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CoFMPy

A Flexible FMI-based Co-Simulation Framework for Digital Twin Applications

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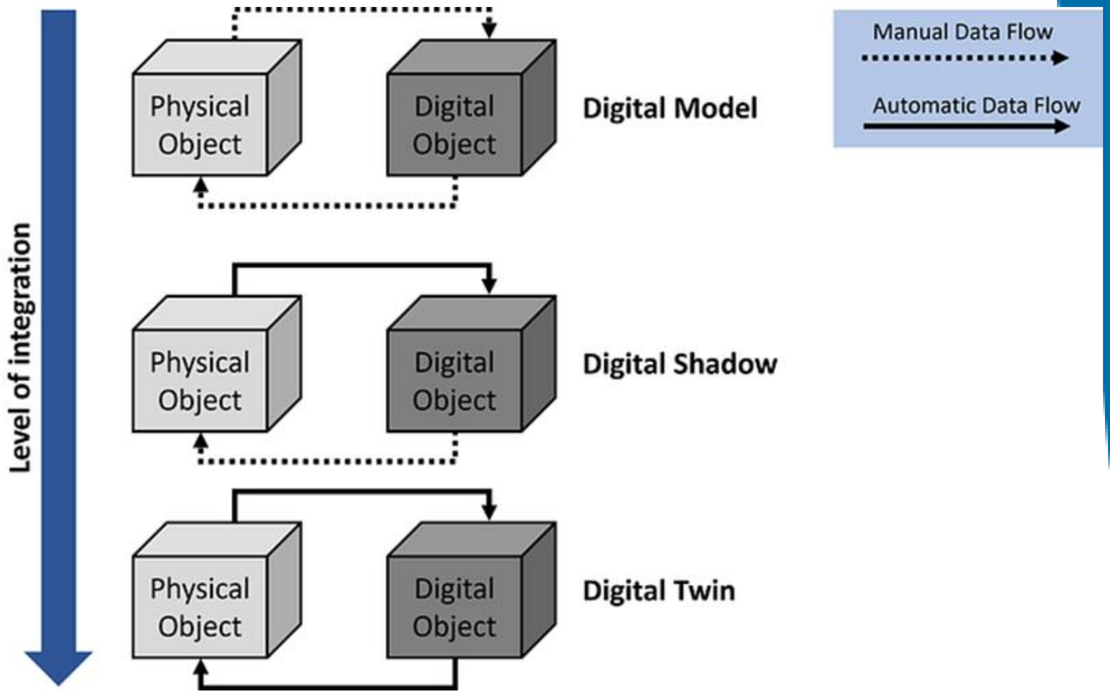
From Simulation to Digital Twin (DT)

Digital models

- Mature simulation tools for predefined offline analysis
- Useful for feasibility studies, early-stage design validation, and controlled experiment
- Lack of adaptability or real-time updates (manual reconfiguration)

Digital twins (shadows)

- Continuous, real-time updates from physical systems
- Can interact and evolve with the physical twin
- Proactive decisions through predictive analytics



