EUROPEAN TRANSONIC WINDTUNNEL

A New Balance for New Testing Capabilities – ETW's New Balance B010 and the Lean Secondary Roll Mechanism

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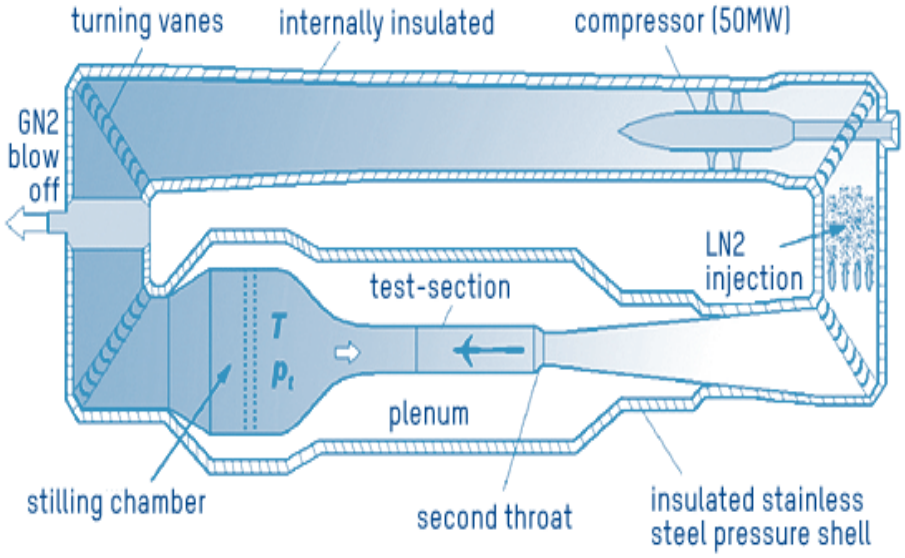
European Transonic Windtunnel

- High Reynolds-number testing facility located in Cologne, Germany
- Pressurized, cryogenic closed circuit tunnel using nitrogen as test gas
- Capable to vary pressure and temperature independently

  ➡ pure Reynolds-number, Mach-number and aerodynamic model deformation effects can be investigated separately



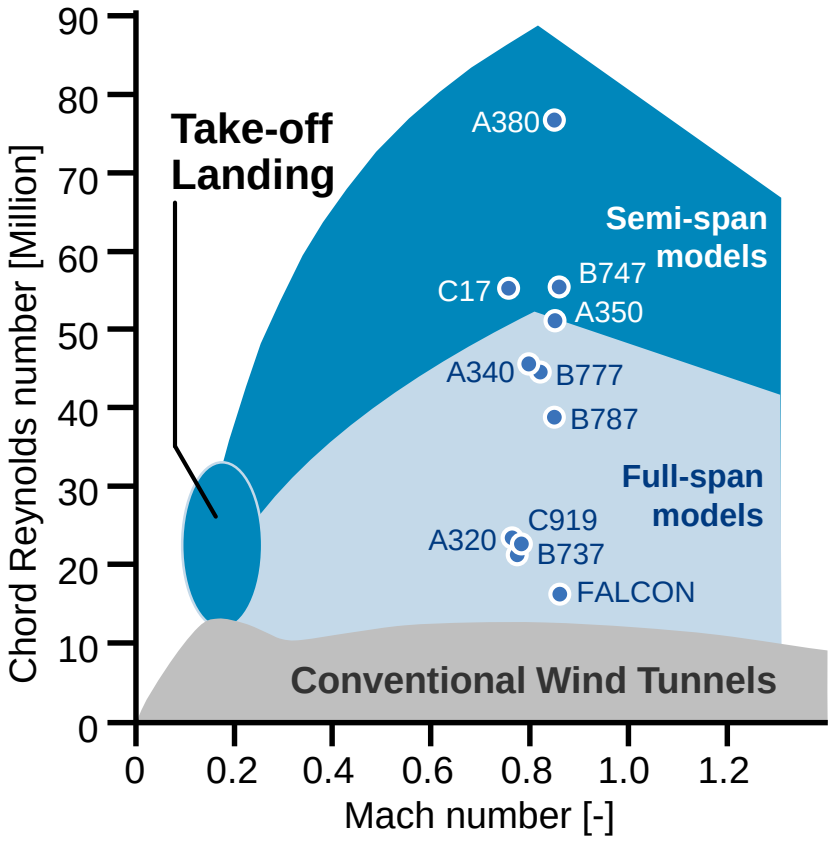
ETW Specifications and Reynolds Number Envelope

Cryogenic, Göttingen-type tunnel

Test Section	2.4 m x 2.0 m
Slotted Walls	0% - 7.4%
Mach Number	**0.15 - 1.35**
Stability	±0.0005 - ±0.0010
Total Pressure	**1.15 bar - 4.5 bar**
Stability	±0.1%
Temperature	**110 K - 313 K**
Stability	± 0.25 K

