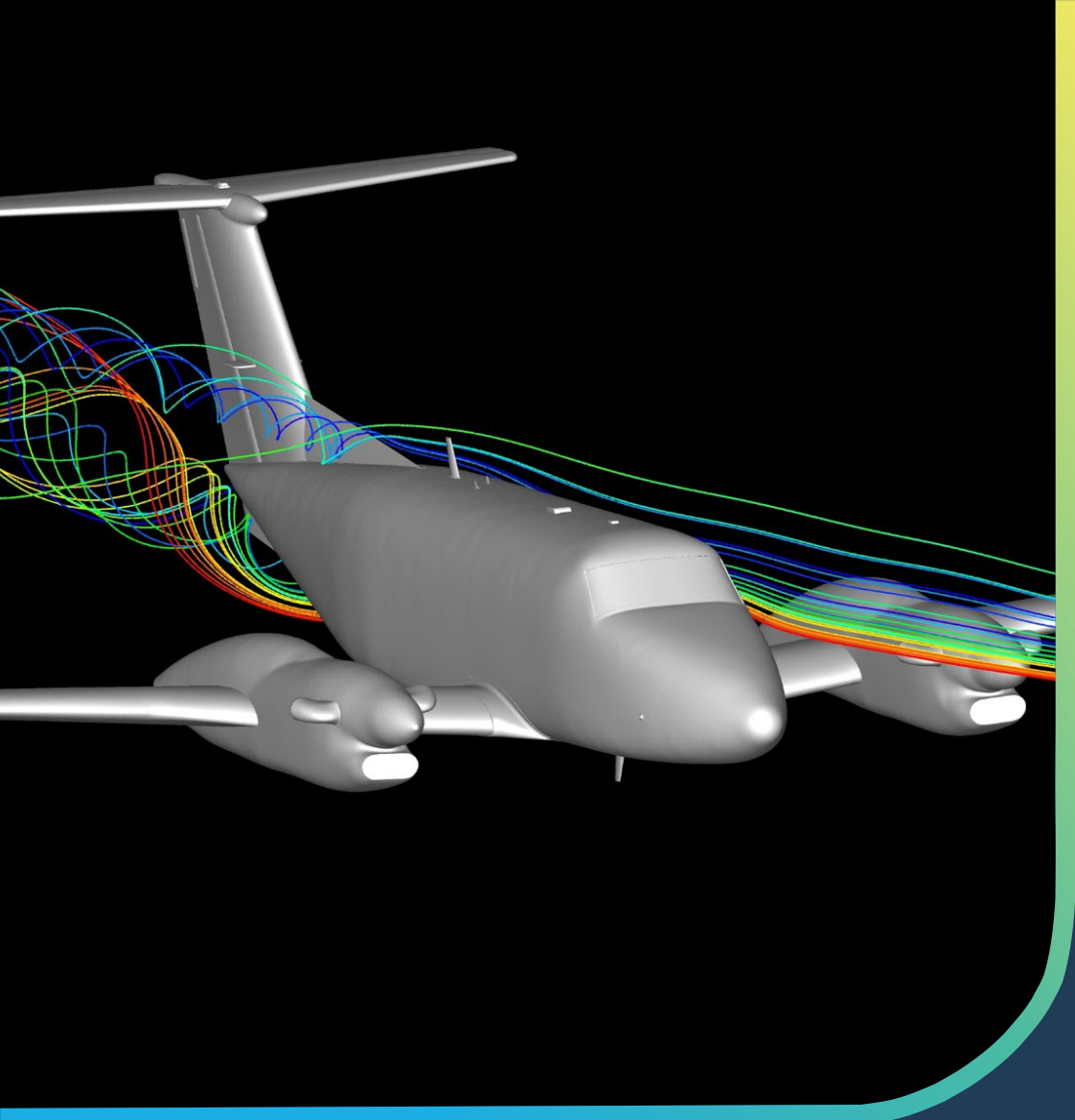




From First Prediction to Flight Test: How aircraft performance models gain credibility

Presented by Adam Croft
IMechE Simulation and Modelling 2026 Conference, Birmingham UK