Source: Kritzinger et al. 2018

Digital Twins Applications

Manufacturing (industry 4.0) 🏭

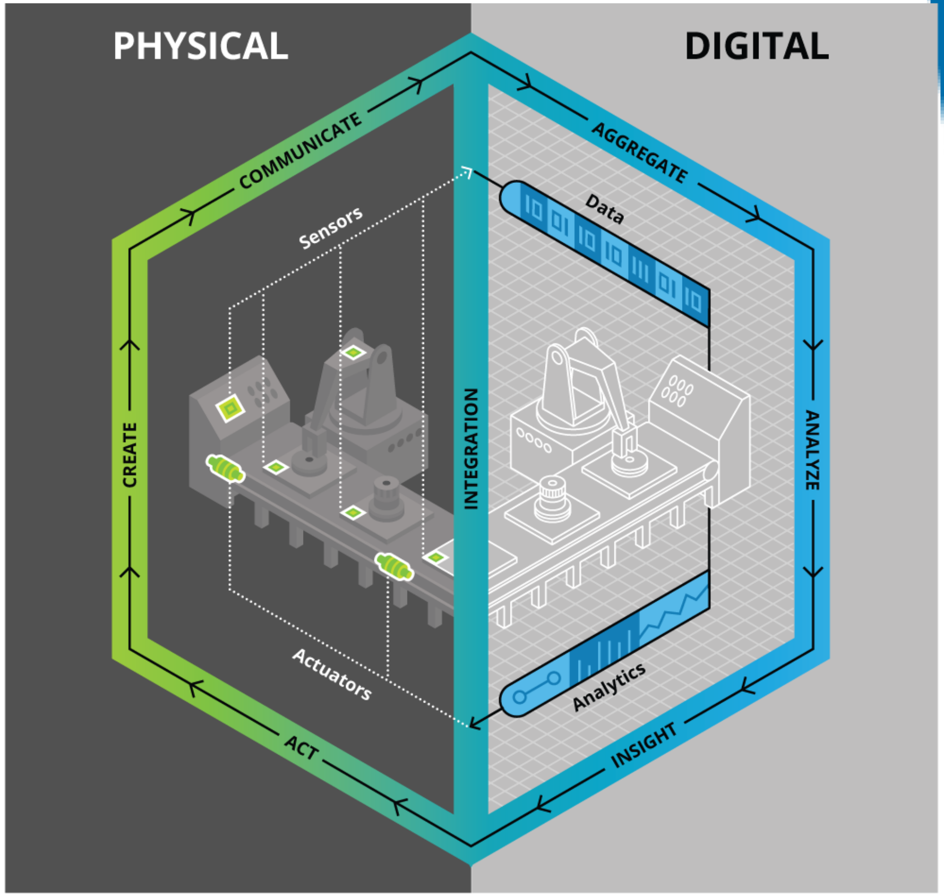
- Monitor production lines
- Enable predictive, condition-based maintenance to reduce downtime

Smart Cities 🏙

- Manage traffic
- Optimize energy distribution
- Monitor infrastructure health

Aerospace & Defense ✈

- Simulate performance
- Optimize energy use
- Predict system failures in real time.



Source: Deloitte University Press.

Deloitte University Press | dupress.deloitte.com

Co-simulation Requirements For Digital Twins

✓ Multi-domain integration

- Seamless coordination between heterogeneous multidisciplinary systems

✓ Modularity and Interoperability

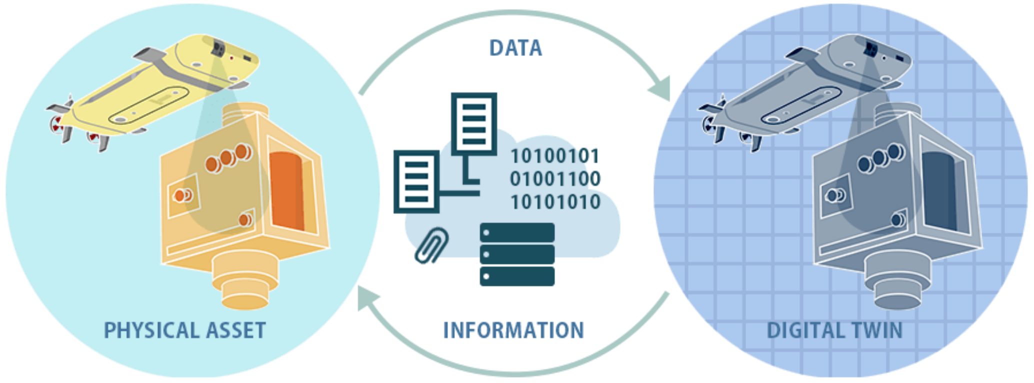
- Modular design to enable flexible model integration and updates

✓ Bidirectional Data Flow

- Real-time updates and feedback loops

✓ Scalability

- Ability to handle large systems and multiple components



Digital Twin wishlist

Industry (High TRL)	R&D (Low TRL)
Complete	Rapid Prototyping
Optimized	Open-source
Real-time	Essential DT Features