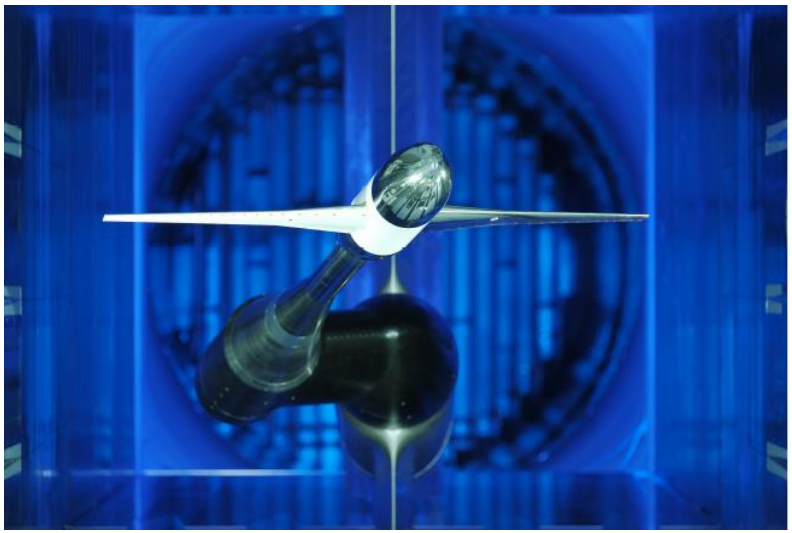
Max. Reynolds number 50 million
full-span models

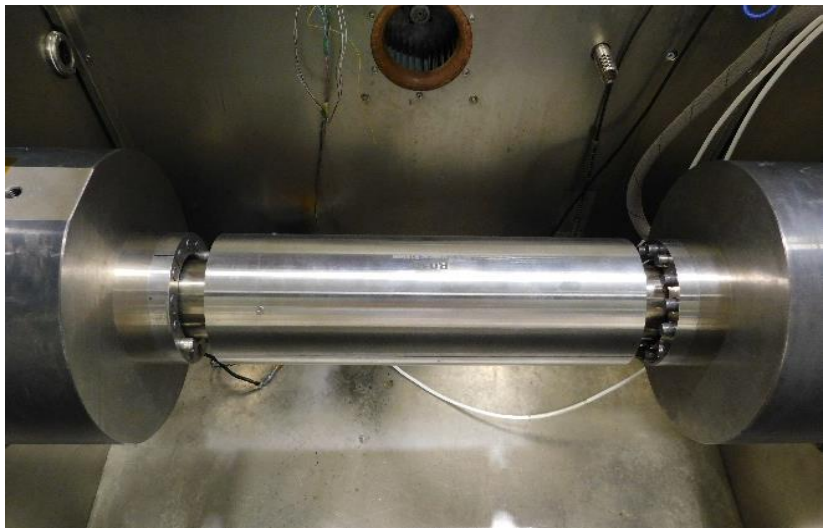
Max. Reynolds number 90 million
semi-span models



New Hardware for New Testing Capabilities

ETW is always trying to enhance its testing capabilities to offer customers a broad variety of test setups answering as many of their aerodynamic questions as possible





To add the wings level sideslip testing capability to the portfolio, ETW established two projects to develop new hardware components, the:

- **Lean Secondary Roll Mechanism (LSRM)**
- **Balance B010**

Wings Level Sideslip Testing

Motivation

Wings level sideslip testing enhances ETW's testing capabilities by the following advantages:

