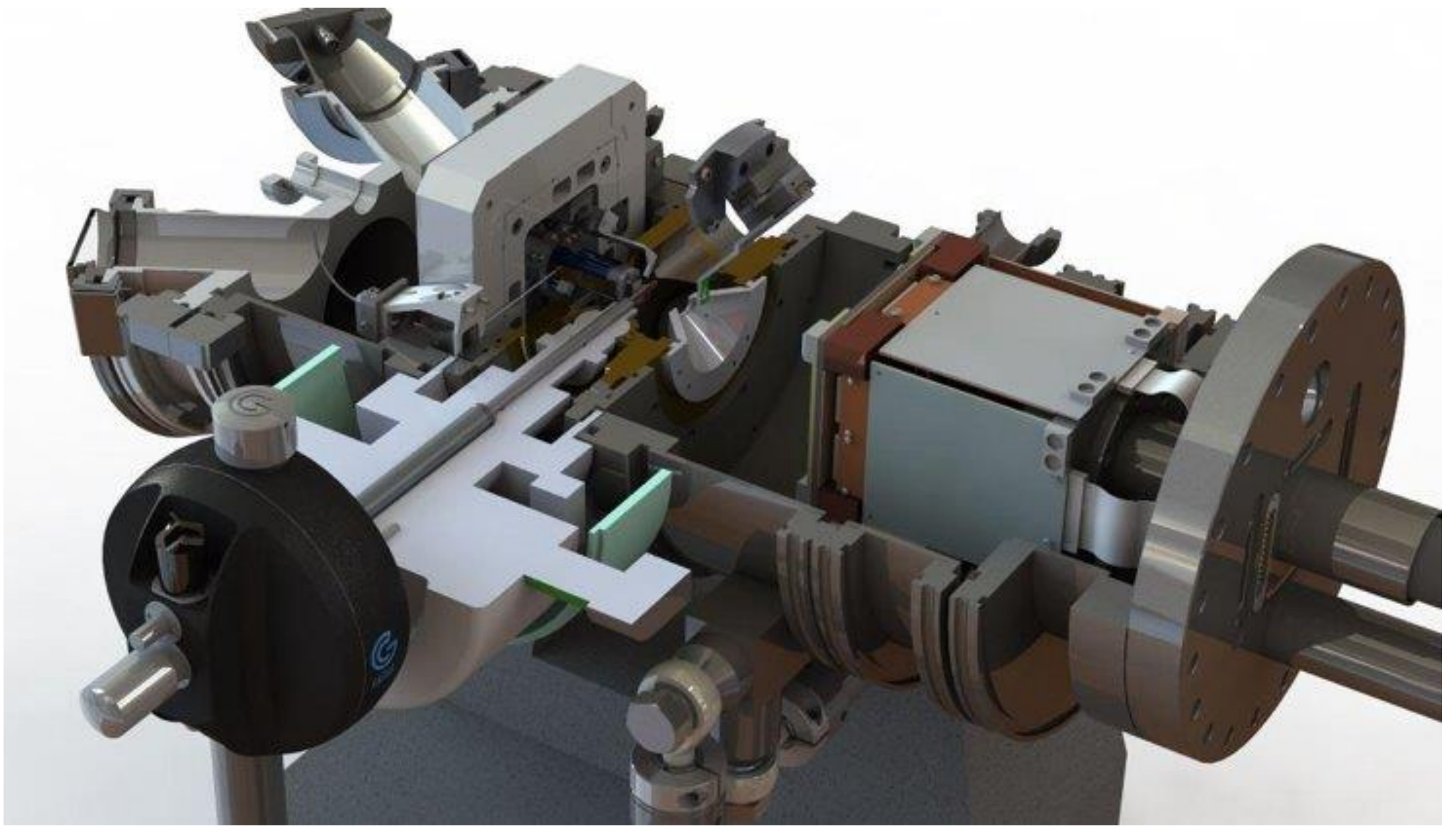
NVIDIA AI+HPC

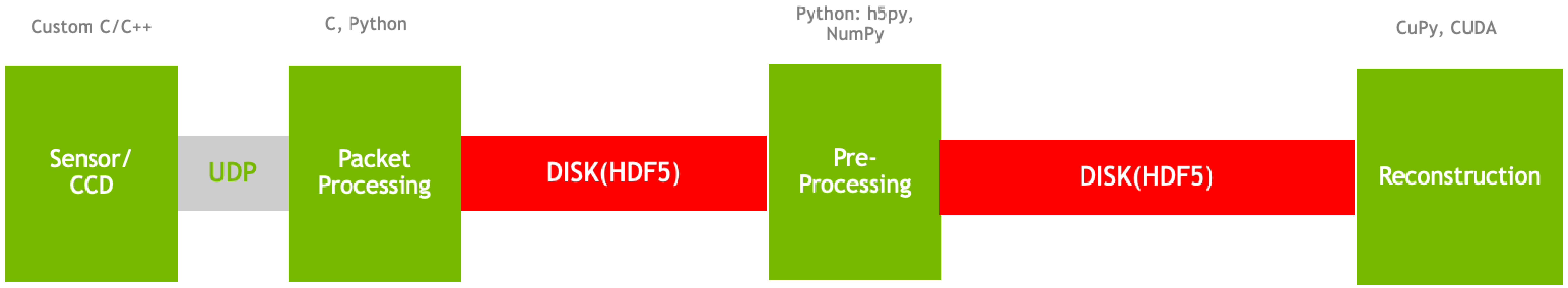
CUDA-X | RAPIDS | TRITON | TRT

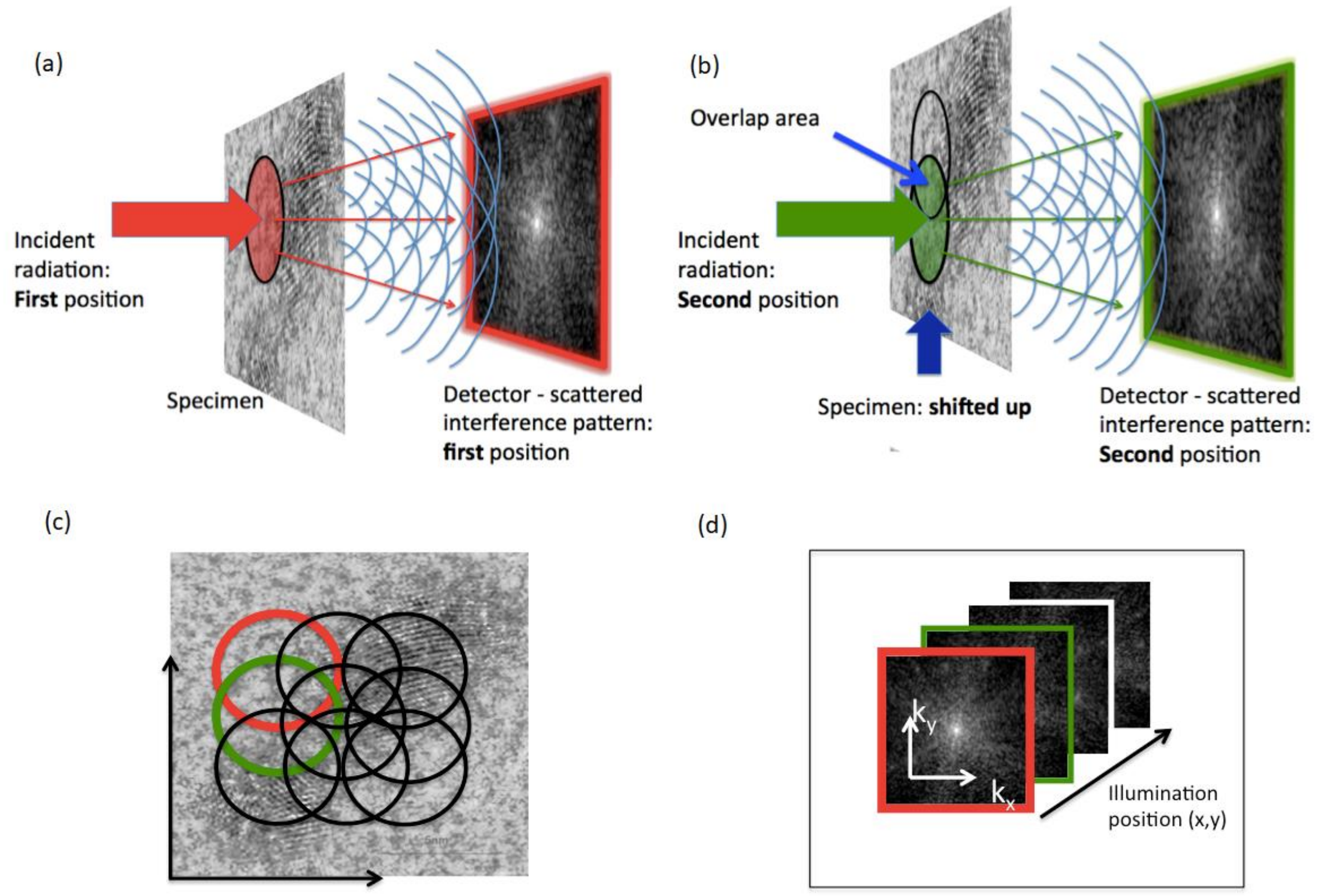
AGX Orin | DGX Workstation | DGX/OEM Server

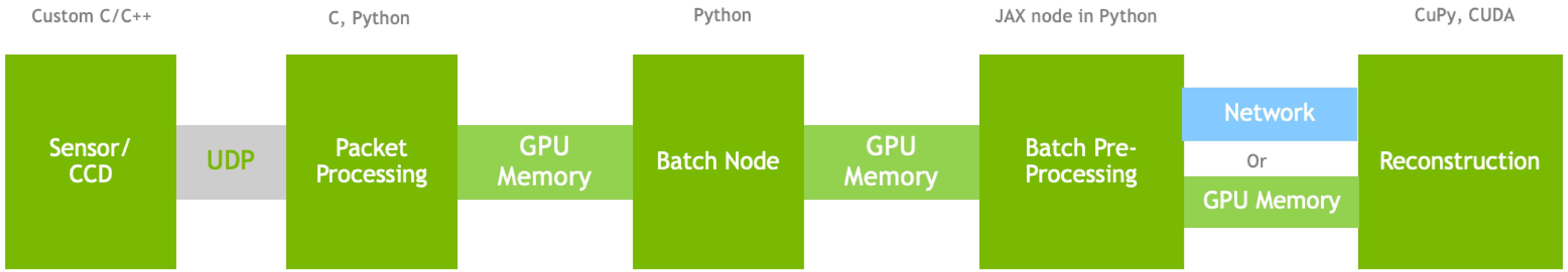
- Build their applications using a mix of C++, Python, JAX
- Develop AI microservices combining low-latency data streaming while passing more complex tasks to data center resources
- Scale from embedded to datacenter