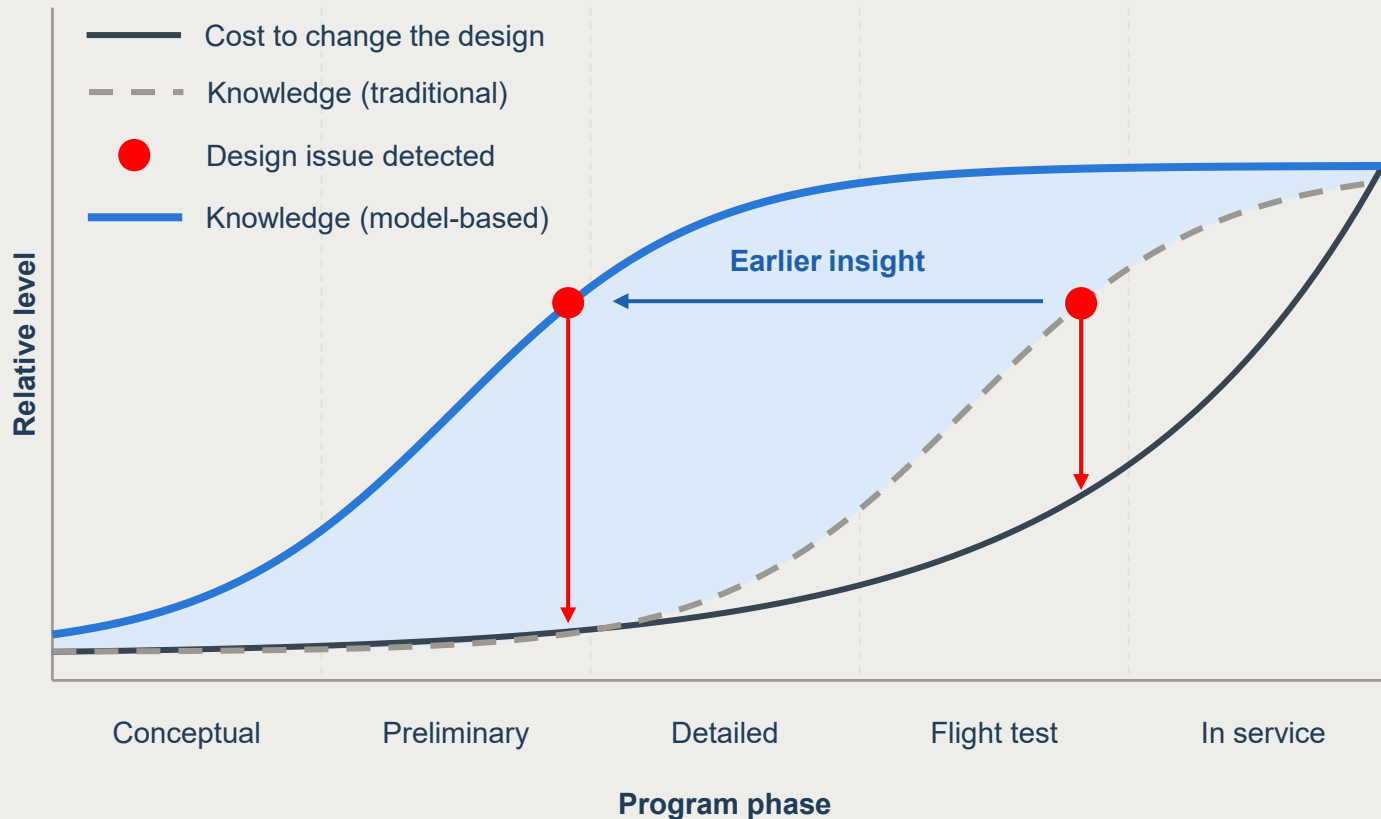


**How do we build confidence
in an aircraft performance
model that hasn't flown?**

**How should we use flight
test data to build
confidence?**

The Value of Early Prediction

Knowledge of how the aircraft will perform arrives while design changes are still cheap