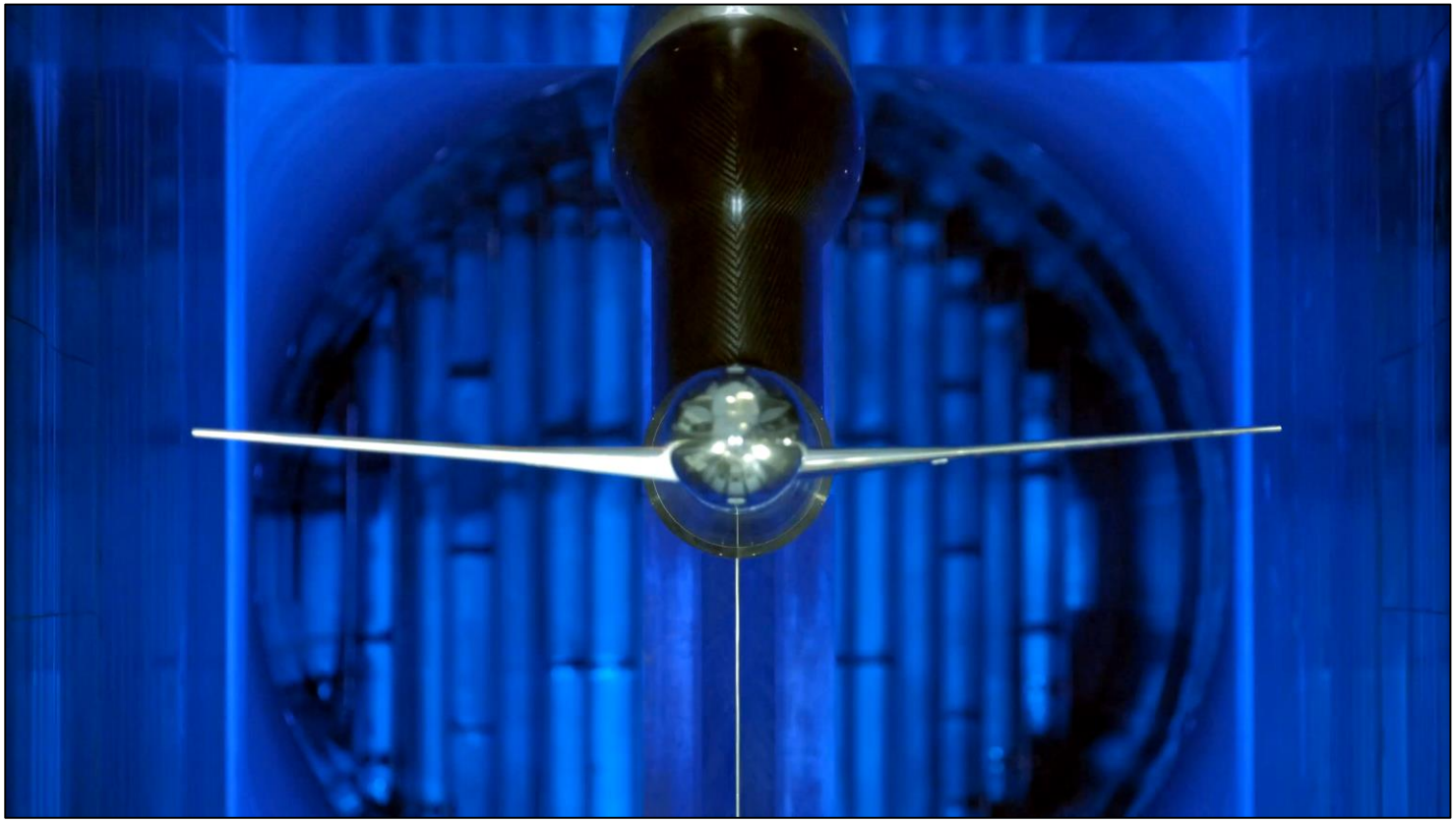
- Accurate angle of attack measurements by standard onboard measurements
- All optical measurement techniques such as TSP, PSP, or model deformation can be applied at all conditions
- Continuous angle of attack and angle of sideslip polars are possible
- Model position relative to the test section walls is well defined, leading to a better definition for the wind tunnel corrections
- Model position observation enabled with fixed camera and lighting installations

This will enable ETW to combine performance testing with handling quality testing in a very efficient manner

Wings Level Sideslip Testing

The Lean Secondary Roll Mechanism

The Lean Secondary Roll Mechanism was successfully designed, manufactured and commissioned !



The new Lean Secondary Roll Mechanism is ready for client testing !

Balance B010

Motivation

The new balance B010 enhances ETW capabilities by the following advantages:

- Measuring the characteristics of full span models supported from single sting supports over the complete operating range of ETW
- Highly accurate and repeatable measurements for performance testing
- High load range
  - In side force and yawing and rolling moment for applications with the LSRM
  - In axial force for high-lift testing at high angles of incidence

With its extended load range and high accuracy the new balance B010 enables ETW to use it in various test applications, including performance testing, and allows the use of the LSRM to its full extent.

Balance B010

Specification

- Six components strain gauges balance with two independent axial force bridges
- Operational conditions: ETW's full test envelope
- Same dimensions and interfaces as existing full model balances (e.g. B003)
- Accuracy:
  - 0.1% of the combined operating load capacity for primary components
  - 0.2% of the combined operating load capacity for secondary components
- Static combined operating load capacity (+20% dynamic loads superimposed)

• Axial Force X	± 4 000 N	(± 4800N)
• Side Force Y	± 6 400 N	(± 7680 N)
• Normal Force Z	± 26 000 N	(± 31200 N)
• Rolling Moment L	± 2 000 Nm	(± 2400 N)
• Pitching Moment M	± 1 500 Nm	(± 1800 N)
• Yawing Moment N	± 1 500 Nm	(± 1800 N)

- Infinite life duration
- Maximum stiffness
- 10 Temperature Sensor (PT100)