ADVANCED LIGHT SOURCE : @ LBNL





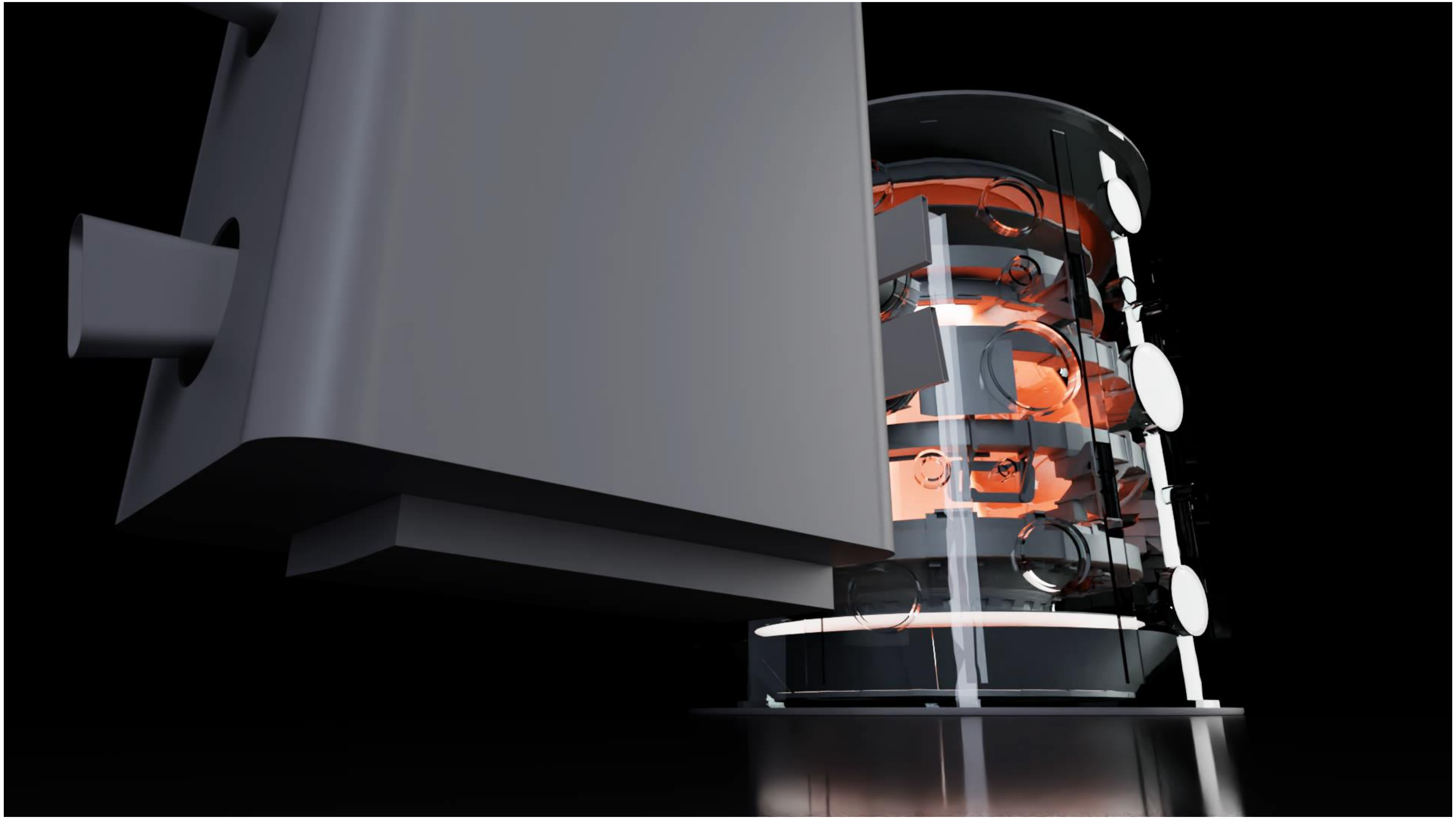

(a)
Incident radiation: **First** position
Specimen
Detector - scattered interference pattern: **first** position
(b)
Overlap area
Incident radiation: **Second** position
Specimen: **shifted up**
Detector - scattered interference pattern: **Second** position
(c)
(d)
k_y
k_x
Illumination position (x,y)



From ~105 seconds to 12 seconds

- For more details watch : Accelerating Sensor Processing Pipelines with NVIDIA Toolkits
- The GTC talk may reference internal names used during initial development