1. Design issues are detected early

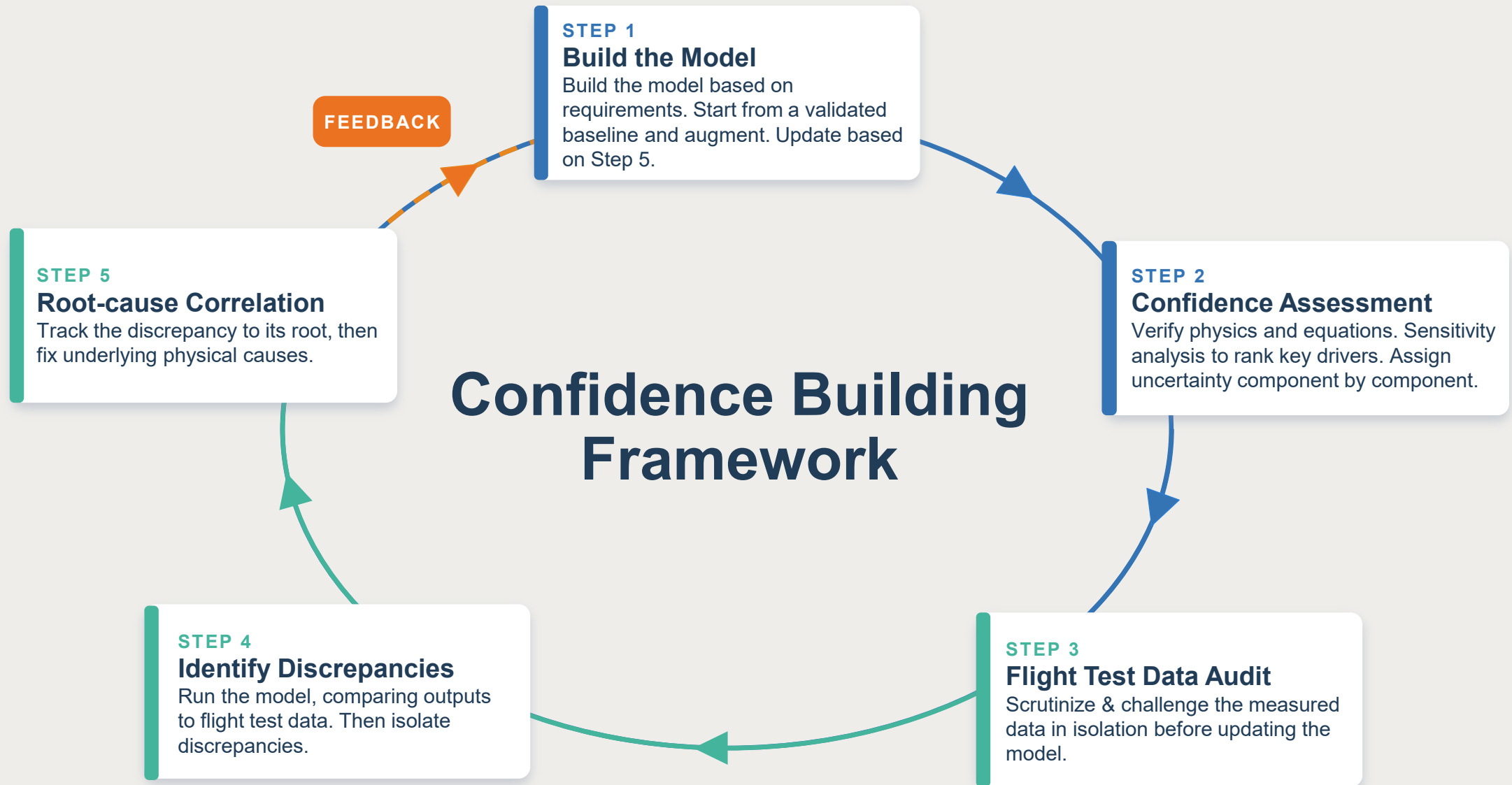
Design can be tested and iterated at low cost without changing hardware.

2. Assessment of existing type-certification

Early assessment of the impact of changes on the existing type-certification is crucial for Modified programs.

3. Marketing and investment

Early performance predictions may be important for marketing purposes or to attract investment.



Build the Model

PROGRESS

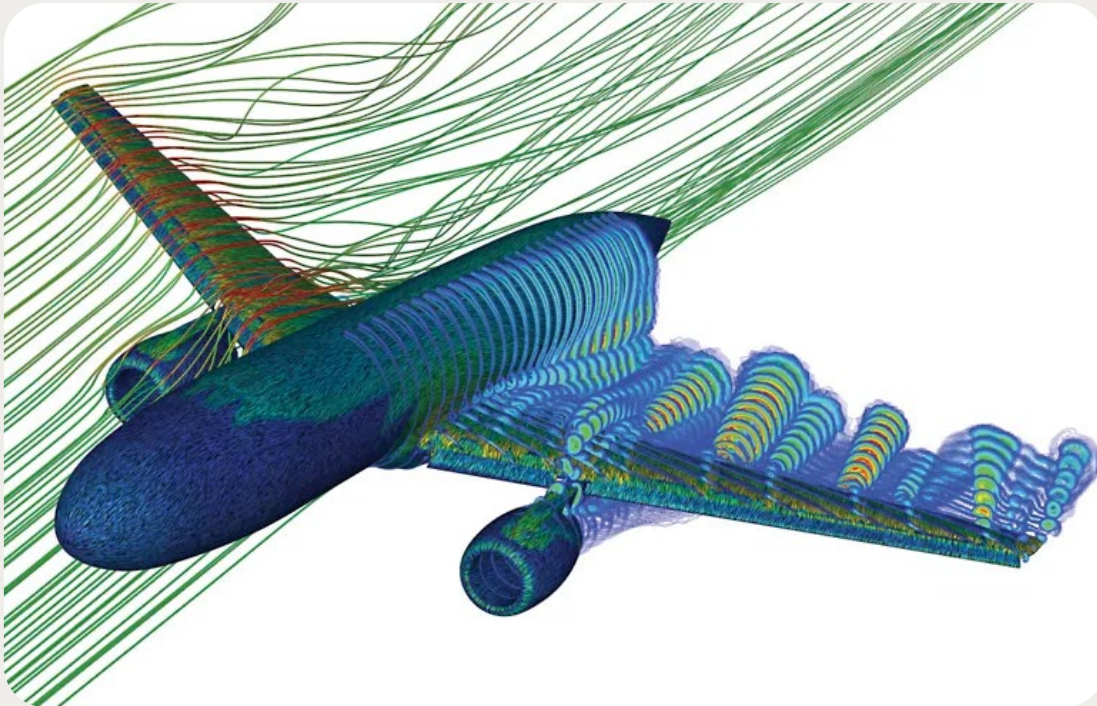
01. Build the Model

02. Confidence Assessment

03. Flight Test Data Audit

04. Identify Discrepancies

05. Root-Cause Correlation



Build Model Architecture from Requirements

Ideally start from a validated baseline so that we inherit a verified structure. Modifications may still be necessary to suit the requirements of the project.