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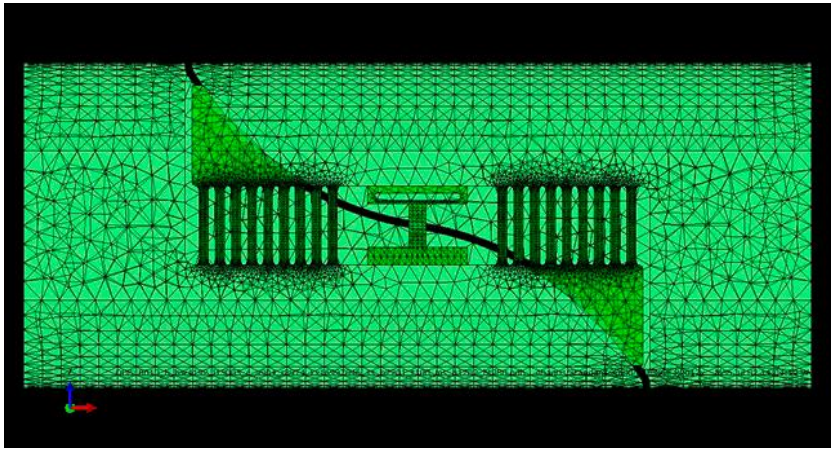
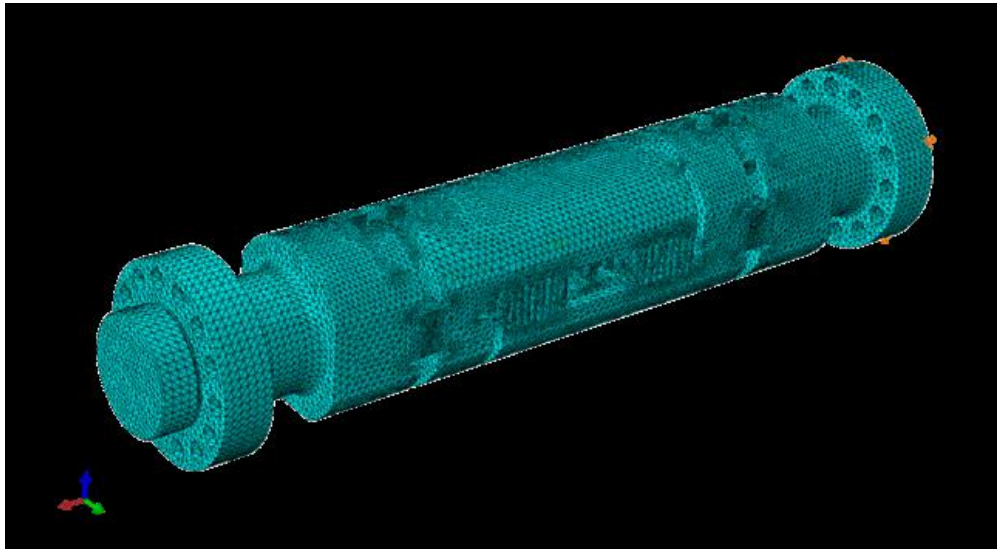
- Infinite fatigue life
- Maximum stiffness
- 10 Temperature Sensor (PT100)

Balance B010

Design and Optimization

- B010 was designed by NLR
- The midsection with axial force and rolling moment gauges was optimized using a Design of Experiments approach and a parametric Finite Element model with 9 independent design parameters
- 3 Design Of Experiments runs were performed
- Finally a detailed finite element model was developed and used to optimize the overall balance performance

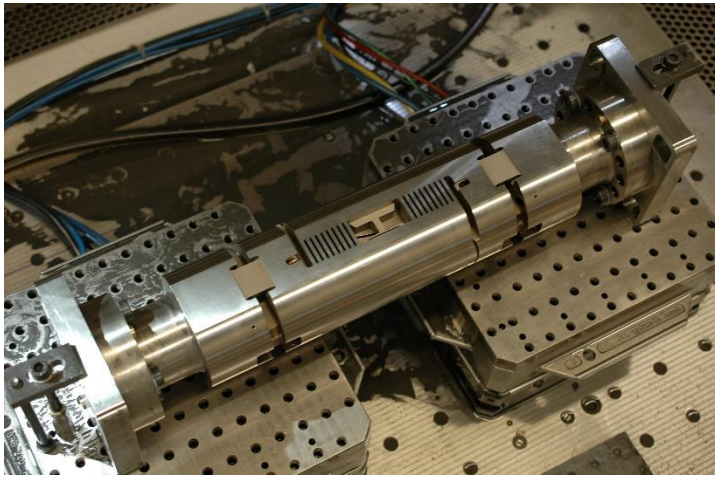


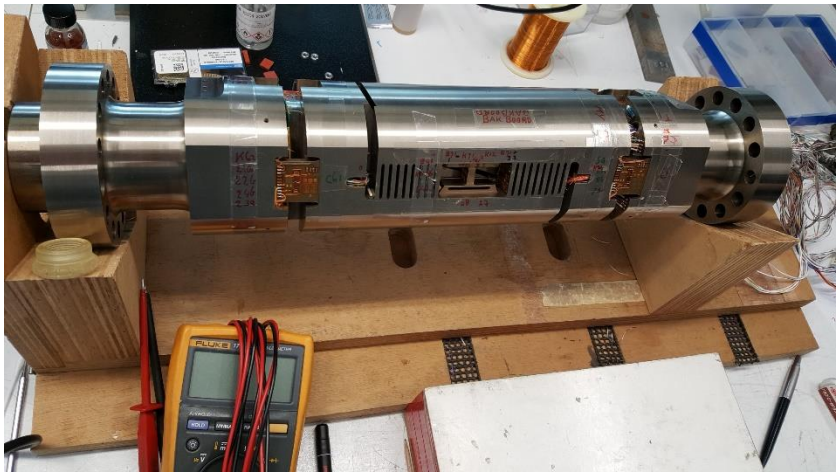


Balance B010

Manufacturing

- B010 was manufactured and instrumented by NLR
- B010 was manufactured from 250 grade maraging steel
- B010 is manufactured as one piece balance by conventional machining and spark eroding
- Pre-selected strain gauges were combined to seven temperature compensated Wheatstone bridges realized by eight strain gauges for each bridge