UKAE EARLY VERSION OF DIGITAL TWIN FOR TOKAMAK REACTOR



ENGAGEMENTS WITH HPC*AI*EDGE

Workflow between Datacenter & Experiment

Simulation

Trained Model or Surrogate

Control System for Experiment

Sensor/Instrument

Data Acquisition

Inference

Data Analytics Post Process

Results

Workstreams

Instrument to Edge ↔ Data Transmission ↔ Sim + DM/A + AI

ALS/LBNL

Optimizing Ptychography pipeline

CNMS/ORNL

Automating Microscopy

APS/ANL

AI accelerated Nanoscale x-ray imaging

DIII-D/GA/UKAE

AI surrogate, CGYRO, Digital Twin

LHCb/CERN

Design complete for using NVIDIA A40 for HLT

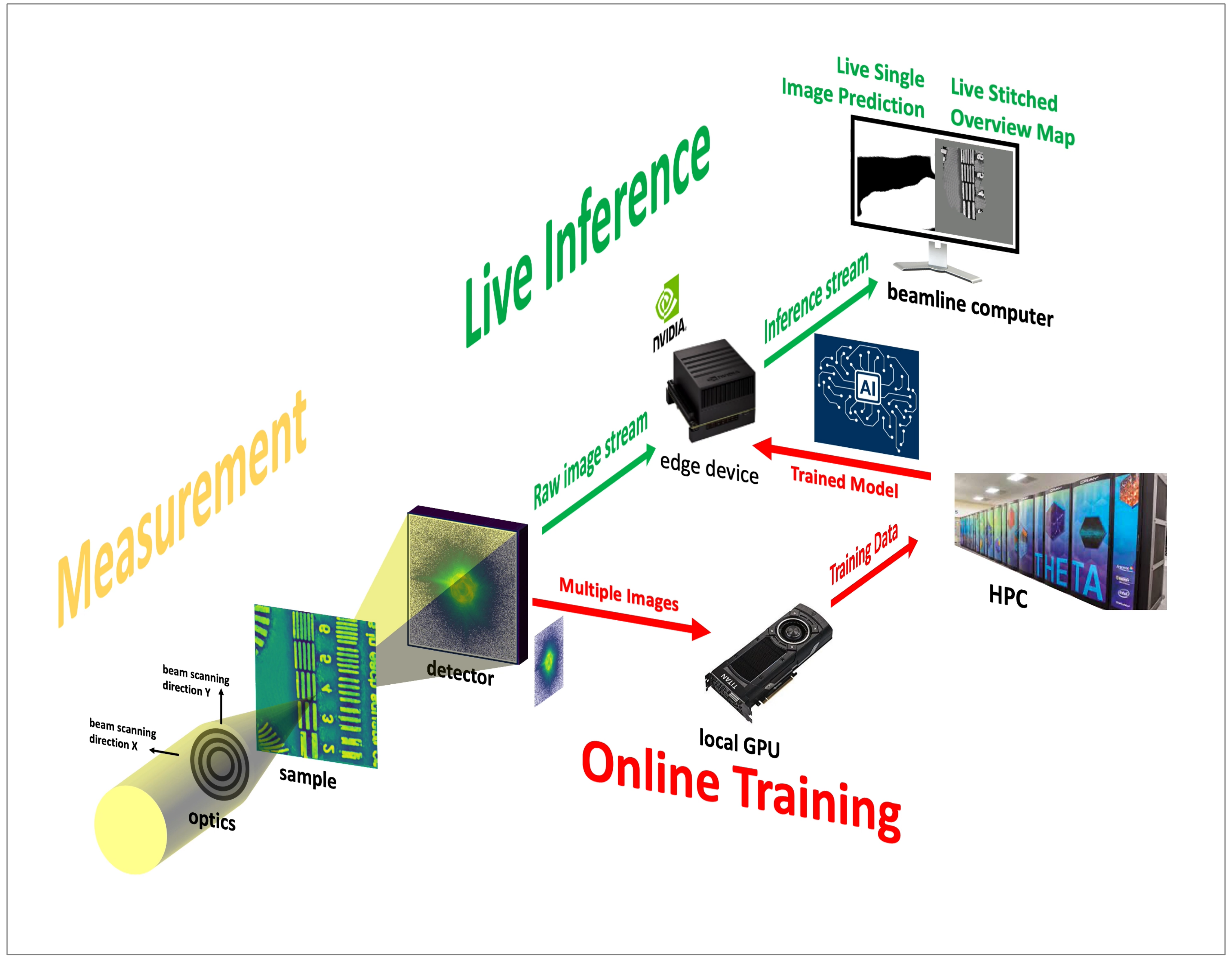
HED Physics/LLNL

HRR HED laser plasma experiments workflow

NVIDIA®

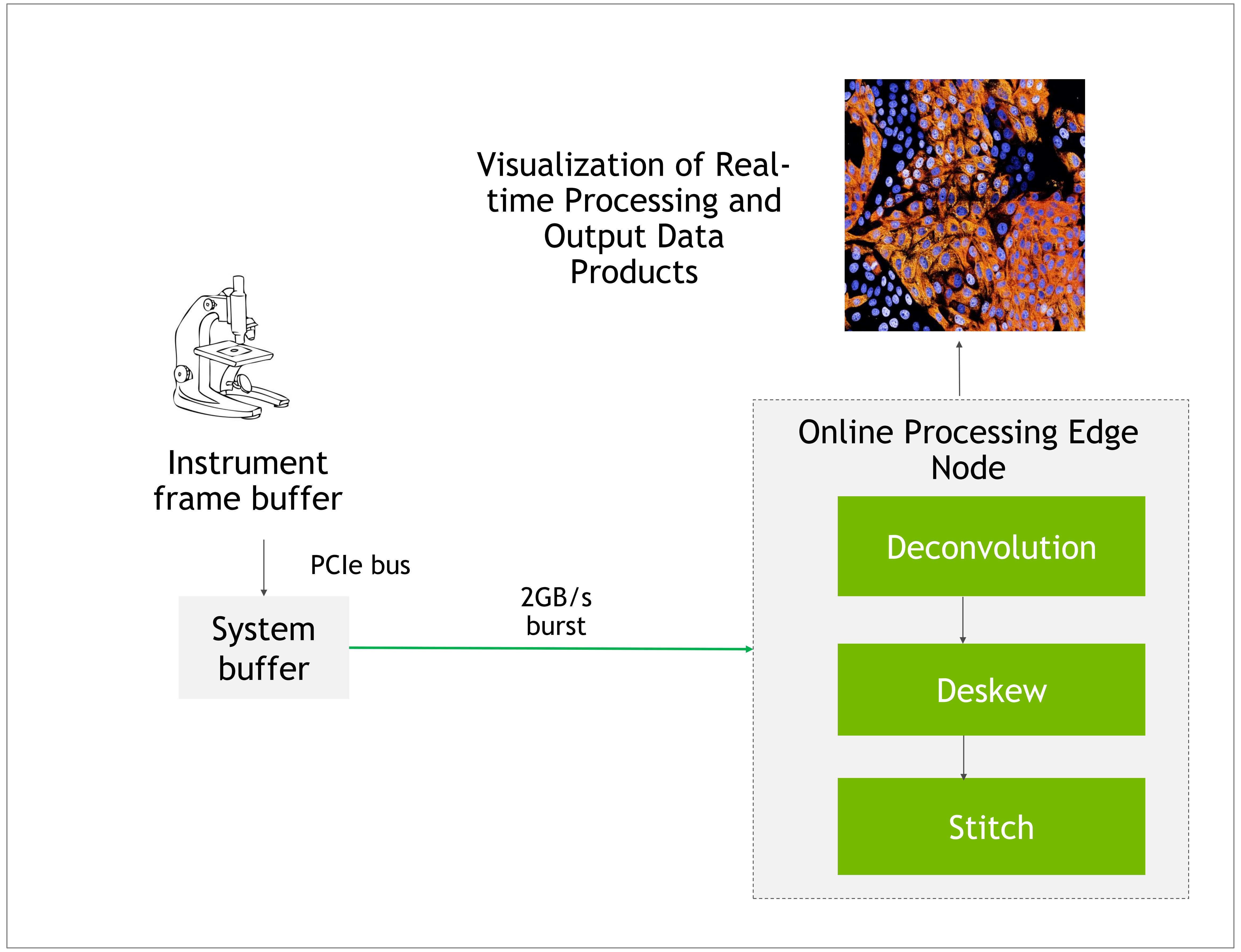
SUPERCHARGING SCIENCE EXPERIMENTS AND INSTRUMENTS

ANL/ APS ACCELERATES X-RAY PTYCHOGRAPHY 300X WITH PTYCHONN



PtychoNN paper: AI-enabled high-resolution scanning coherent diffraction imaging

ADVANCED BIOIMAGING CENTER @UC-BERKELEY REAL TIME LIVE CELL IMAGING LIGHT SHEET MICROSCOPY



Visualization of Real-time Processing and Output Data Products

Instrument frame buffer

PCIe bus

System buffer

2GB/s burst

Online Processing Edge Node

Deconvolution

Deskew

Stitch

Link to keynote video - https://youtu.be/rXG27G3bWzY

RISE OF HPC AT THE EDGE

Posing a New Set of Challenges for HPC

10X - 100X MORE DATA

50+ GIANT SCALE INSTRUMENTS WW

ELT ESO

ALS @LBNL

LIGO

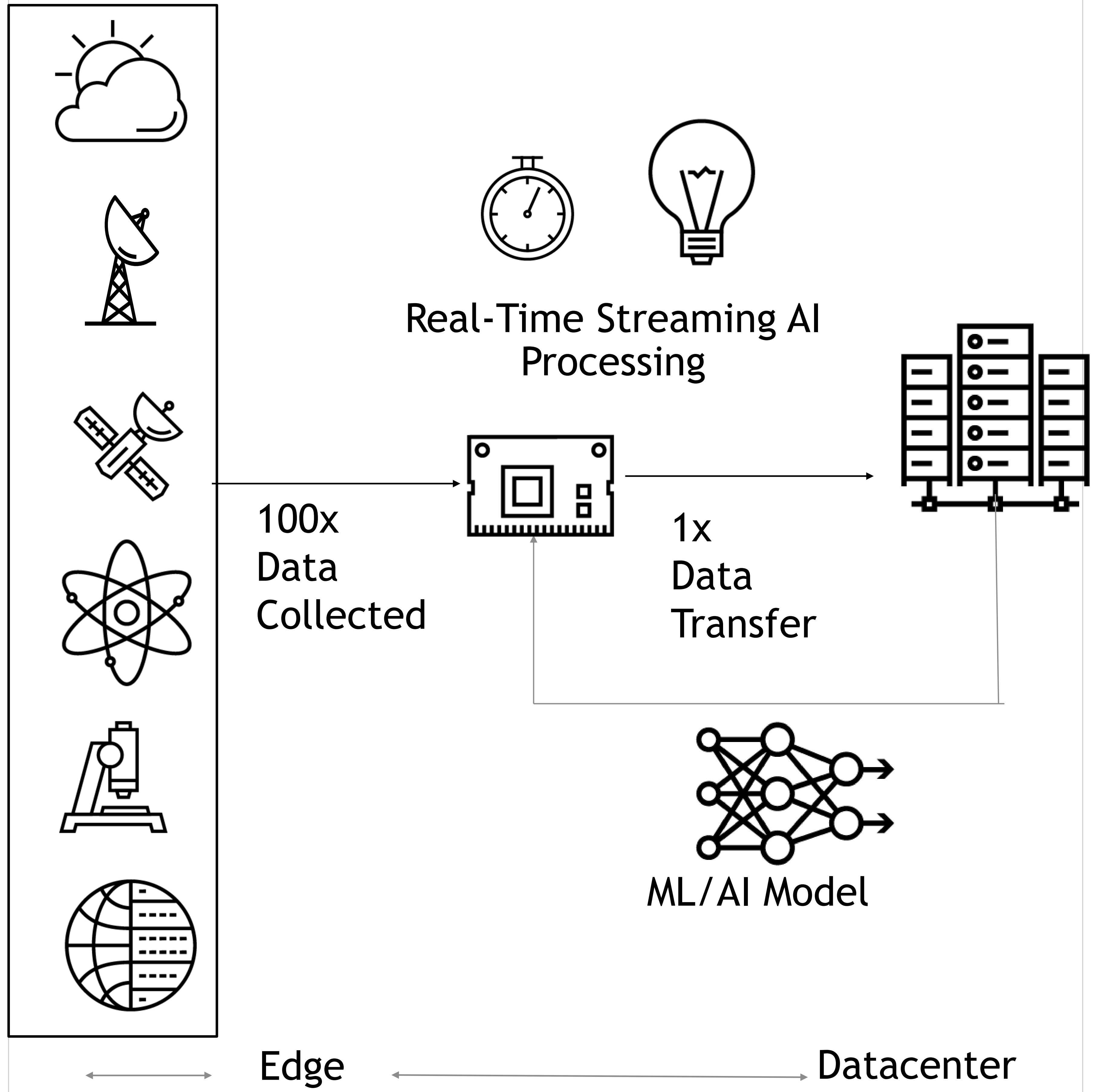
APS @ANL

SKA

Diamond, UK

AI SUPERCOMPUTING AT THE EDGE

ENABLES REAL-TIME INSIGHTS AND CONTROL


Real-Time Streaming AI Processing

100x Data Collected

1x Data Transfer

ML/AI Model

Edge

Datacenter

STREAMING DEPLOYMENT IS HARD

FOR DATA SCIENTISTS, RESEARCHERS AND DEVOPS

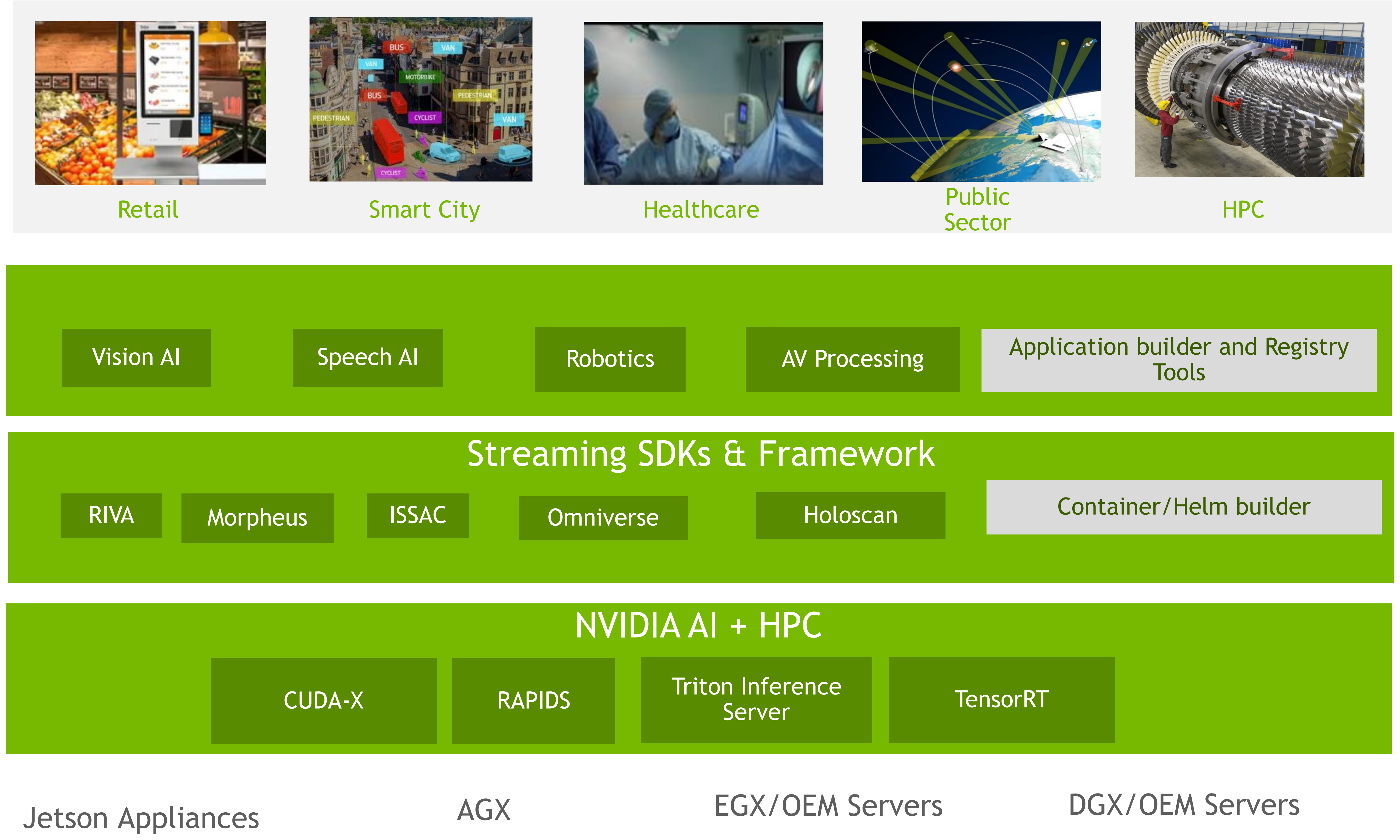
Streaming Data Performance

Easily Scale Implementation

Developer Ease-of Use

Combining multiple datastreams

ASSIMILATION OF SENSOR DATA ACROSS MULTIPLE INDUSTRIES



Retail

Smart City

Healthcare

Public Sector

HPC

Vision AI

Speech AI

Robotics

AV Processing

Application builder and Registry Tools

Streaming SDKs & Framework

RIVA

Morpheus

ISSAC

Omniverse

Holoscan

Container/Helm builder

NVIDIA AI + HPC

CUDA-X

RAPIDS

Triton Inference Server

TensorRT

Jetson Appliances

AGX

EGX/OEM Servers

DGX/OEM Servers

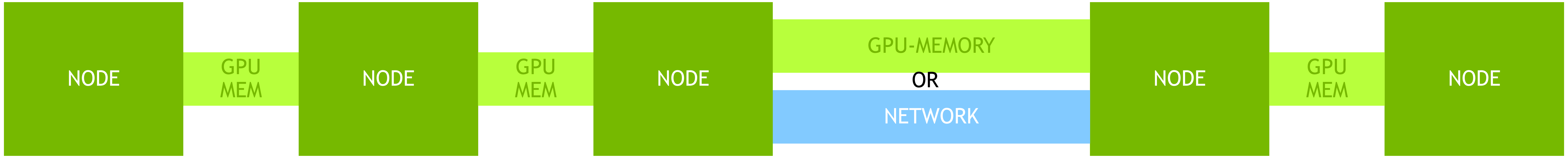
VISION

Harmonize the streaming AI framework architecture for developing cloud native, disaggregated scalable applications from embedded systems to Datacenter

Maximize reuse

Modular

COMPOSING AN HPC STREAMING DATA PIPELINE USING STREAMING REACTIVE FRAMEWORK (SRF*)