Build Input Data

Augment baseline data with CFD where available. Use interpolation to fill envelope gaps.

Capture Assumptions and Input Uncertainty

Ensure the assumptions of the performance model are compatible with the aircraft. Every input parameter carries **uncertainty bounds**, which must be **explicitly captured** at this stage.

How do we build early confidence?

PROGRESS

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We cannot validate the model

We cannot claim the model is validated without flight test data, but we can build confidence in other ways.

Verify equations and physics

Unit test to verify the physics implementation, in isolation from the real data.

Sensitivity analysis

Tells us which inputs matter; allows us to focus effort on the important ones.

Decompose the uncertainty

Explicitly state the uncertainty in the inputs, and where the uncertainties in the model architecture lie. Set output bounds.

What we're actually claiming



Not a validation claim

Binary pass / fail. Impossible before flight test, and not the goal at this stage.



A graded, documented confidence argument

Decompose the uncertainty component by component. Show where confidence is strong, and quantify what remains.

Honest about what we know and what we don't.

Verify Equations and Physics

PROGRESS

01. Build the Model

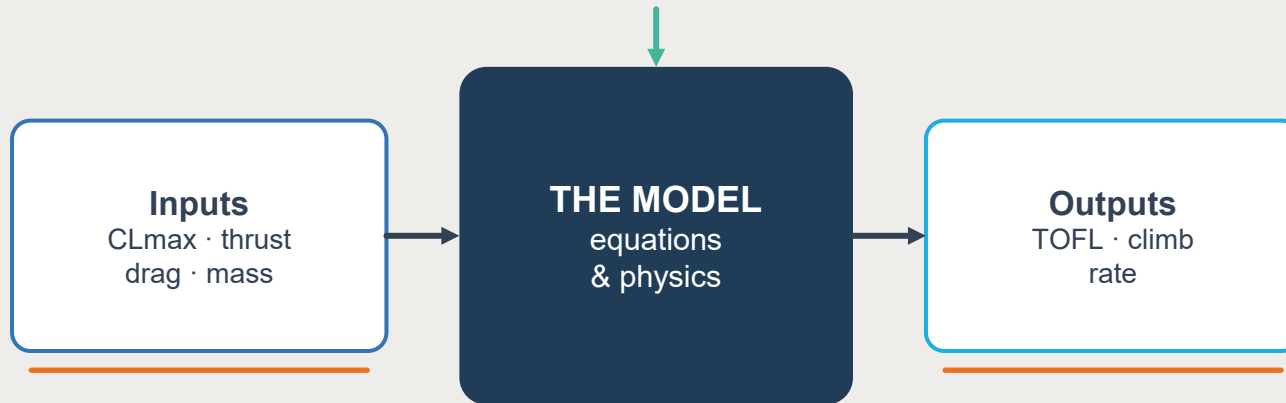
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Does the model reproduce known behaviour?