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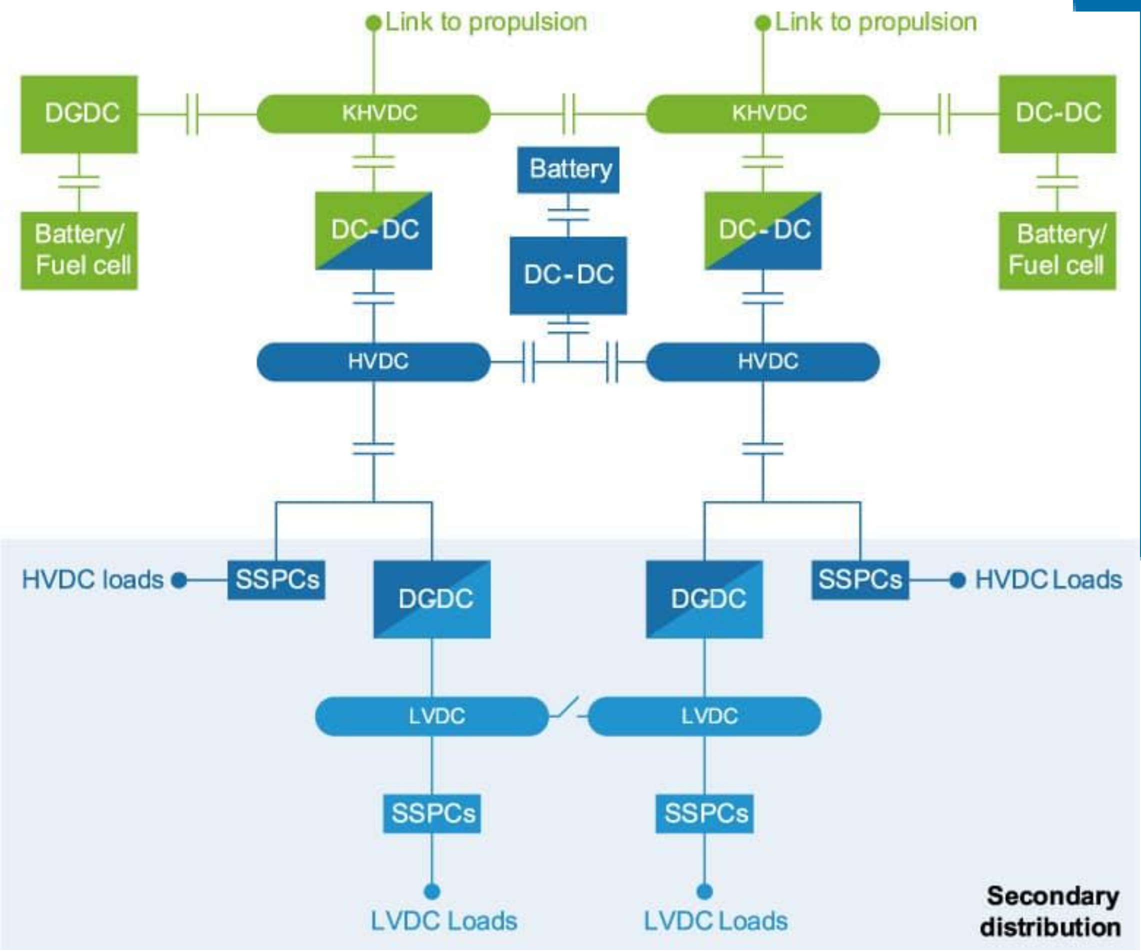
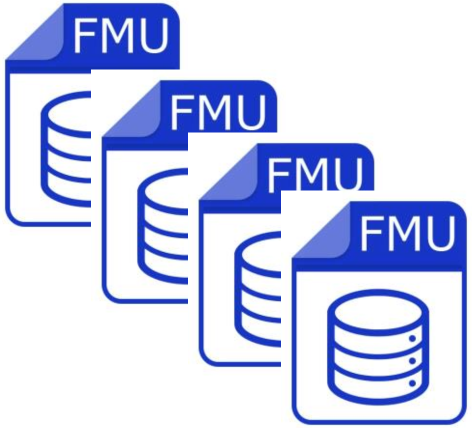
HECATE project