Balance B010

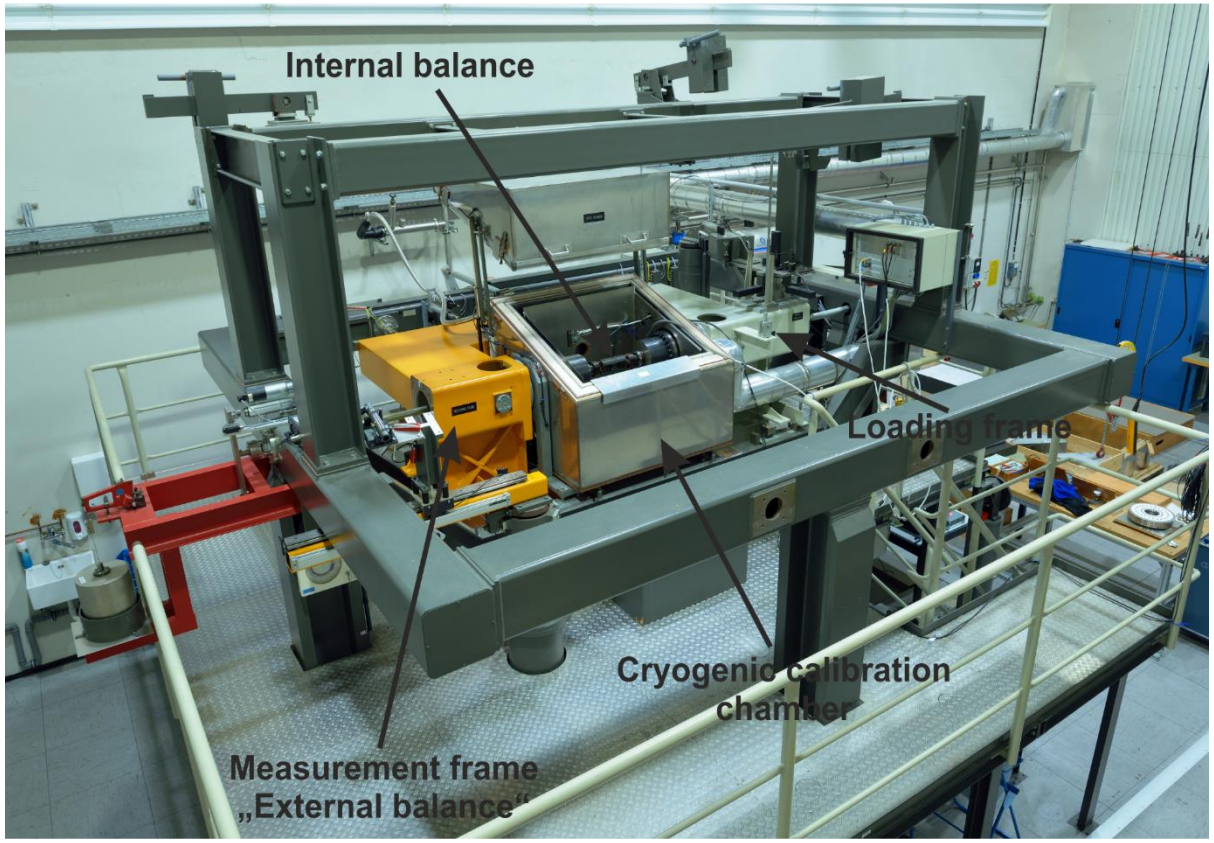
Calibration

B010 was calibrated over ETW's full temperature range using ETW's automated Balance Calibration Machine (BCM)

BCM load capacity:

- Fx = 1500 N
- Fy = 3000 N
- Fz = 25000 N
- Mx = 2000 Nm
- My = 1200 Nm
- Mz = 1000 Nm

BCM load capacity is not sufficient to calibrate B010 over its full load capacity