No flight test data needed

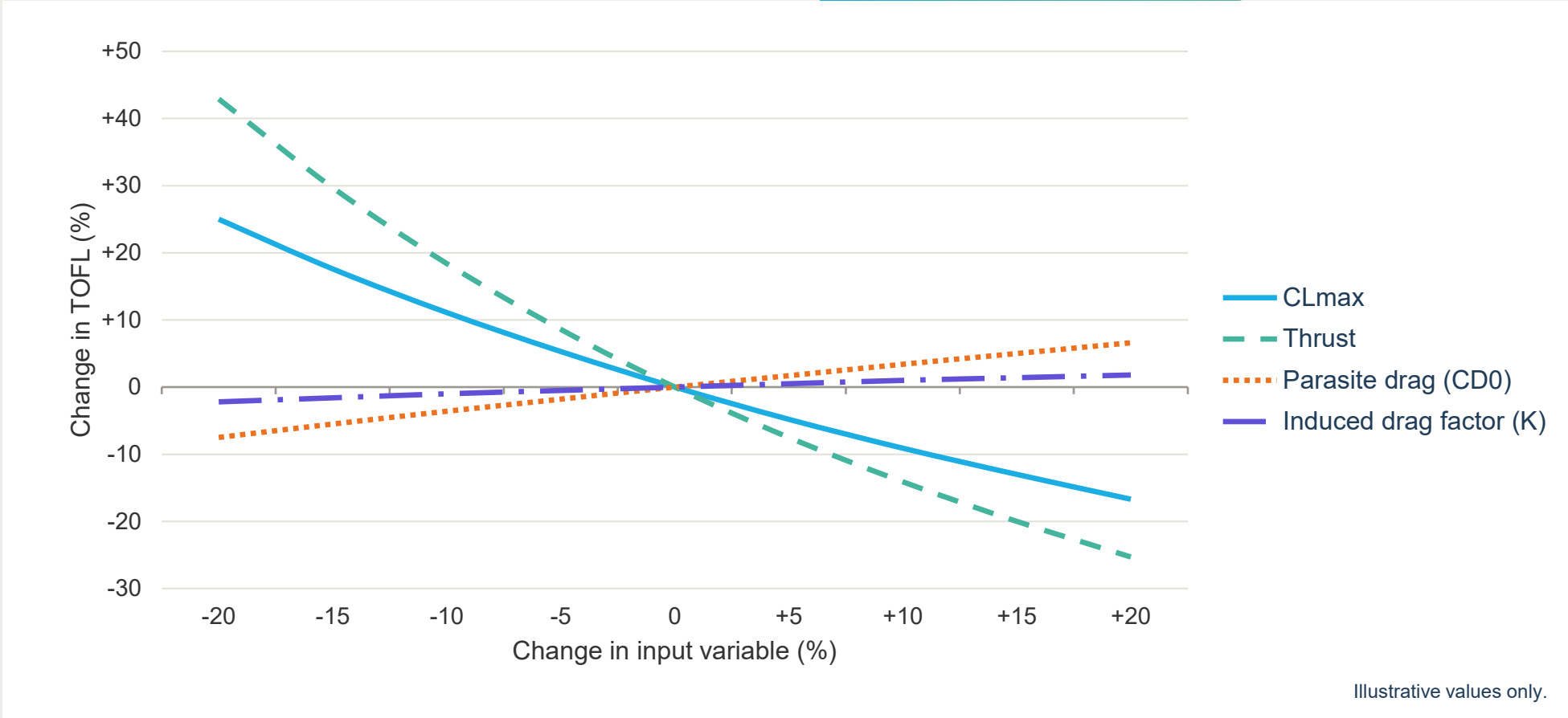
- ✓ **Unit test in isolation:** Verify that known inputs map to known outputs, using validated datasets
- ✓ **First-principles trends:** Where validated datasets are not available, sanity check trends, e.g. climb rate is proportional to excess thrust.

Parametric uncertainty is assessed separately

Sensitivity Analysis

PROGRESS

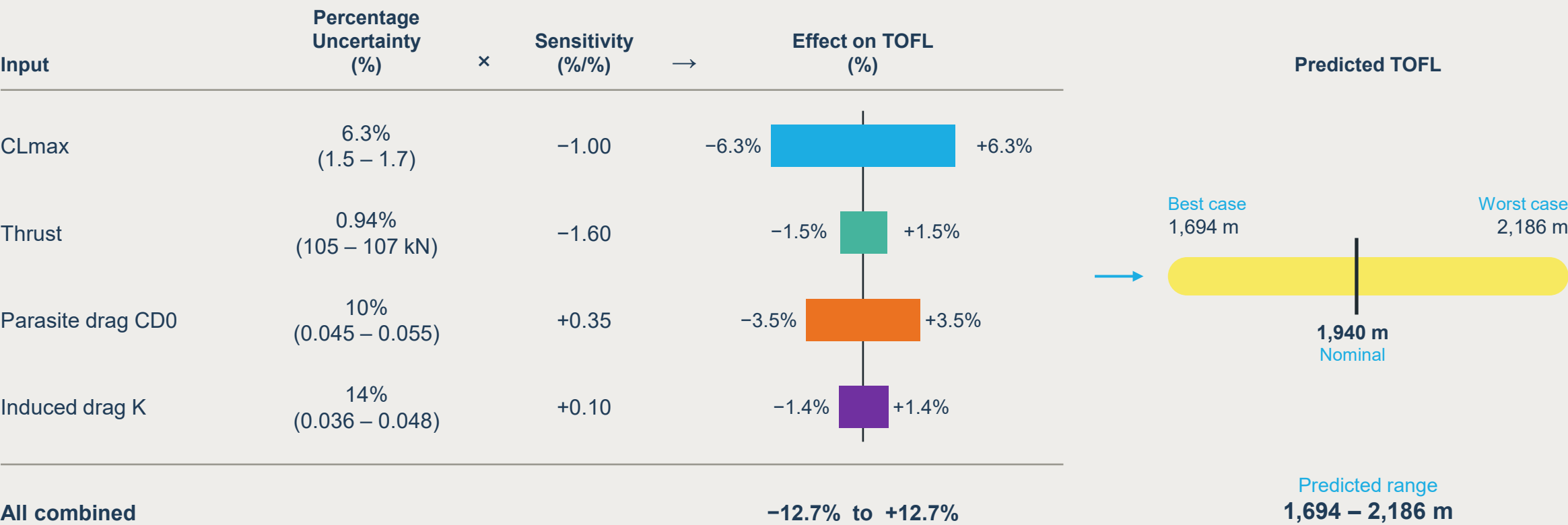
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Parametric Uncertainty

PROGRESS

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Illustrative values only – assumes linear sensitivities.