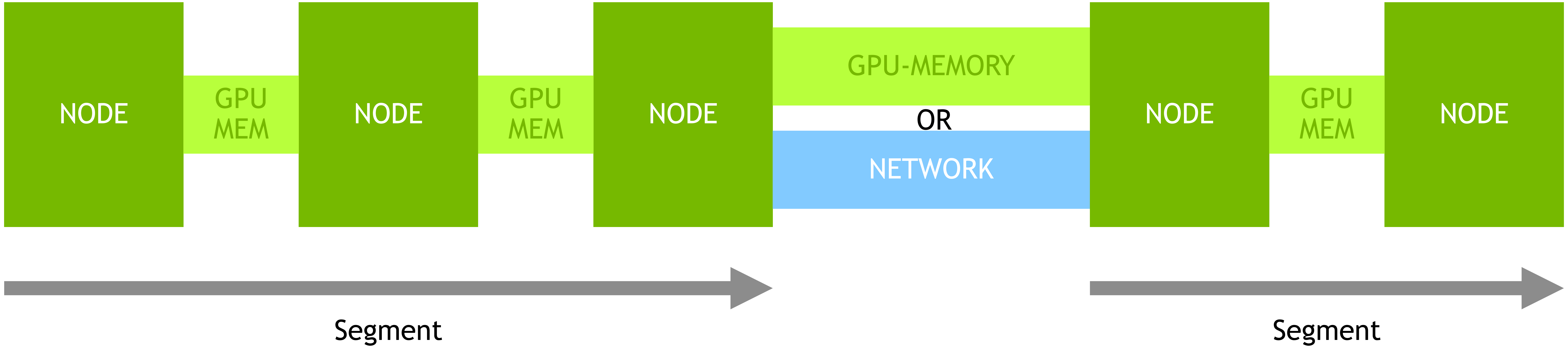


SRF* is a **reactive, network-aware, flexible,** and **performance-oriented** streaming data framework that standardizes building modular and reusable pipeline mixing C++, Python, JAX

- Asynchronous computation and mitigation of I/O and GPU blocking
- Distributed computation with message transfers over RMDA using UCX
- Dynamic reconfiguration to scale up and out at runtime
- Designed to mitigate backpressure with concurrent blocking queues between stages
- Hybrid HPC and Cloud Native

*SRF is under development. Final name subject to change

ANATOMY OF A SRF PIPELINE



Definitions

- A SRF pipeline is composed of Segments
- Segments are composed of Sources, Sinks, and Nodes (Source + Sink)
- Segments also guaranteed compute within a single node, can connect nodes via network (Edge, Cloud, or Datacenter), and contain MPI support
- Nodes process an input stream, create an output stream, and can be implemented with Python or C++
- Components are linked by Edges which are implemented as Channels
- Channels move data from sources to sinks and provide a backpressure policy

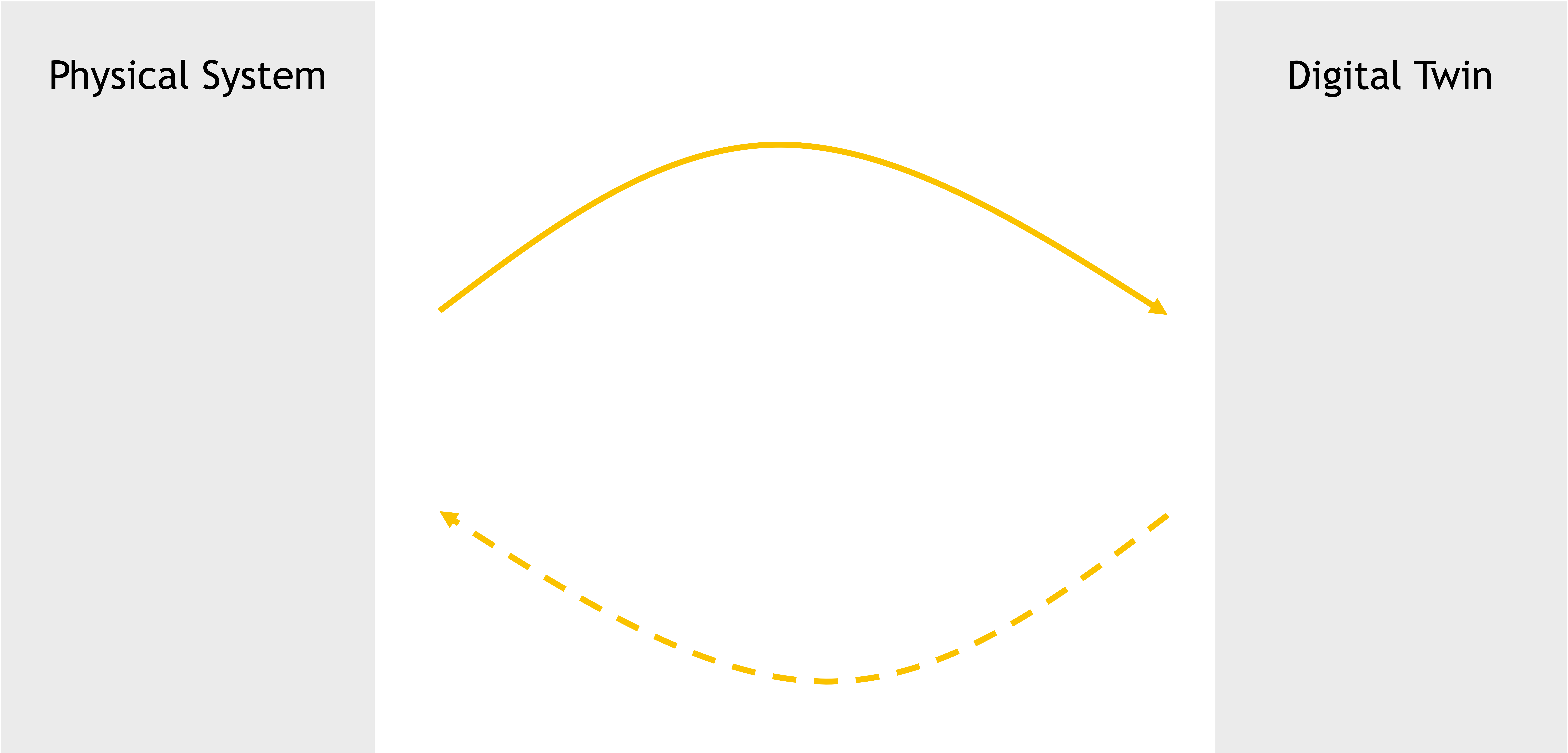
TO LEARN MORE ABOUT SENSOR DATA PROCESSING

- Blog Facing the Edge Data Challenge with HPC + AI
- GTC Spring 2022 High Performance Geospatial Image Processing at the Edge*
  - Geospatial image analysis using DPUs in an edge device designed to meet the Size-Weight-and-Power requirements for aircraft deployment.
- PtychoNN paper: AI-enabled high-resolution scanning coherent diffraction imaging
  - The Advanced Photon Source at Argonne National Laboratory runs PtychoNN on an Orin AGX at the x-ray detector. It is available for use at other light sources around the world.
- GTC Spring 2022 Accelerating Sensor Processing Pipelines with NVIDIA Toolkits*
  - Faster imaging pipelines by using JAX and SRF to processing streaming data with applications in Ptychography and Micrsocopy
- See the SRF description above and the GitHub page

*The GTC talk may reference SRF as ”Neo” which was the internal name used during initial development