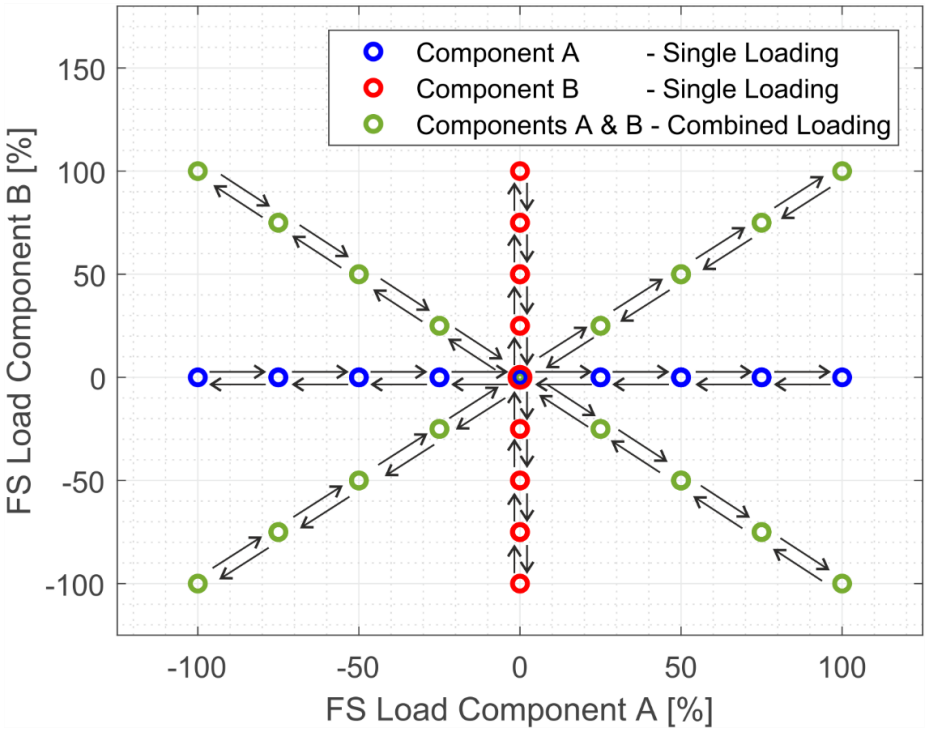


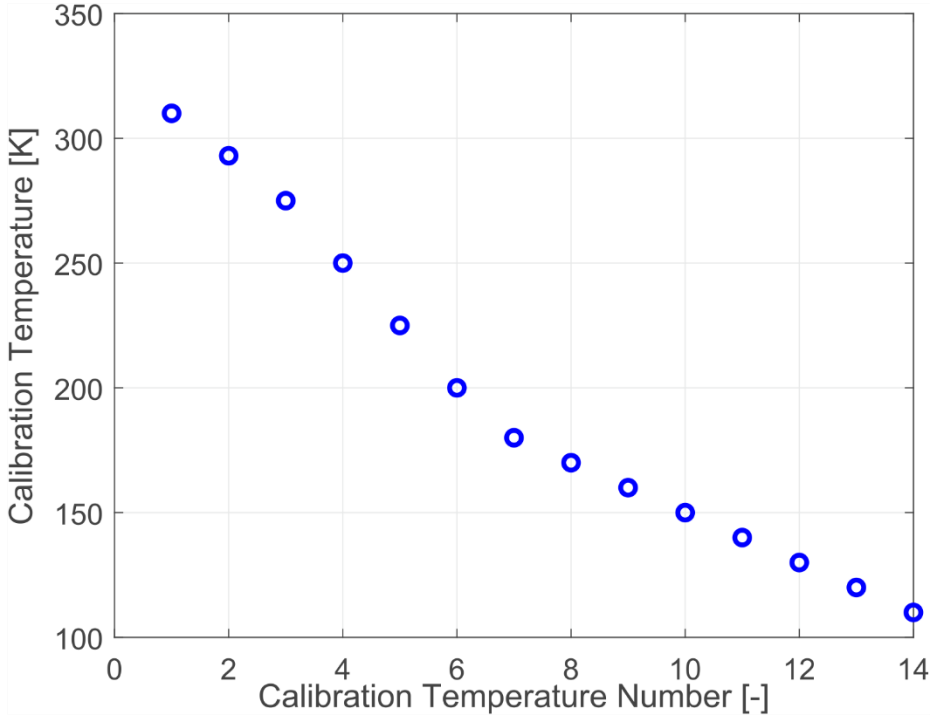
Balance B010

Calibration – Load Schedule

The calibration followed ETW's standard calibration scheme, calibrating each load component combined with each other load component over the machines full load range at discrete temperatures

- 597 calibration points at each temperature, representing 299 different load cases