Early Confidence Final Assessment

PROGRESS

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THE MODEL

CONFIDENCE

EVIDENCE

Physics and equations

High

Verified against known behaviour

Architecture and Orchestration

Medium

Adapted from a validated baseline; adjusted for our aircraft with assumptions

THE INPUTS

Propulsion / thrust

High

Validated against bench data

Mass and inertias

High

Weighed components / CAD-derived

Drag (CD0, K)

Medium

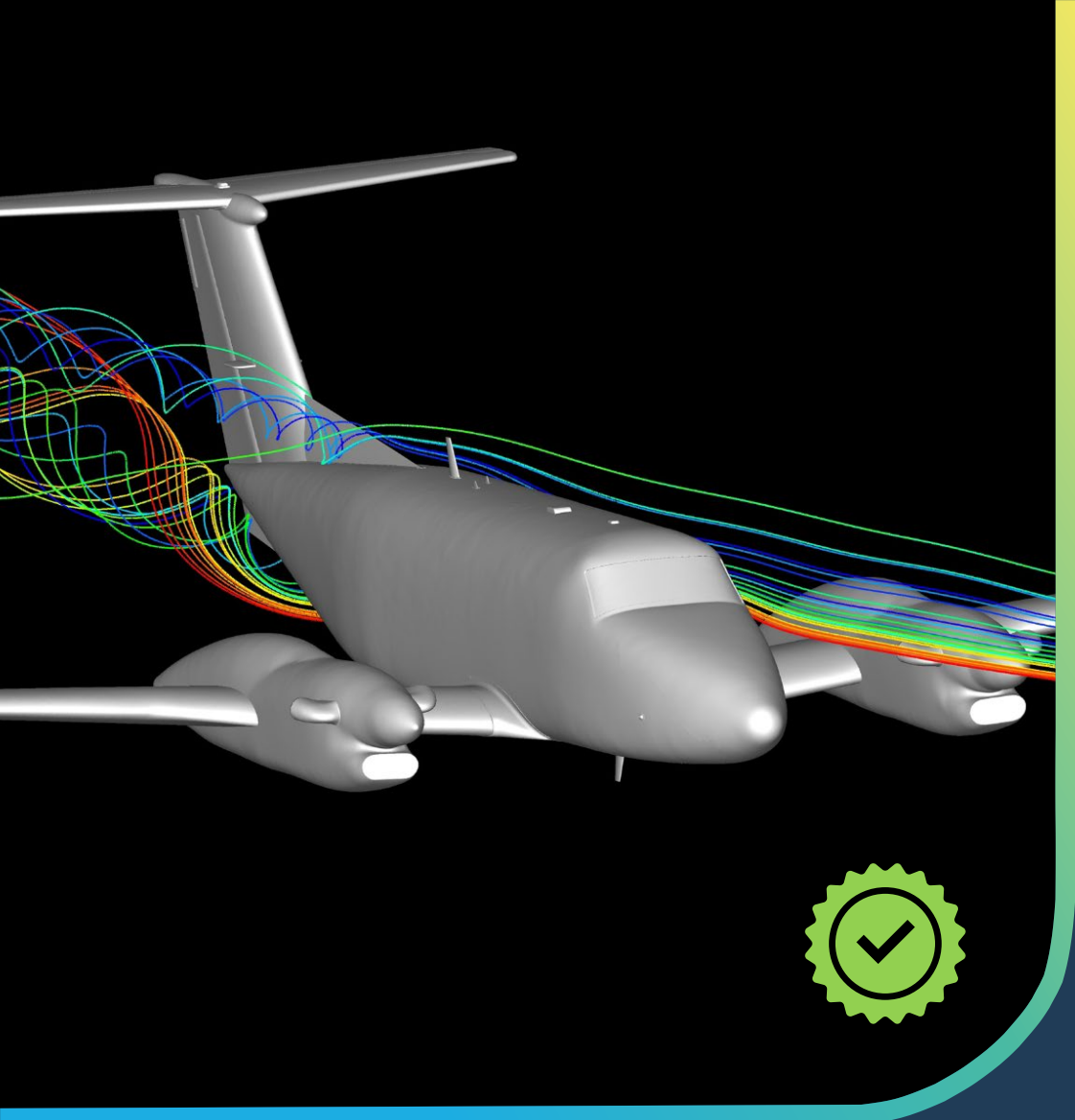
CFD only, high percentage uncertainty but low sensitivity ($\pm 4.9\%$ TOFL uncertainty)

Lift / CLmax

Low

CFD only, medium percentage uncertainty but high sensitivity ($\pm 6.3\%$ TOFL uncertainty)

Lift should be closely assessed in flight test. No need to assess thrust closely → Cost efficient flight testing



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Flight Test Data Audit

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Audit before running the model

Resist the temptation to compare the model outputs with the data at this stage. Understand the data first.

