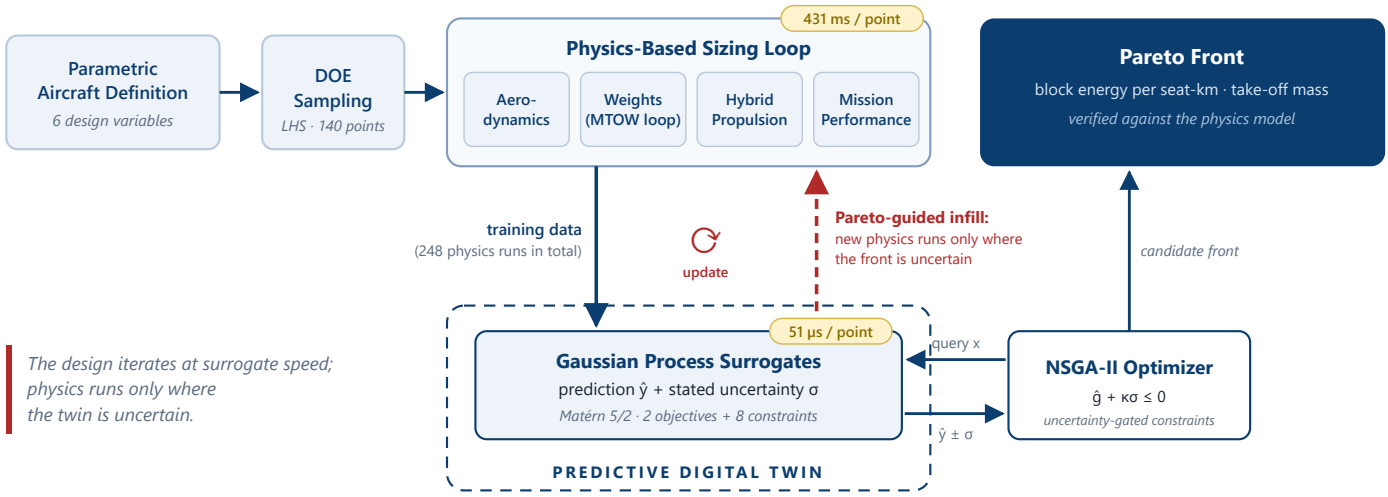
ERHAM — AVIATION APPLICATION & RESEARCH CENTER · ERCIYES UNIVERSITY · TÜRKIYE

Machine Learning–Assisted Digital Twin for Aircraft Conceptual Design MDO

A full optimization cycle in 5 minutes instead of 1.2 hours, with each prediction's uncertainty stated up front.

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16th EASN International Conference
Toulouse · 27–30 Oct 2026 · Digital Design session

THE FRAMEWORK: ONE LOOP, TWO SPEEDS



THE CHALLENGE

Conceptual design locks in most of an aircraft's life-cycle cost, yet it is the stage where physics-based analysis is used least, because each design point costs too much. Hybrid-electric and hydrogen configurations have **no historical data to fall back on**, so their design space has to be explored with physics.

THREE FINDINGS

1. **Judge a surrogate where the optimizer uses it.** Active learning gives no global accuracy gain over an equal-budget static sample (0.50 % vs 0.48 %), but at the Pareto front its error is **29× lower** (0.03 % vs 0.84 %).
2. **−10.5 % block energy, fuel and CO_2** relative to an ATR 72-500 reference that the model reproduces to within 1 %. The gain comes from aspect ratio 15.9 and cruise *L/D* rising from 14.9 to 16.9.
3. **Battery specific energy is the gate.** At 350 Wh/kg (pack level) the energy optimum is a conventional turboprop. Hybridisation starts to pay above **560 Wh/kg** and saves 13.7 % at 1500 Wh/kg.

MEASURED COST — 70-seat hybrid-electric regional aircraft

	Physics model	This framework
One design evaluation	431 ms	**51 µs ×8 400**
Full optimization cycle, all training charged	1.16 h	**5.0 min ×14**
Re-run after a changed requirement	1.16 h	**44 s**
Mean error, 120 independent designs	—	**0.50 %**
Error at the Pareto front	0.84 % (static)	**0.03 % ×29**

The physics layer is mid-fidelity, so these speed-up ratios apply to it only. With RANS/FEM the per-point ratio grows, while the number of samples one can afford shrinks. The framework itself is fidelity-agnostic.

We are looking for: an industrial **use case** to test the framework against a real early-stage trade study, and **partners** for Horizon Europe / Clean Aviation proposals.

Companion talk at this conference: *Experimental Validation of an Aircraft Digital Twin: From Concept to Validation* (A. N. Dişlitaş, M. Yıldız), which asks how good a test must be before it can validate a model like this one.

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