DIGITAL TWINS

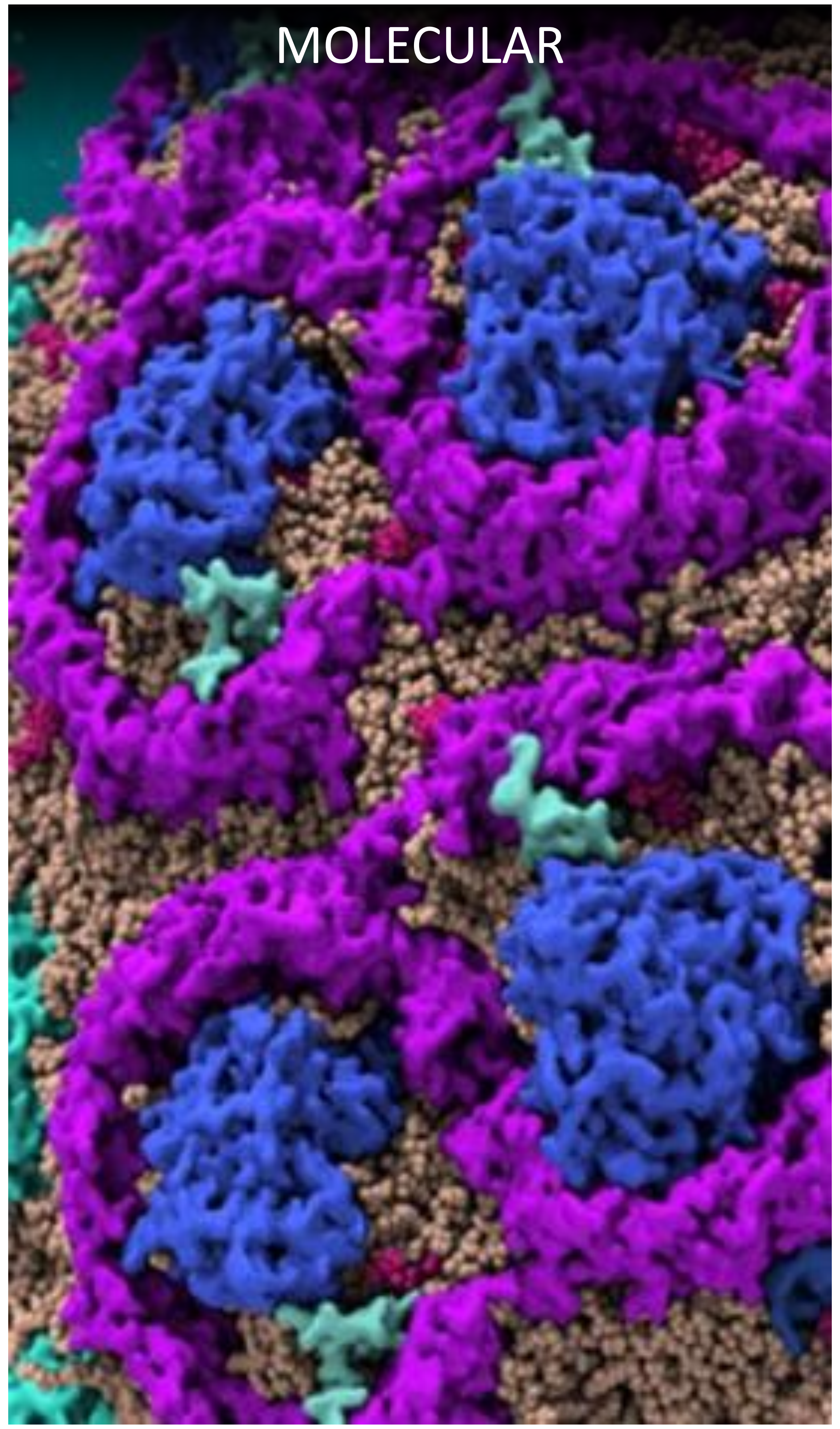
DIGITAL TWIN: ACTIONABLE RESULTS AN ACTIONABLE TIME



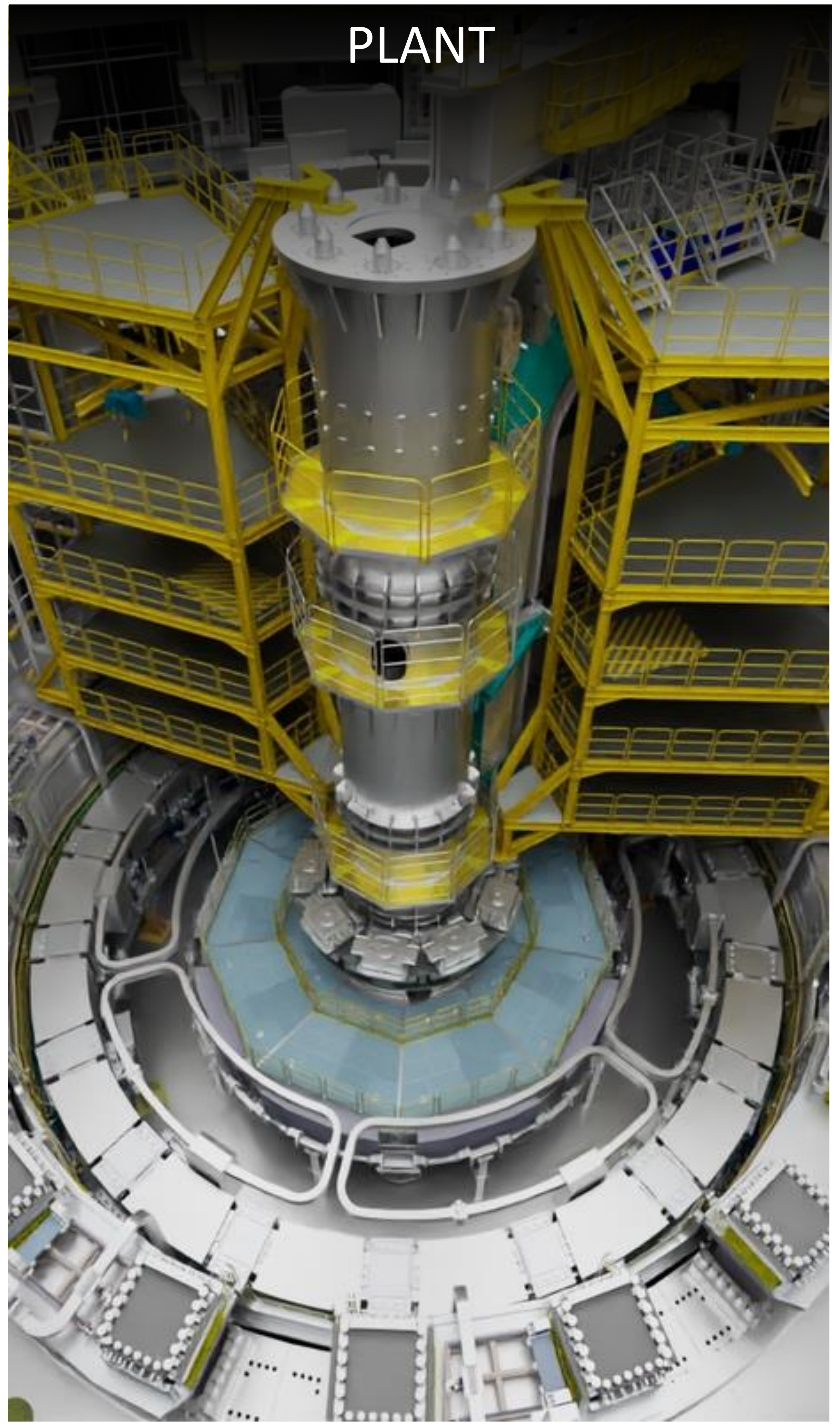
Physical System

Digital Twin

DIGITAL TWINS WILL EXIST AT EVERY SCALE

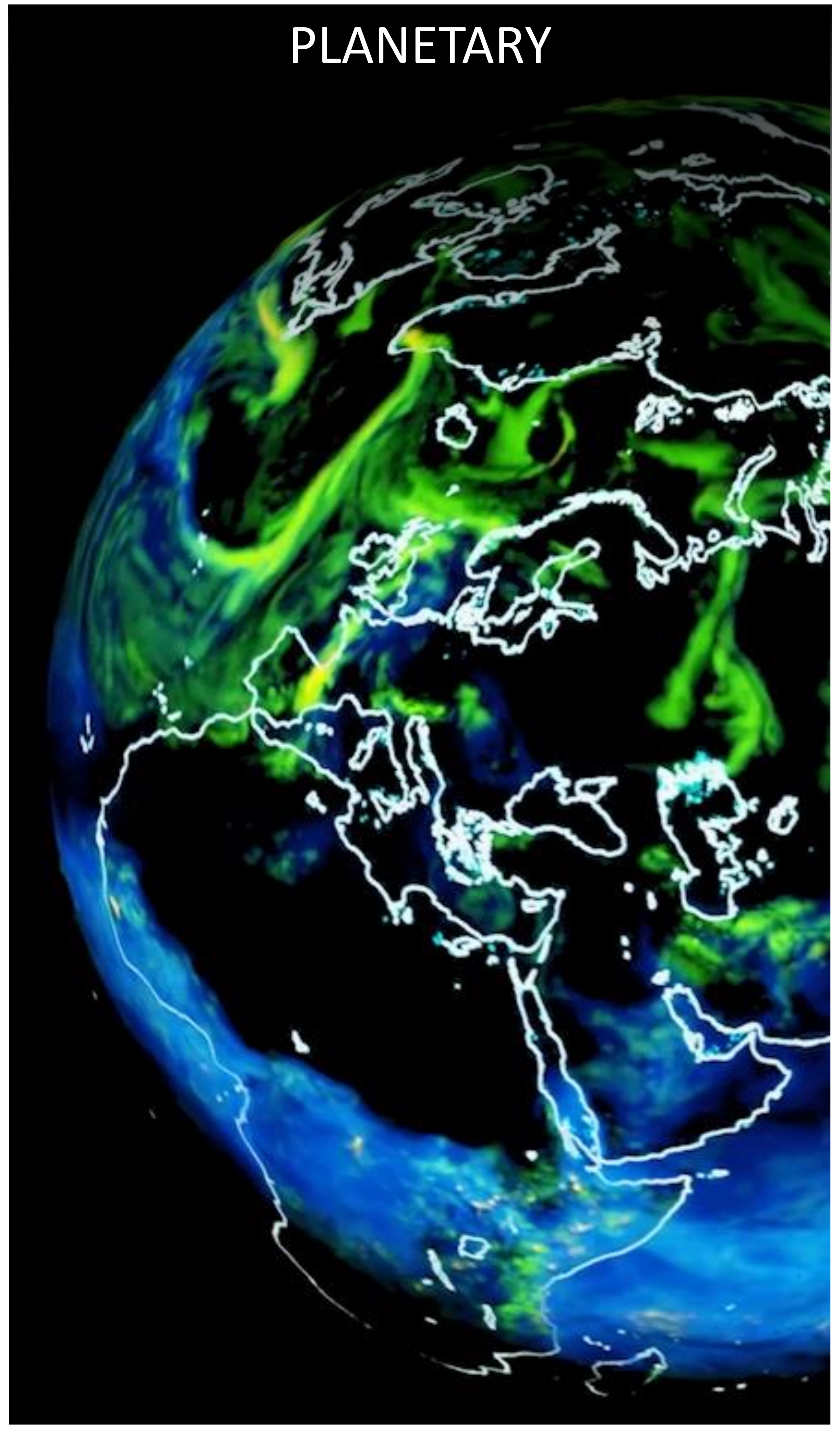


MOLECULAR



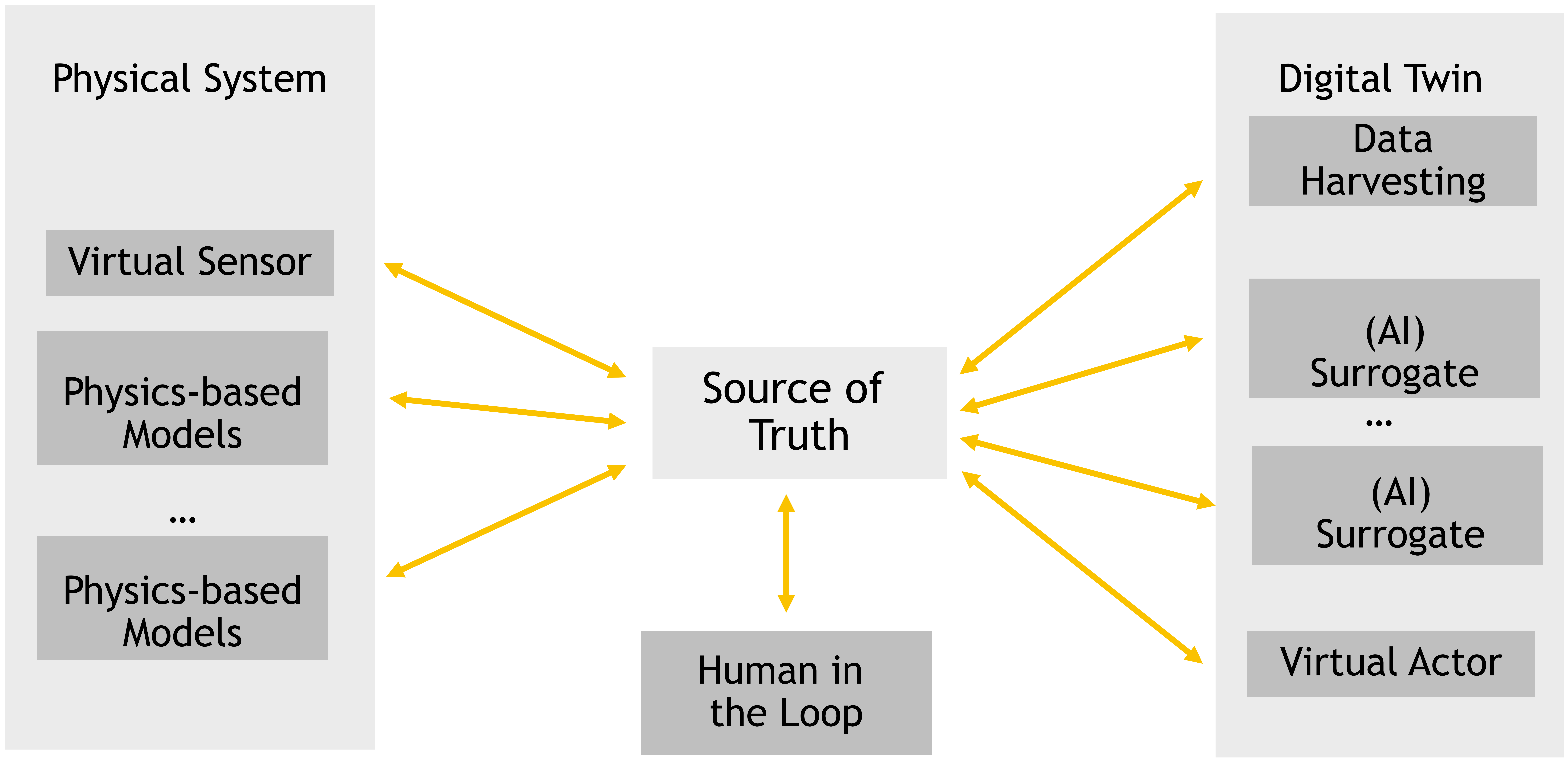
PLANT

CITY



PLANETARY

DIGITAL TWIN AT REALISTIC COMPLEXITY



Physical System

Virtual Sensor

Physics-based Models

...