Scrutinise the data in isolation

Flight test data is not a perfect source of truth. Check for outliers and unexpected trends. Challenge the data if necessary.

Check operational details

Compare operational details and assumptions with the assumptions in the performance model architecture. If they don't match up, the outputs likely will not either.



Assumption Mismatch Example

Landing gear retraction – model fixes retraction at 50ft, but the test pilot retracted early in some cases, so those cases are not on the modelled drag schedule.

Identify Discrepancies

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⚡ Run the model to identify discrepancies

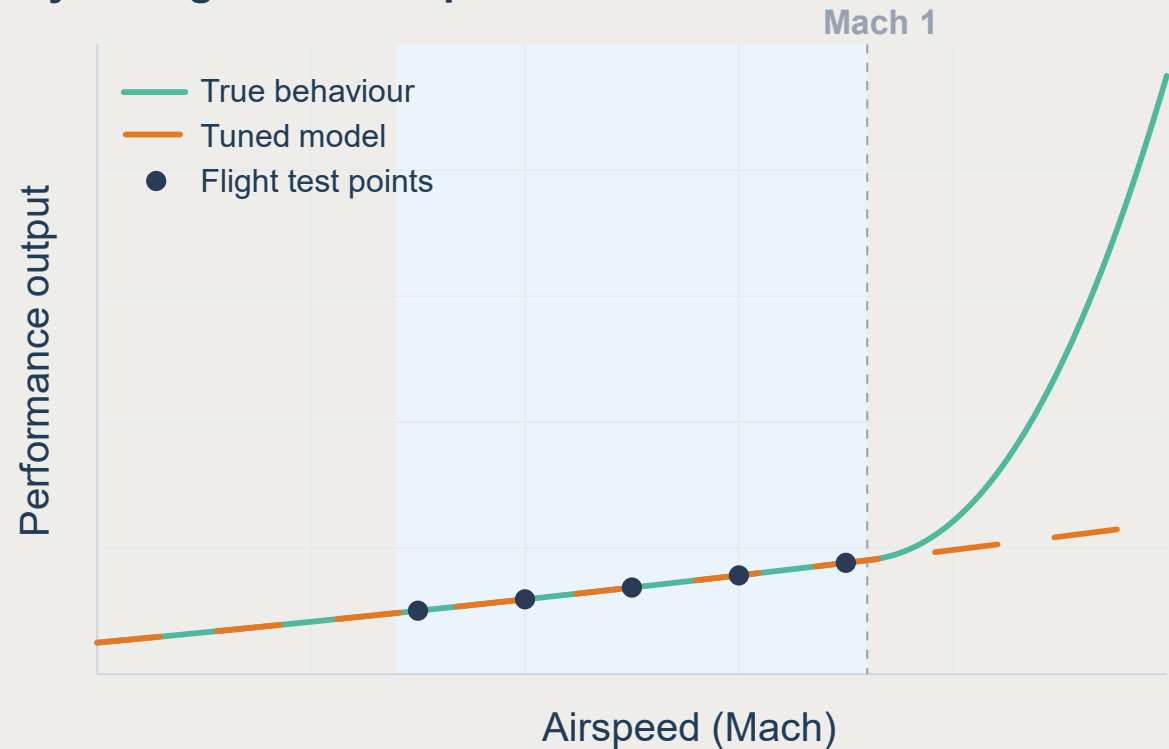
Replicate the flight-test conditions in the model and compare the outputs point by point.

⚠ Don't tune discrepancies away

Treat each discrepancy as something to diagnose. Tuning without understanding hides the key to fixing the issue. The model becomes a lookup table and the real issue remains.

Matching data points does not guarantee full envelope performance

Why tuning to the test points fails



Root-Cause Correlation

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Trace the symptom to its root

Follow each discrepancy back down the physics chain until the true physical cause is found.



Correct the cause

Fix the underlying data or assumption at its source, so the correction holds across the whole flight envelope.



Feed the fix back around

Return the corrected physics to Step 1, then re-verify and assess uncertainty and confidence at Step 2.

