

# The Future of Aircraft Maintenance: Goals and Challenges of Digital Twins for In-flight Operations

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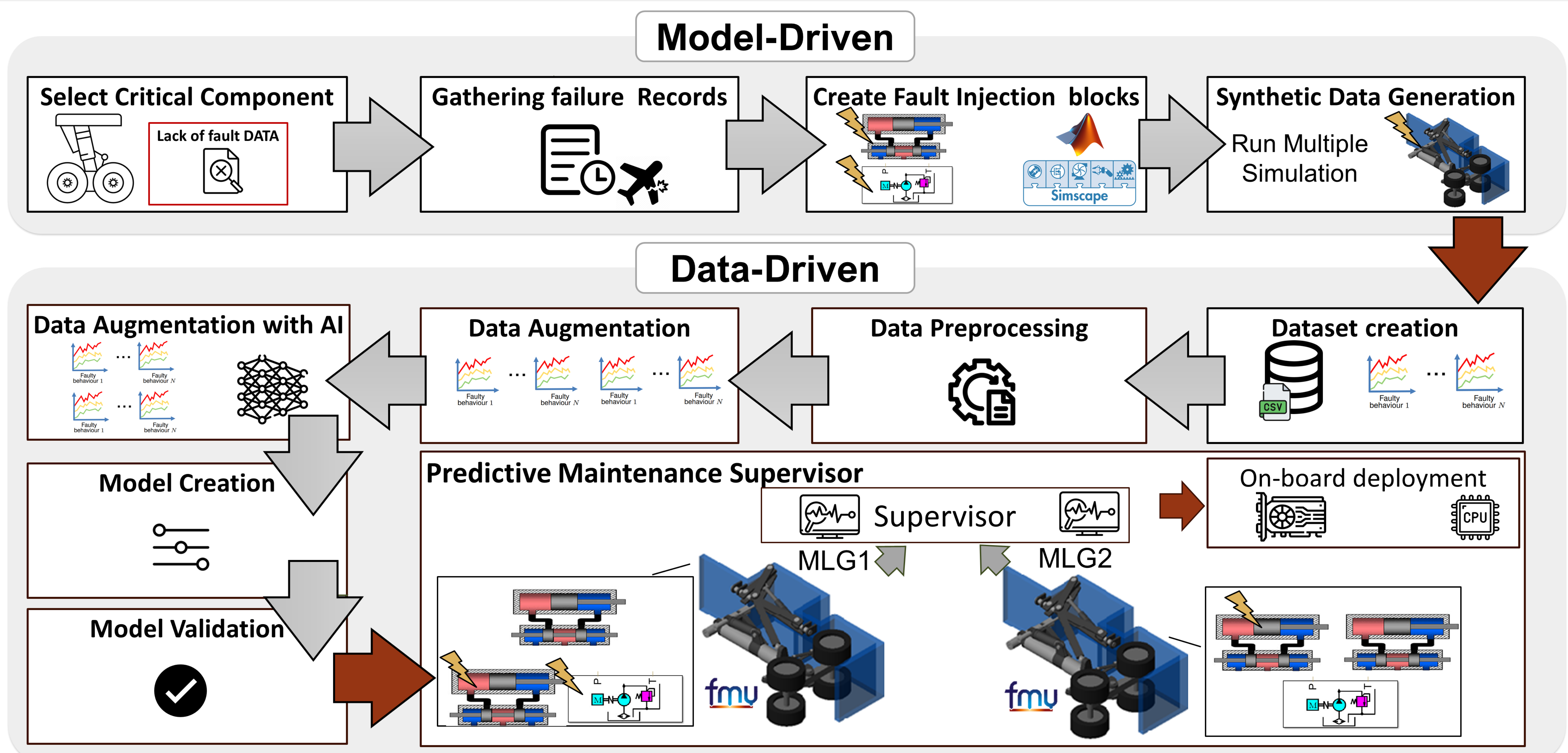
## Motivations

- From Time-Based Maintenance to **Predictive Maintenance (PdM)**
- **Improve safety:**
  - Predict potential failures before they occur
- **Cost mitigation:**
  - In 2022, **76\$ billion** was spent for maintenance
- **Challenges for PdM:**
  - **Complexity and Explainability:** Models must be accurate and interpretable for stakeholders
  - **Data Availability:** Scarcity of publicly available datasets to train and validate predictive models
  - **Safety Risks:** Ensuring the reliability of predictions

## Background

- **Digital Twin (DT):** Virtual replica of a physical asset that allows for real-time monitoring and simulation
- **Functionality:**
  - **Real-Time Insights:** Monitors equipment continuously, identifying performance issues early
  - **Reducing downtime** and minimizing maintenance costs
- **Challenges for Digital Twin:**
  - **Lack of formal definition** of DT
  - **Lack of standardized methodologies** for DT creation
  - **Interdisciplinary**

## Hybrid Digital Twin Framework



## Use-Case: Landing Gear System

- **Essential Aircraft Component:**
  - Safe takeoffs, taxiing and landings
- **Maintenance Costs:**
  - Accounts for 20% of the airframe's maintenance
- **Multi-Domain Model:**
  - Mechanical and Hydraulic Systems
- **Challenges**
  - **Limited Sensors:** few sensor available for condition monitoring
  - **Data Scarcity:** lack of public datasets



## References

- 1) F. Biondani, N. Dall'Ora, F. Tosoni, E. Fraccaroli, and F. Fummi, "Fault Injection for Synthetic Data Generation in Aircraft: A Simulation-Based Approach" IEEE 22nd International Conference on Industrial Informatics (INDIN).
- 2) F. Biondani, D.S. Cheng, and F. Fummi, "Adopting OPC UA for Efficient and Secure Firmware Transmission in Industry 4.0 Scenarios", IEEE 33rd International Symposium on Industrial Electronics (ISIE).
- 3) Centomo, Stefano, Nicola Dall'Ora, and Franco Fummi. "The design of a digital-twin for predictive maintenance" 2020 25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA).

## Take Home Message

Hybrid Digital Twin framework for Predictive Maintenance, Data Augmentation with Generative AI