Physics-based Models

Source of Truth

Human in the Loop

Digital Twin

Data Harvesting

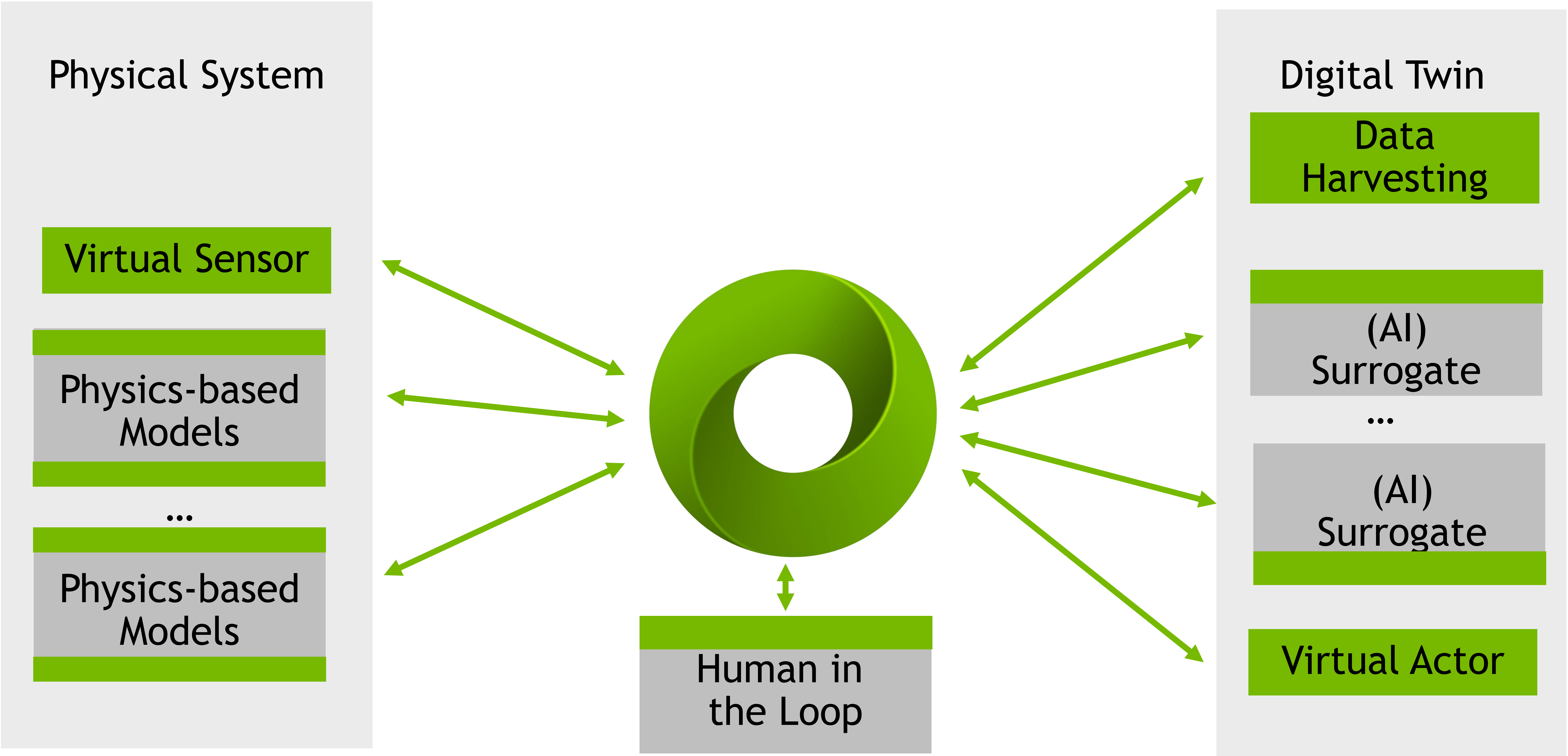
(AI) Surrogate

...