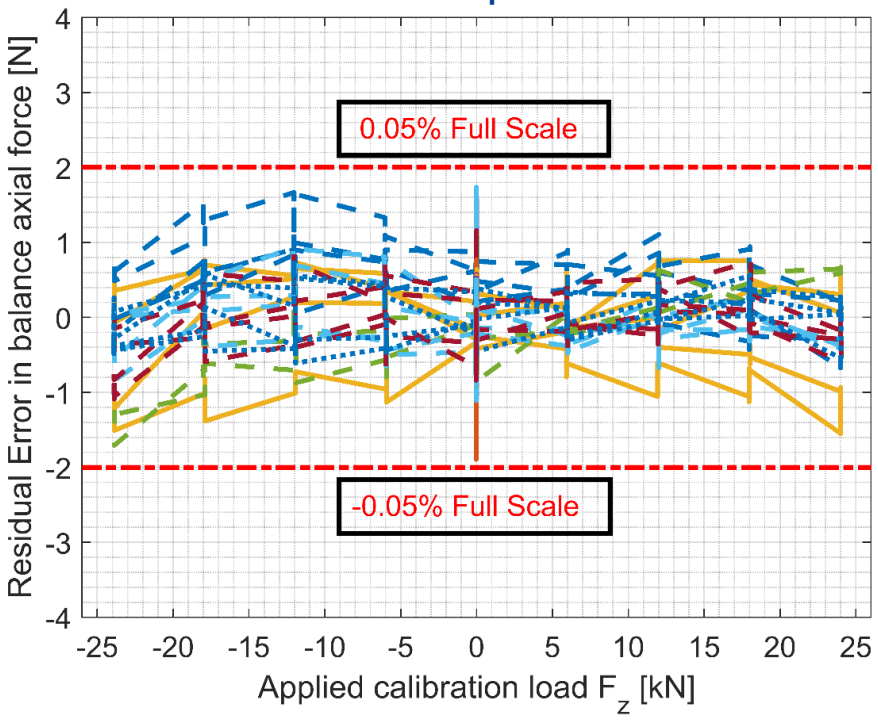
Balance B010

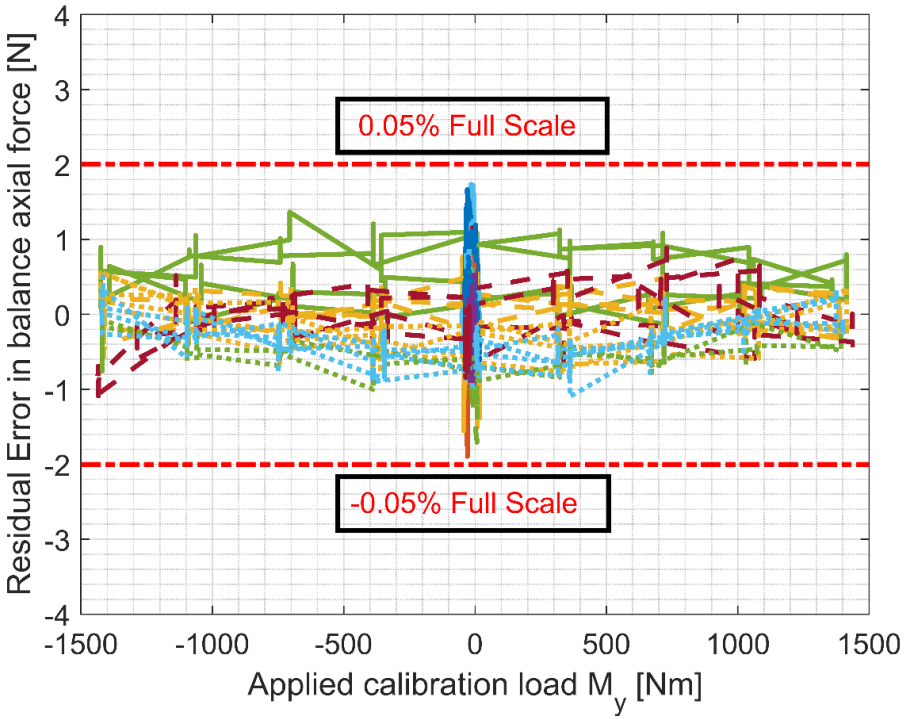
Calibration – Calibration Results

The calibration validated the high accuracy of the balance:

- All residual errors for all balance components are clearly below ± 0.1% of full scale loads
- All bridges show a reproducible trend over temperature