ROOT-CAUSE EXAMPLE Take-off field length

- **Symptom** Model over-predicts Take-off field length vs data.
- **Analyse** Thrust, drag or lift? Thrust is high confidence, so drag or lift issue most likely. Speed matches the reference, so less likely to be drag.
- **Root cause** CFD under-predicted the lift.
- **Fix** Correct the CL dataset at source

CLOSING THE LOOP · Cycle back to Step 1 with changes from Step 5

STEP 5

Root cause identified

FEED-BACK

STEP 1/2

Update model & inputs.
Re-anchor uncertainty

STEP 4/5

Re-run cases; flight test
data match improved

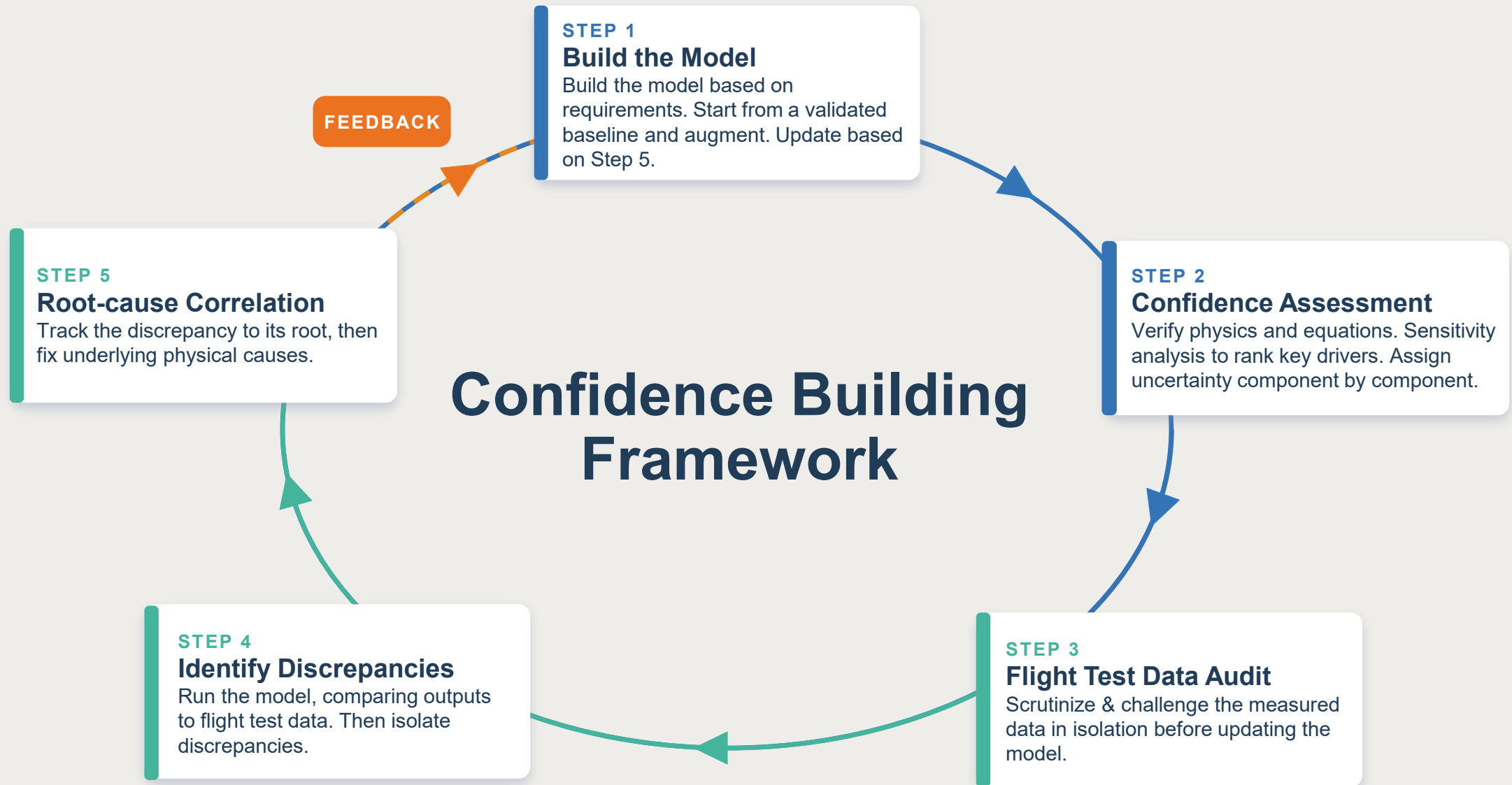


Confidence rises

How Confidence Increases

THE MODEL	CONFIDENCE BEFORE	CONFIDENCE AFTER	EVIDENCE
Physics and equations	High	High	Verified against known behaviour
Architecture and Orchestration	Medium	High	▲ Adapted from a validated baseline; assumptions corrected in-line with flight test
THE INPUTS			
Propulsion / thrust	High	High	Partially validated against bench data
Mass and inertias	High	High	Weighed components / CAD-derived
Drag (CD0, K)	Medium	High	▲ Speed during take-off matches reference data
Lift / CLmax	Low	High	▲ Correlated increase in lift with improved TOFL prediction (mean error <1%)

High confidence across the model means we have confidence in the performance prediction across the rest of the envelope, limiting need for further flight test.



Send Questions



Adam Croft

Modelling and Simulation Engineer
adam.croft@stirling-dynamics.com

Image Sources



https://images.ansys.com/is/image/ansys/aerospace-cfd-airplane-wing?wid=773&fmt=png-alpha&op_usm=0.9,1.0,20,0&fit=constrain,0

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