- **HECATE = Hybrid Electric Regional Aircraft Distribution Technologies**
- **Ongoing European project supported by the Clean Aviation Joint Undertaking (CAJU)**
- **One of the challenges – build a Digital Twin:**
  - Primary distribution with very high voltage DC (KHVDC), from 800 to 1500 V
  - Secondary distribution with low and high voltage DC (LVDC and HVDC), from 28 to 540 V
  - DC-DC power converters
  - etc.



HECATE project

- **Each partner of the project provides FMU files corresponding to their subsystem simulation (distribution, converters, loads, etc.)**



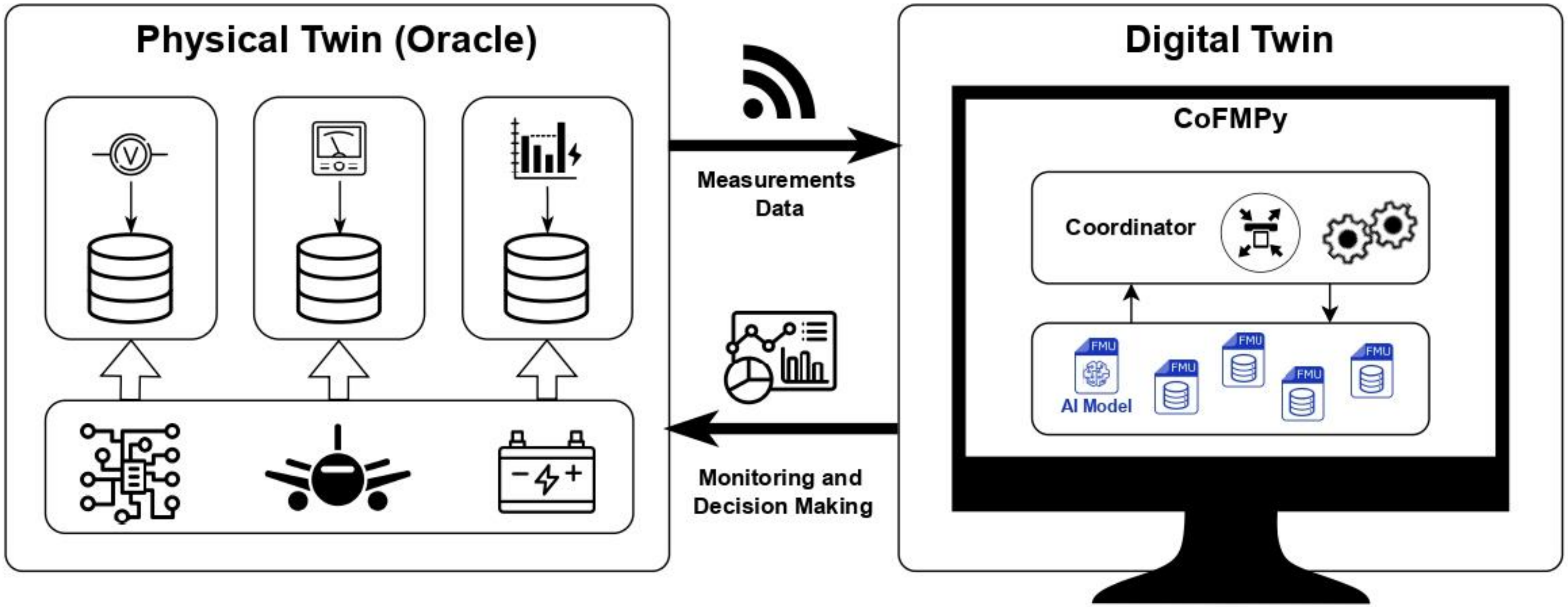
NEED FOR A RAPID PROTOTYPING DT TOOL

- **handling co-simulation from different FMUs with algebraic loops**
- **supporting inbound and outbound data streams**
- **storing and visualizing simulation results**
- **lightweight with flexible, generic and customizable components**

