Augmented Hybrid Engineering

ID Card	
Main breakthroughs	• Robust decision making in critical systems, while handling missing and faulty measurements, few data to model and predict a complex behaviour and encountering new situations. • Fast decision making from sensor acquisition at the edge to actuation or interaction with decision makers, through stochastic simulations of nonlinear system-of-systems and distributed decision making using hybrid twins.
Why these breakthroughs	• Robustness is required for critical systems, and a purely data-driven approach cannot lead to reliable and explainable decisions under all situations. • A complex system-of-systems with nonlinear behaviours and interactions is hard to predict and requires innovation to alleviate the deficiencies of pure physics-based or data-based approaches.
How the WP addresses these breakthroughs	By improving existing methods for data acquisition and cleaning, modelling and forecast, as well as real-time decision making: • Optimal generation and fusion of data from sensors as well as interactions between data and physics-based models for handling missing and faulty measurements. • Hybrid twin synthesis with uncertainty quantification using deviation data, and in its use for real-time stochastic predictions of system state. • Methodologies and H/W architectures for robust and scalable real-time operational decision making.
Which novelties?	• Combined sensor placement and time-series data fusion w.r.t. economic and/or quality criteria using stochastic optimization and machine learning techniques • Develop AI-based mathematical framework to synthesize hybrid twins with faster than real-time simulations from known physics and available data, along with uncertainty propagation for predictions with confidence bounds. • Reinforcement learning for efficient target cascading which guide controllers associated with a correct-by-design approach, along with out-of-distribution data detection. • Neuromorphic and event-driven approach for resource efficient deployments of hybrid twin based decision making framework.
How do these breakthroughs contribute to Descartes	• Bring an operational framework (methodology and H/W architecture) for scalable and robust real-time decision making in real-life highly-constrained critical systems. • Provide tools for: (i) Efficient generation of clean data incorporating sensor placement, data fusion and model-based information harvesting technologies; and (ii) Synthesis of hybrid twins and real-time state estimation, combining faster than real-time physics models with Hybrid AI based deviation models.
Main skills of the WP's PIs	Statistical physics, theoretical physics, Numerical methods for simulations, computational physics, robust operational optimization of critical systems, forecasting and control synthesis, neuromorphic AI, digital hardware system design