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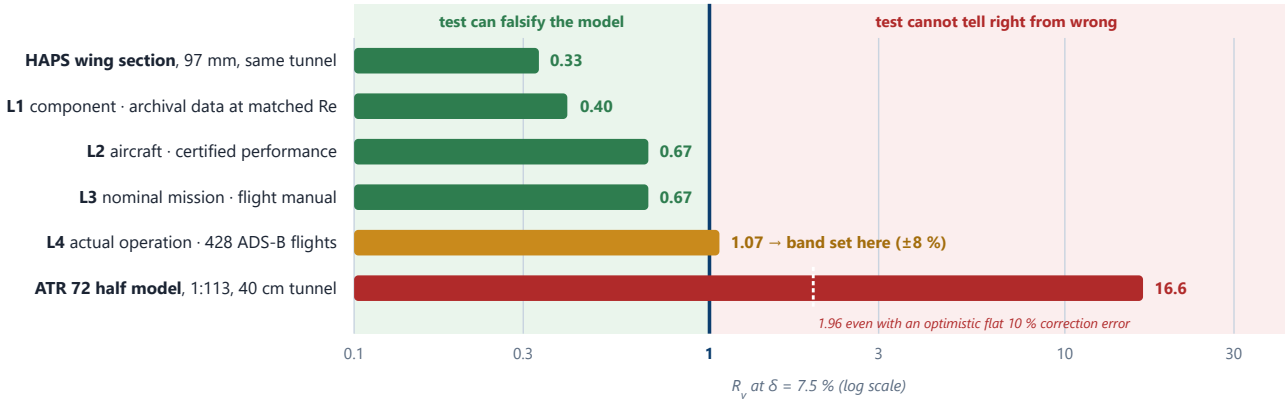
Experimental Validation of an Aircraft Digital Twin: From Concept to Validation

Before building a test, check that it could actually prove your model wrong.

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THE CRITERION: VALIDATION-RESOLUTION RATIO R_v

$R_v = u / (\delta \cdot y)$ — uncertainty of the **corrected** measurement ÷ model discrepancy the test must detect. **Informative only if $R_v < 1$**



THE PROBLEM

Digital twins are usually validated by whatever data can be found. A comparison validates nothing, however, if the correction applied to the measurement is larger than the model error it is meant to reveal. We planned a wind tunnel campaign for an **ATR 72-500 twin** (Simcenter Amesim, 5–10 % accuracy claim) and first audited it on paper.

THREE FINDINGS

1. **The tunnel campaign was cancelled after a one-afternoon audit.** The largest model that fits gives Re = 4.0×10^4 against 1.4×10^7 in cruise (×348). The scale correction is 122 % of the drag coefficient itself, giving R_v = 16.6.
2. **Operational data change the question.** Across 428 ADS-B profiles the median stage is 371 km, while the design mission is 750 km, a distance only 6 % of flights reach. The unknown mass matters less than expected: ±21.5 % in take-off mass gives only ±3.4 % in block fuel.
3. **Match the facility to the aircraft class.** The same tunnel reproduces a 20 km HAPS wing's Reynolds number (1.9×10^5) exactly with a 97 mm chord: R_v = 0.33.

THREE EVIDENCE SOURCES, ONE TEST

Source	Key number	R_v
ATR 72 half model, 1:113, 400×400 mm tunnel	Re gap ×348; correction 122 % of C_D	**16.6**
ADS-B, OpenSky, 428 complete ATR 72 flights	resolves ≈ 8 %; mass → fuel attenuated ×6.4	**1.07**
HAPS wing section, 97 mm chord, same tunnel	Re matched exactly, M 0.087 vs 0.10	**0.33**

The multi-level acceptance bands (±3 / 5 / 5 / 8 %) are what $R_v \approx 1$ gives for the best source at each level. The ratio is not tied to tunnels: flight tests, one-count drag increments and loads models are audited in the same way. When δ is small the criterion is harder to meet.

> **We are looking for: recorded flight data** with known mass (FDM/QAR) to close the operational tier, and **partners** for low-Reynolds HAPS section testing and certification-by-analysis evidence.

Companion talk at this conference: *Machine Learning-Assisted Multidisciplinary Design Optimization in Aircraft Conceptual Design Using Digital Twin Technology* (E. Z. Tekin, M. Yıldız), which builds a fast twin of the same aircraft class.

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