CoFMPy

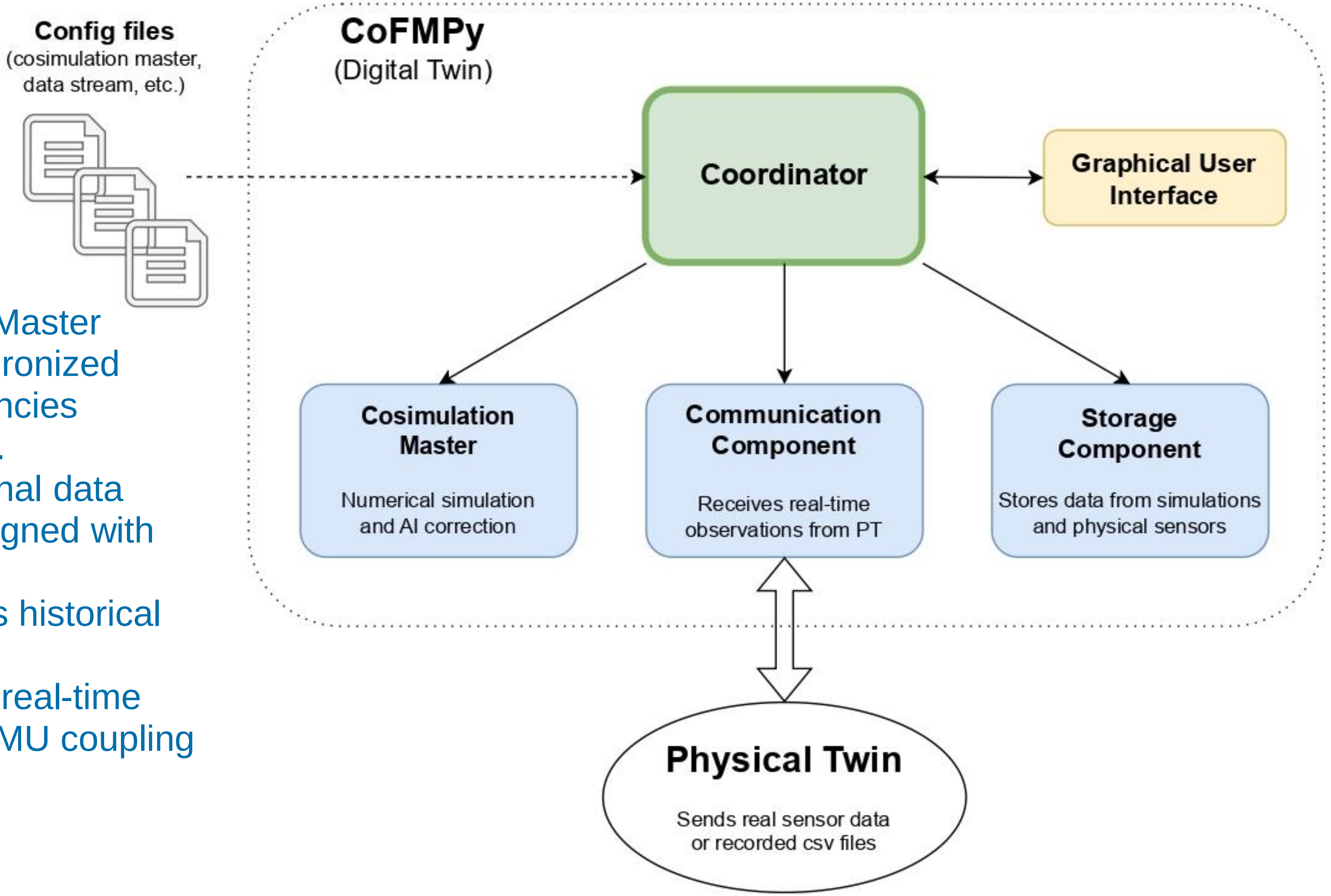
Python open-source library – Rapid prototyping – FMI-based co-simulation