(AI) Surrogate

Virtual Actor

OMNIVERSE: PLATFORM FOR BUILDING DIGITAL TWINS



Physical System

Virtual Sensor

Physics-based Models

…

Physics-based Models

Human in the Loop

Digital Twin

Data Harvesting

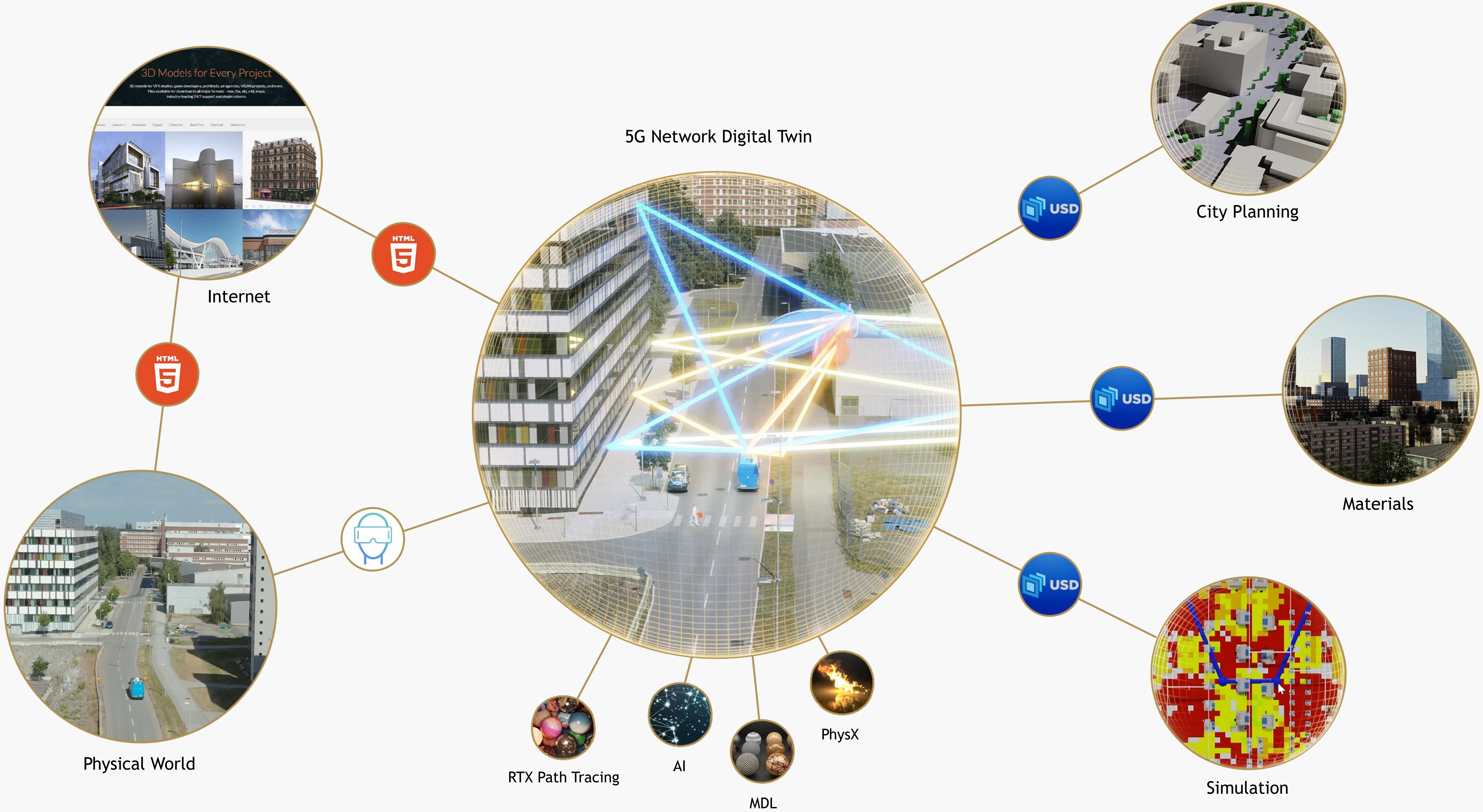
(AI) Surrogate

…

(AI) Surrogate

Virtual Actor

EXAMPLE: BEAM PATTERN EXPLORATION FOR PLACING 5G ANTENNA



ADVANCED TOOLS AND TECHNOLOGIES

Foundational Platform Components

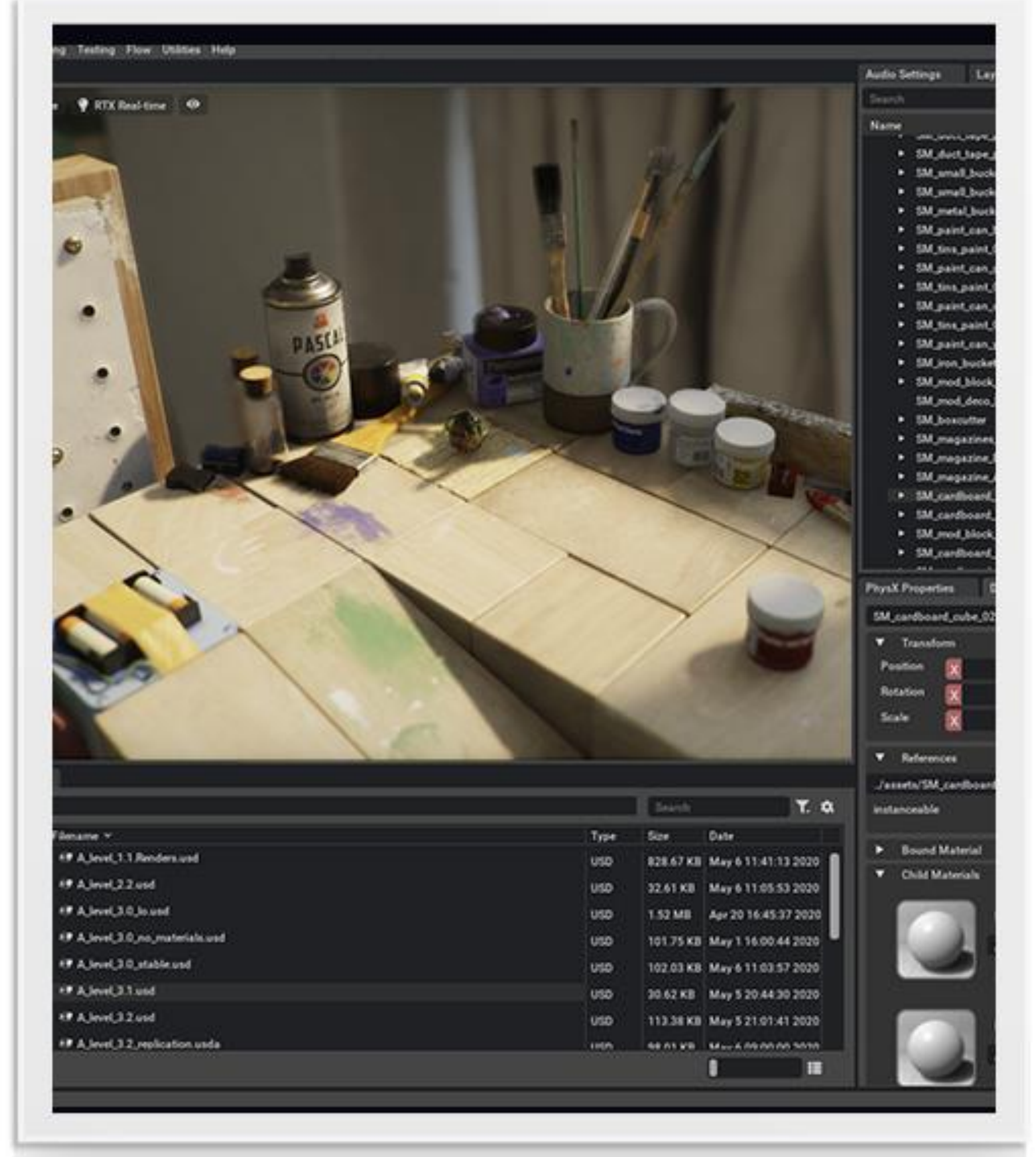
NUCLEUS

Source of truth

CONNECT

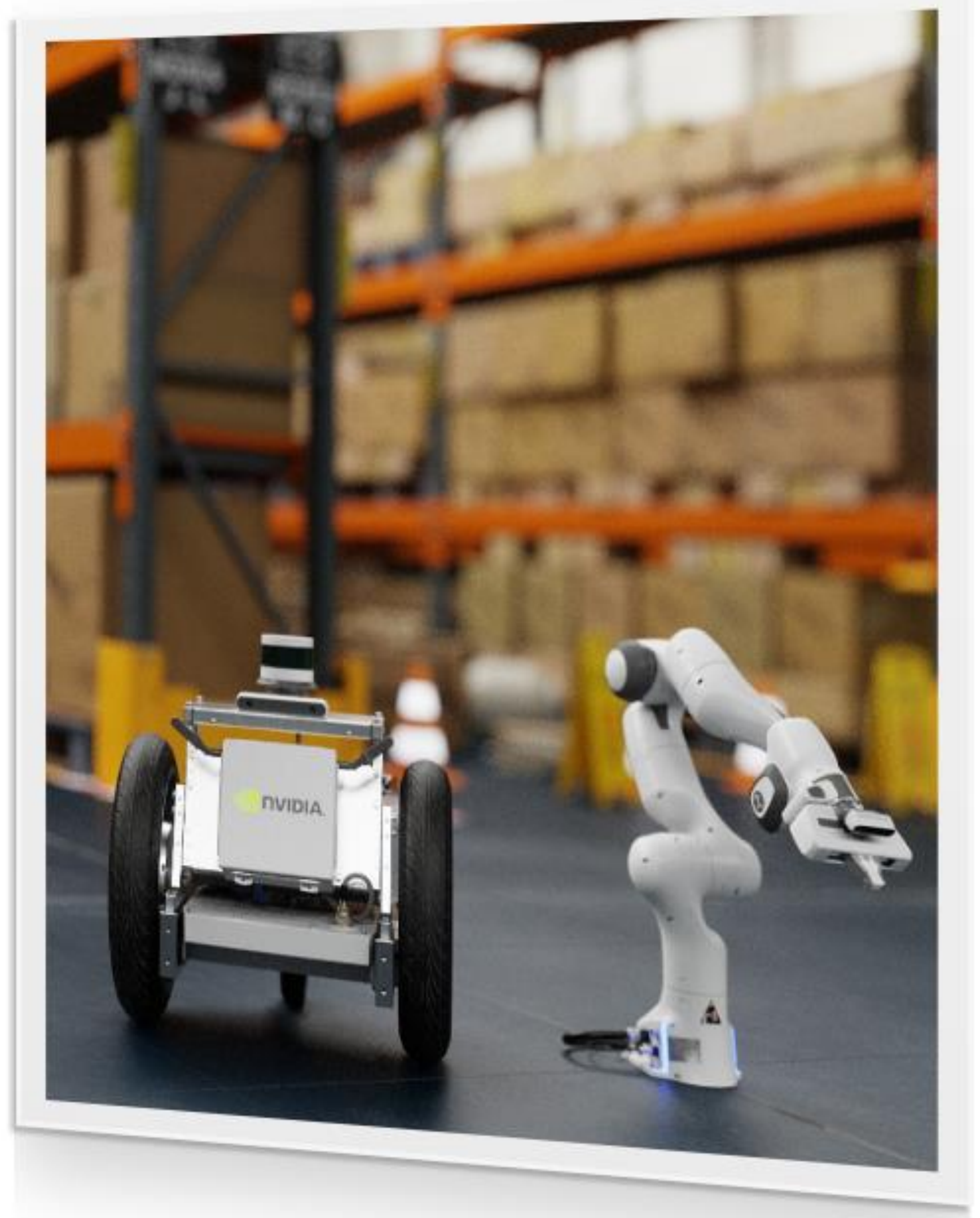
Coupling

KIT



Application API
User experience

SIMULATION



Virtual Actor

RTX RENDERER

Virtual Sensor

DATA HOMOGENIZATION VIA USD

NVIDIA OMNIVERSE™

USD

UNIVERSAL SCENE DESCRIPTION

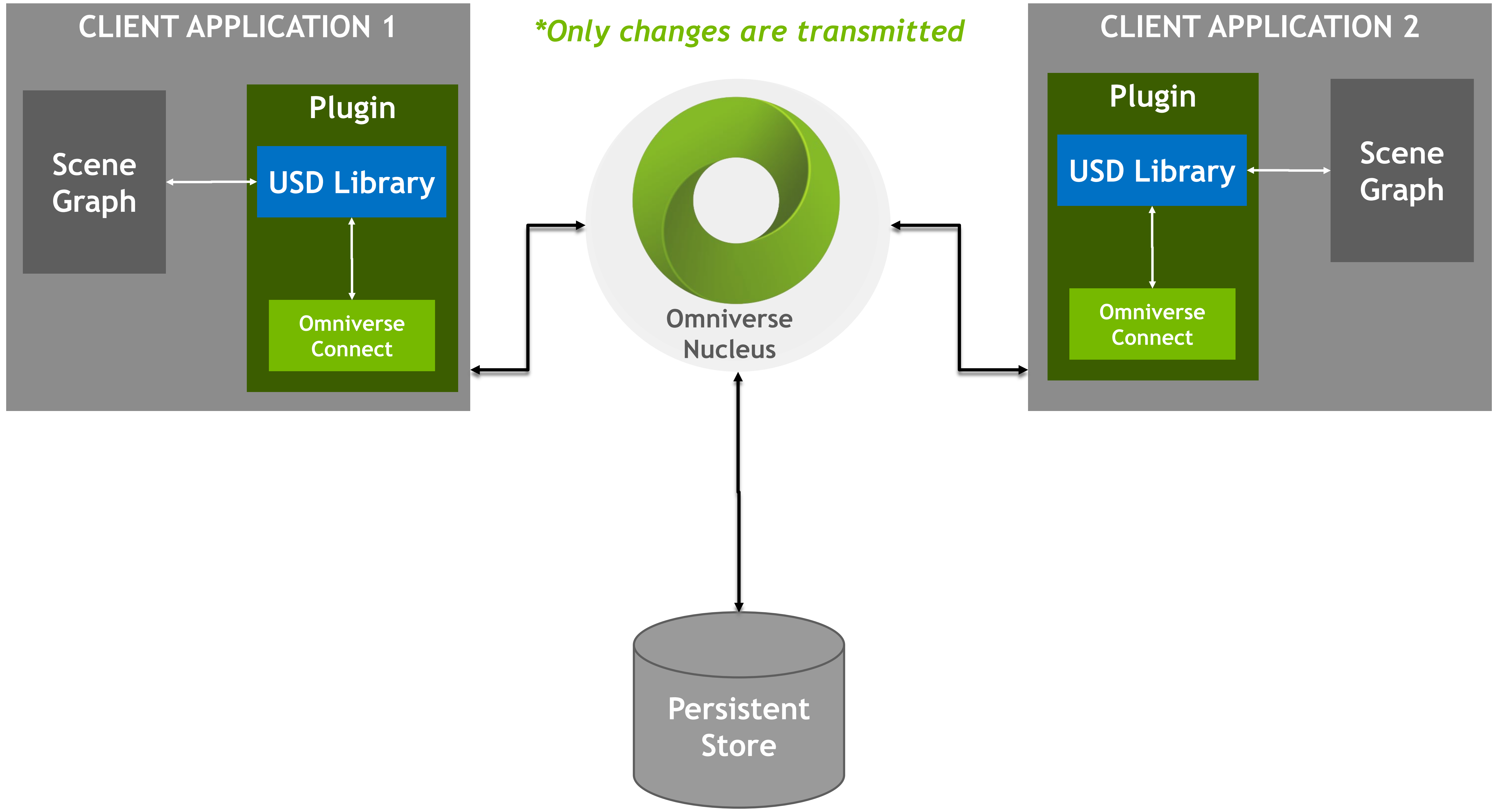
The “HTML” of 3D Virtual Worlds

- Developed by Pixar
- Foundation for NVIDIA Omniverse
- Open-sourced API and file framework for complex scene graphs
- Easily extensible, simplifies interchange of assets between industry software
- Introduces novel concept of layering
- Enables simultaneous collaboration for large teams in different department working on the same scene
- Originated in M&E, now becoming a standard across industries including AEC, Manufacturing, Product Design, Robotics