Lightweight – Customizable



CoFMPy structure

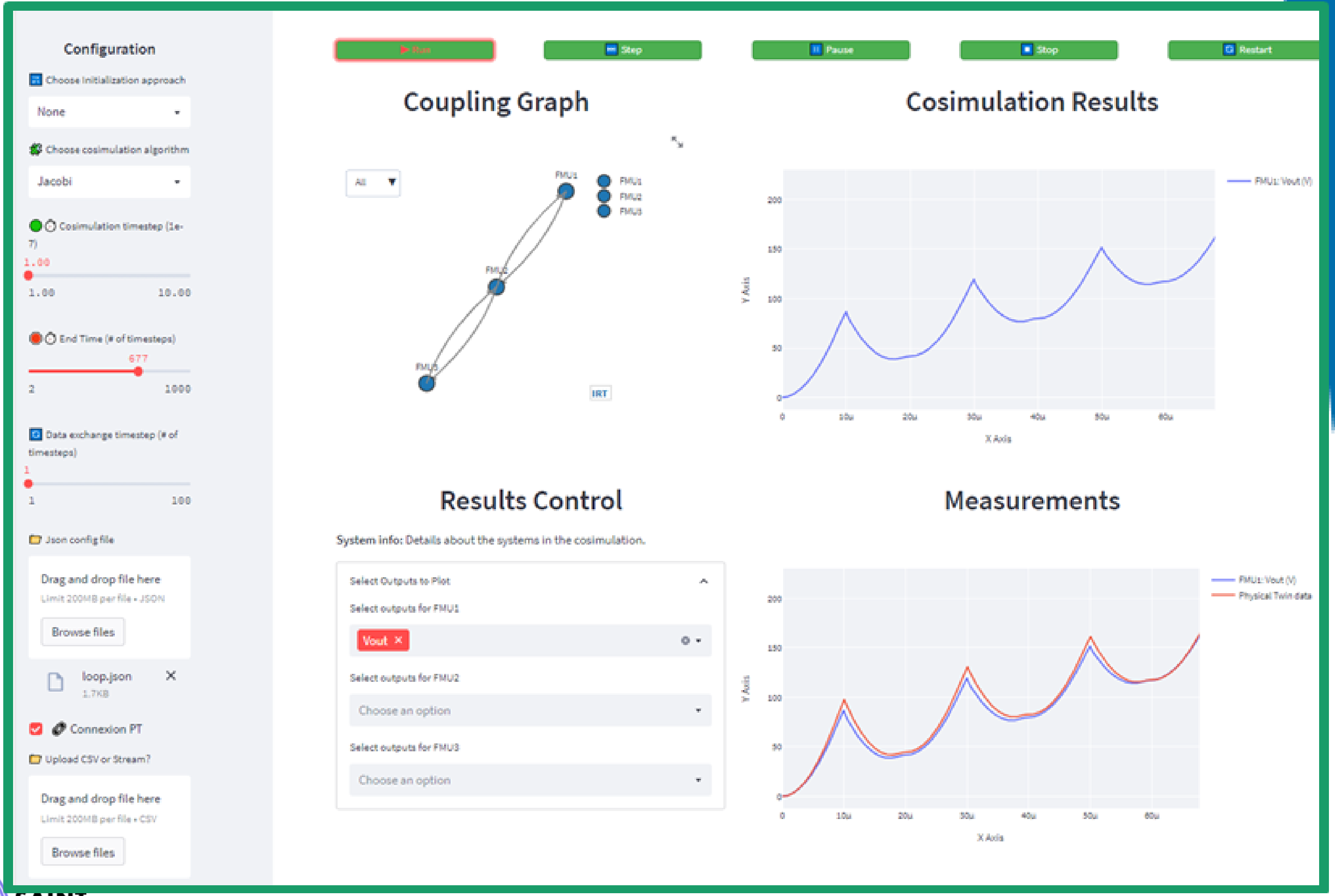
- **Coordinator**: The core unit that supervises the other components and control the interactions between them.
- **Co-simulation Management**: A Master algorithm ensures accurate, synchronized simulations and resolves discrepancies between digital and physical twins.
- **Data Communication**: Bidirectional data exchange keeps the digital twin aligned with the physical twin.
- **Data Storage**: A repository stores historical data, simulation outputs, and logs.
- **User Interface**: A GUI visualizes real-time data, simulation results, and the FMU coupling graph.



CoFMPy in practice

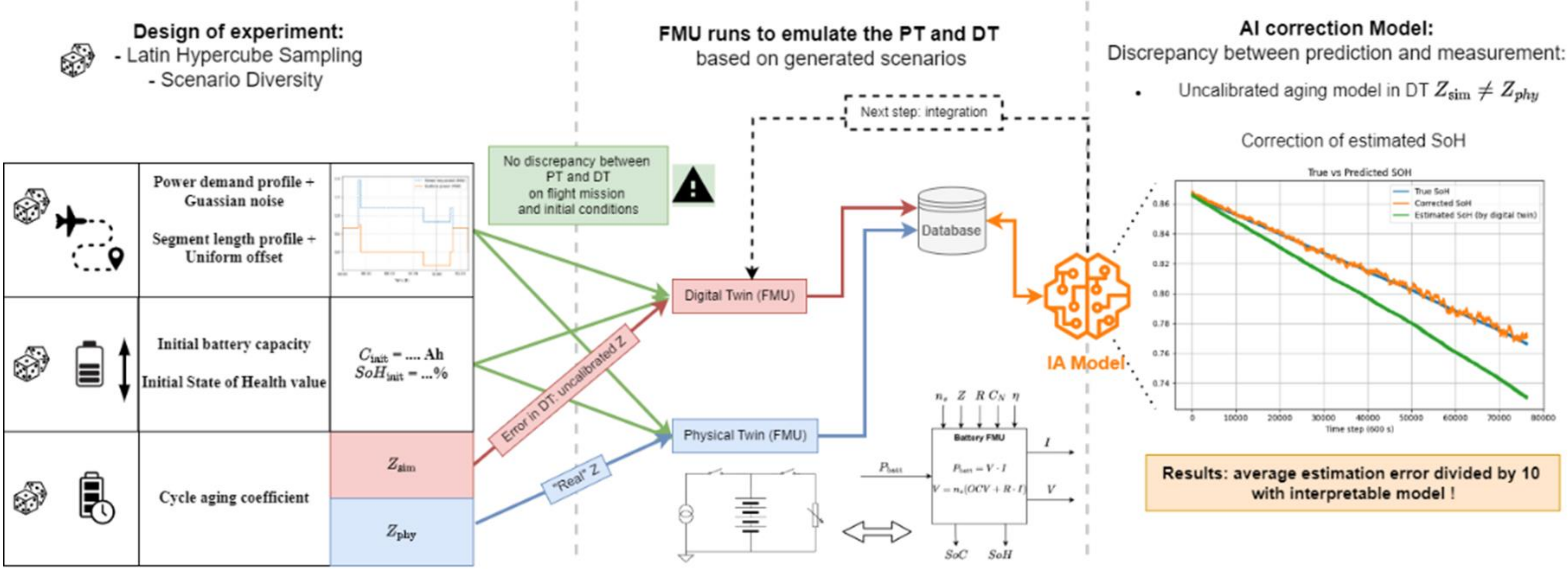
- Easy to use: JSON configuration file with FMUs and connections
- Two modes:
  - User interface
  - Python API (high or low-level)
- FMU execution based on FMPy
- Create your own components:

  master algorithm, inbound/outbound data streams, etc.
- Online documentation



Application: AI-powered DT for battery systems in hybrid aircraft

POC: battery health monitoring with AI correction model



Key takeaways

- **Need for rapid DT prototyping** of FMU-based co-simulation

- **We developed CoFMPy**, an open-source library written in Python with elementary DT features.

- Easy to use, one JSON configuration file, GUI or Python API, flexible and customizable.

- Applied on **battery health monitoring with AI correction**.

Thank you!

Contact points for any question:

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