OMNIVERSE NUCLEUS

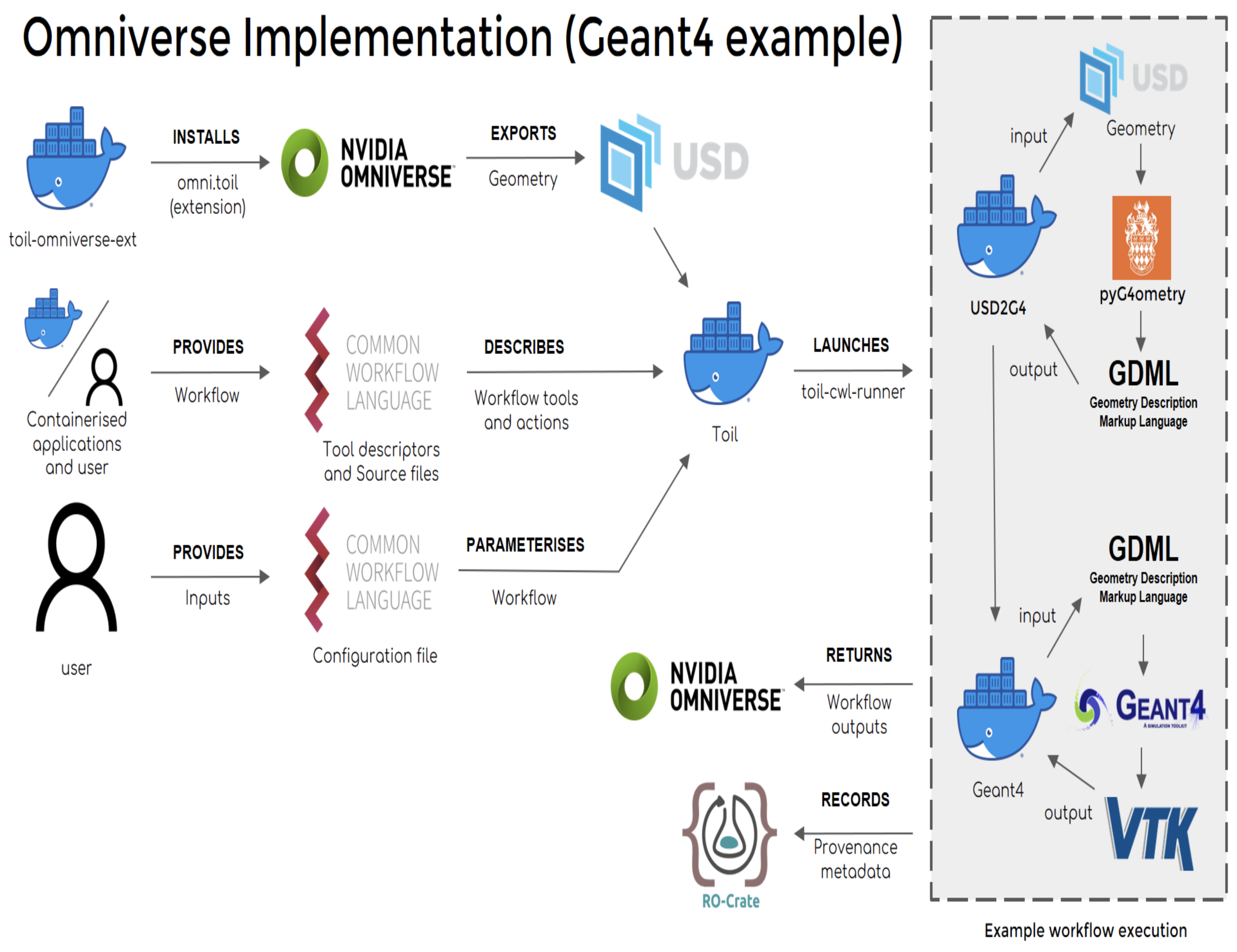
Asset Database and Collaboration Engine

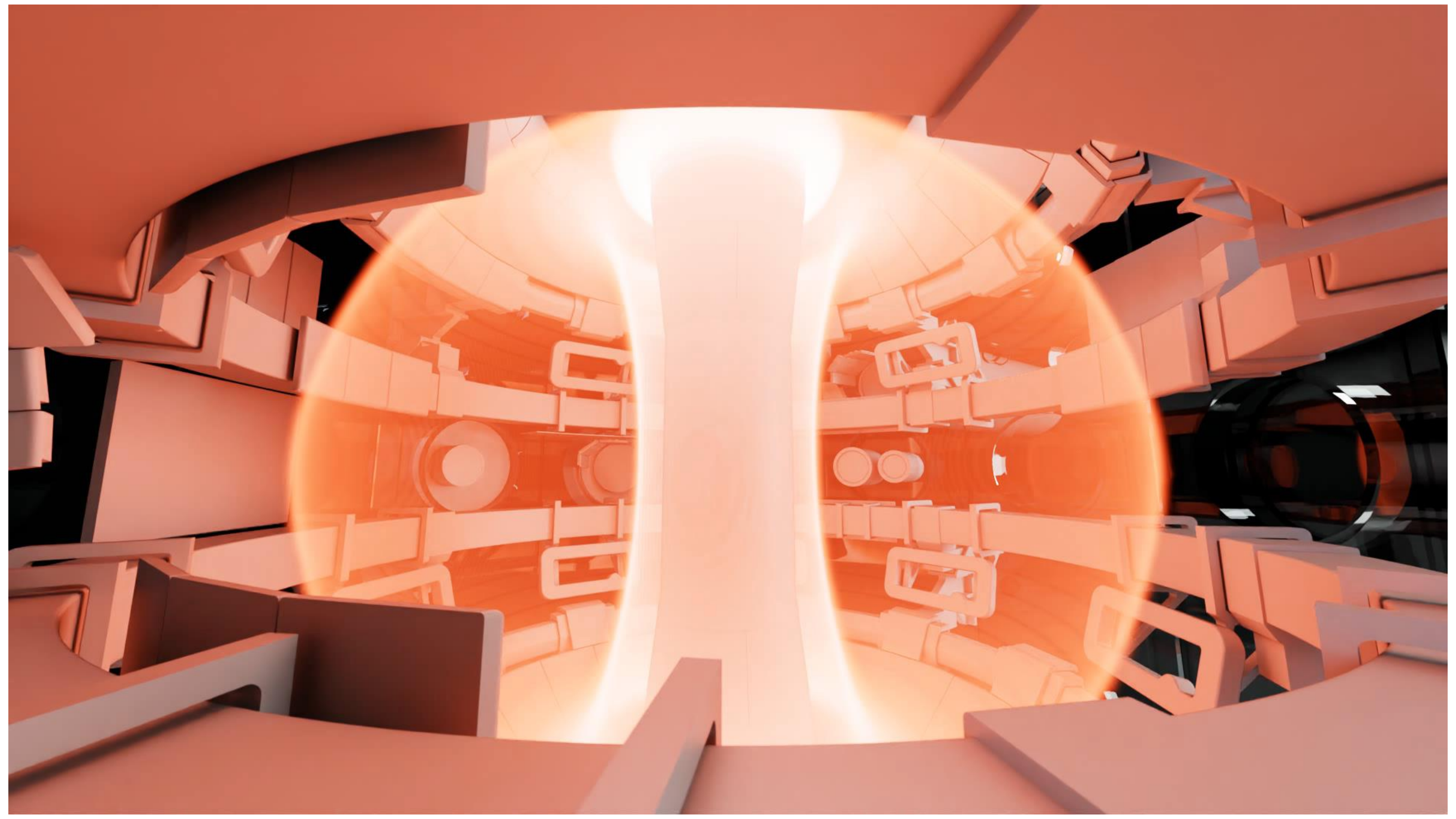
- Allows multiple software tools to talk to each other as well as live sync workflow
- Universal asset exchange – can house assets of any filetype
- Enables collaboration on large, ultra-complex scenes and passes only the change deltas
- Because only deltas are exchanged, extremely fast creation/replication is enabled
- No more hour-long or overnight uploading/downloading of entire scene files – everything is real-time and live
- Enables a single source of truth and eliminates messy, redundant file copies



UKAE EVALUATED OV WITH JOREK SIMULTIONS FOR FUSION REACTOR

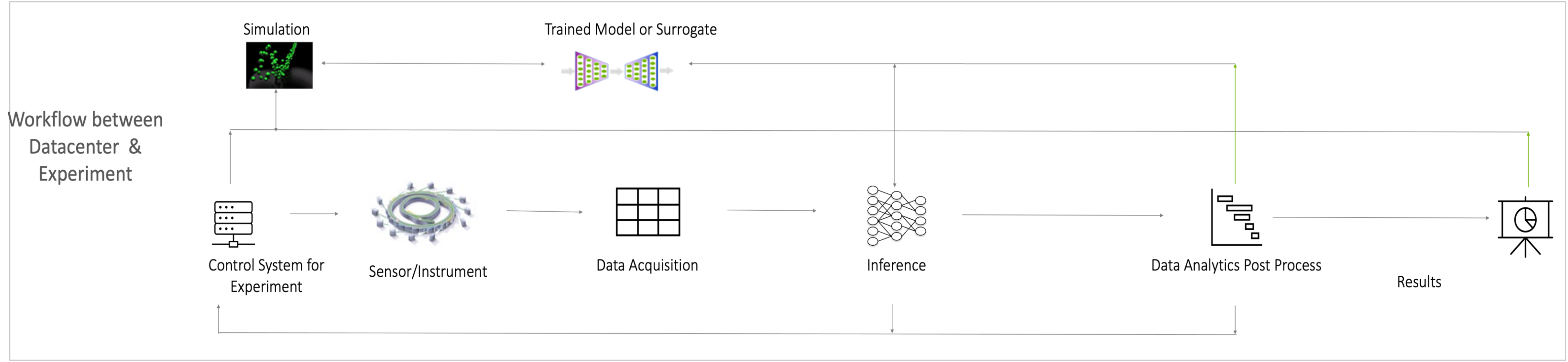
- Integration of open source science application (GEANT4)
- FAIR Workflow with Omniverse
- Building extensions
- Multi-user Collaboration
- Photorealistic rendering with real time Interaction



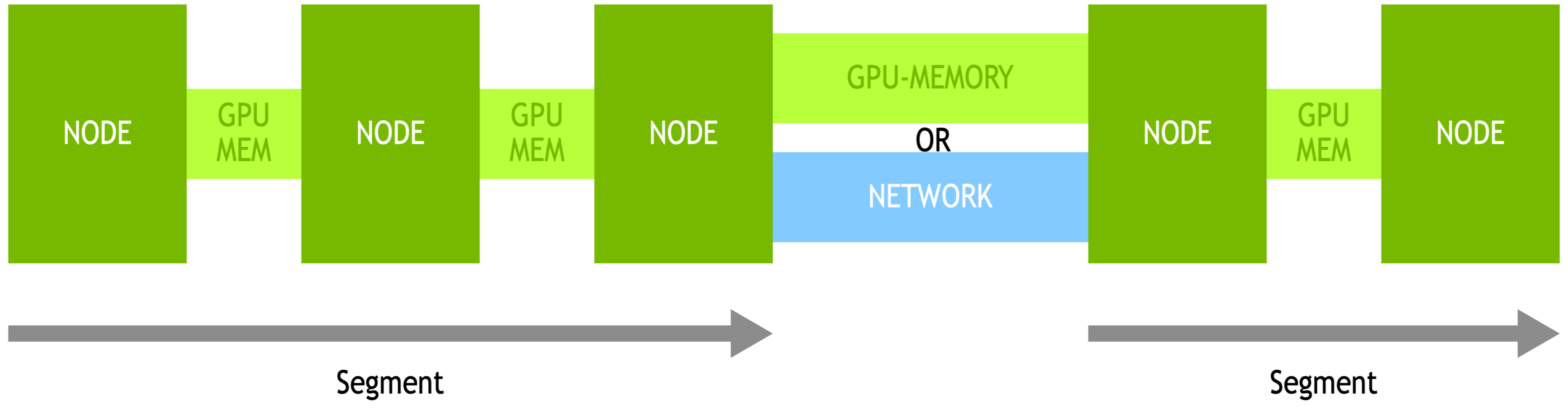


PREPARING FOR THE NEXT DECADE OF SCIENTIFIC COMPUTING

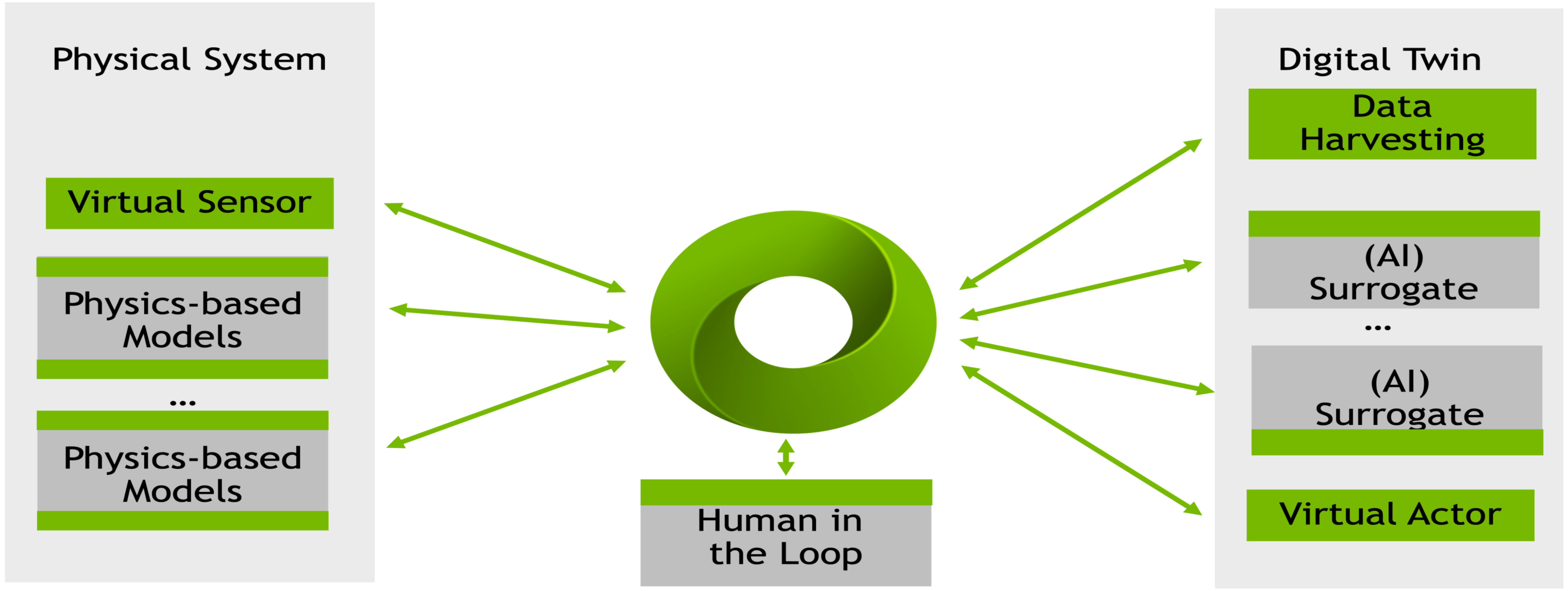
INTEGRATING THE SIMULATION +AI AND EXPERIMENT WORKFLOW


Simulation
Trained Model or Surrogate
Workflow between Datacenter & Experiment
Control System for Experiment
Sensor/Instrument
Data Acquisition
Inference
Data Analytics Post Process
Results

ACCELERATING THE SENSOR /EXPERIMENT DATA PROCESSING



BUILDING A DIGITAL TWIN TOWARDS A SCIENCE GRAND CHALLENGE



NVIDIA®