Example calibration result for all load cases at 110 K

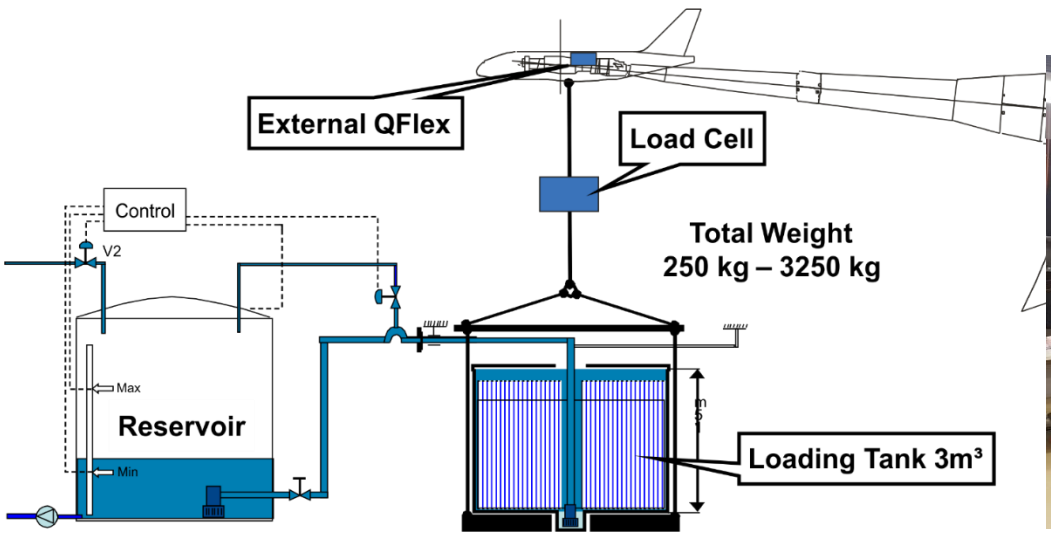


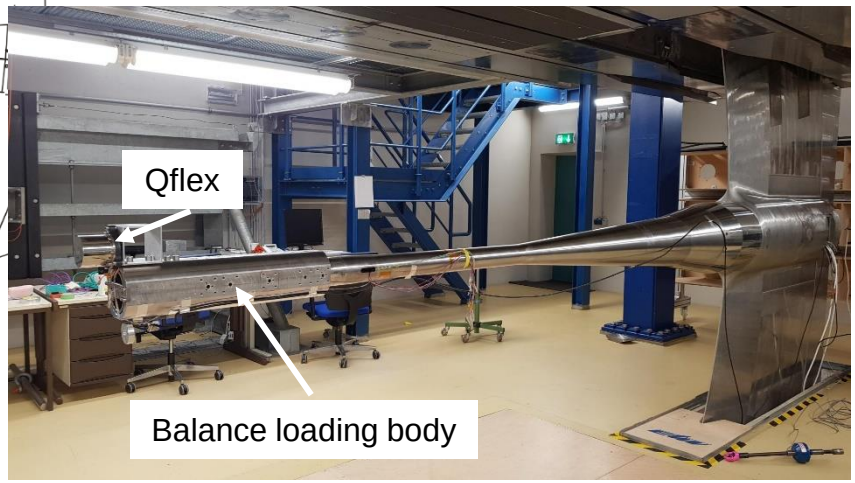


Balance B010

Commissioning

- Check and validate the calibration by dead weight loading up to the calibrated loads under ambient conditions
- Apply multi-component load cases for validation
- Extend dead weight loading for all components up to the maximum balance capacity to verify and extend the validity of the balance calibration
- Perform wind-on commissioning test to investigate the overall balance performance under cryogenic, pressurized conditions

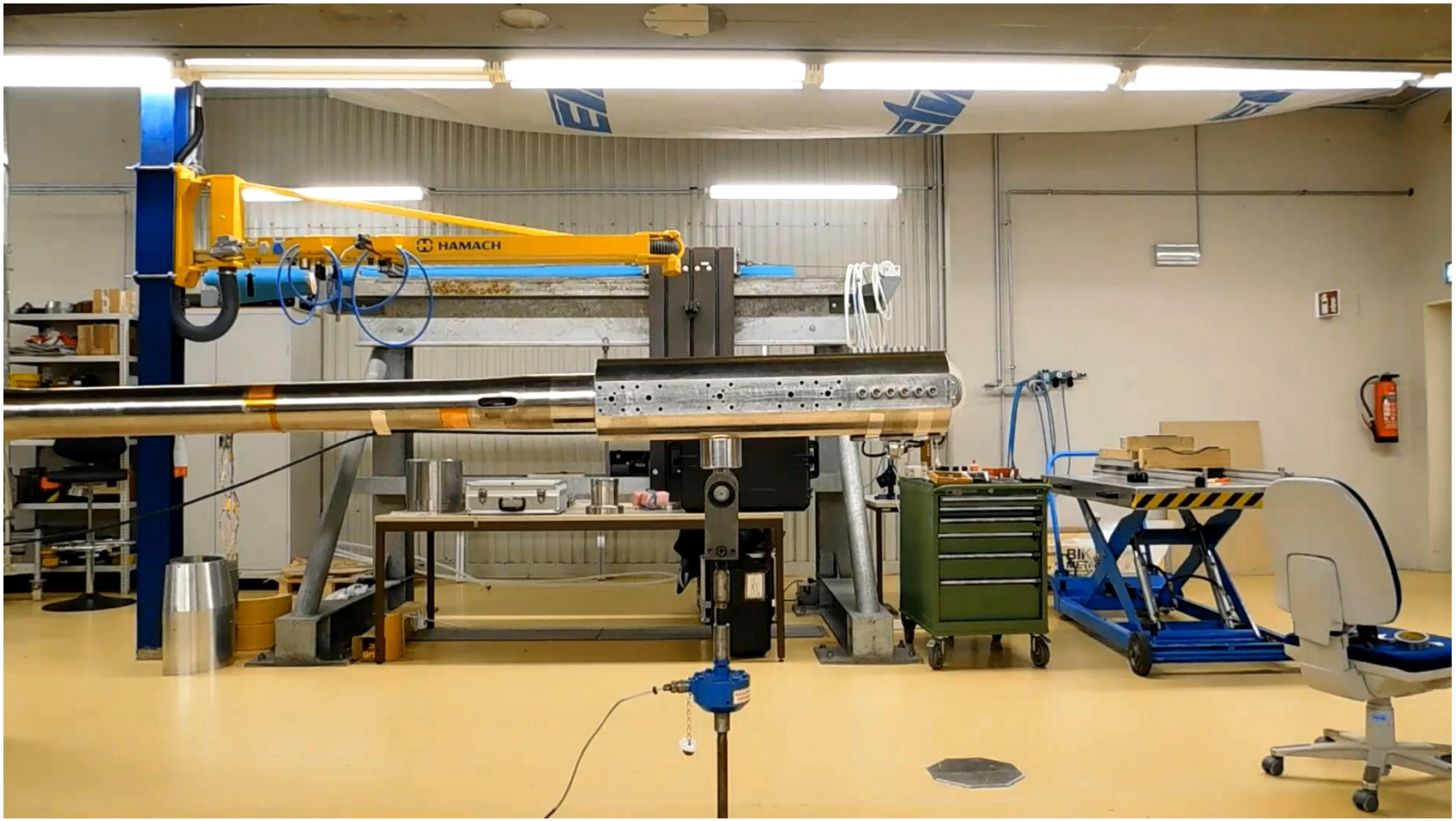




Balance B010

Dead Weight Loading

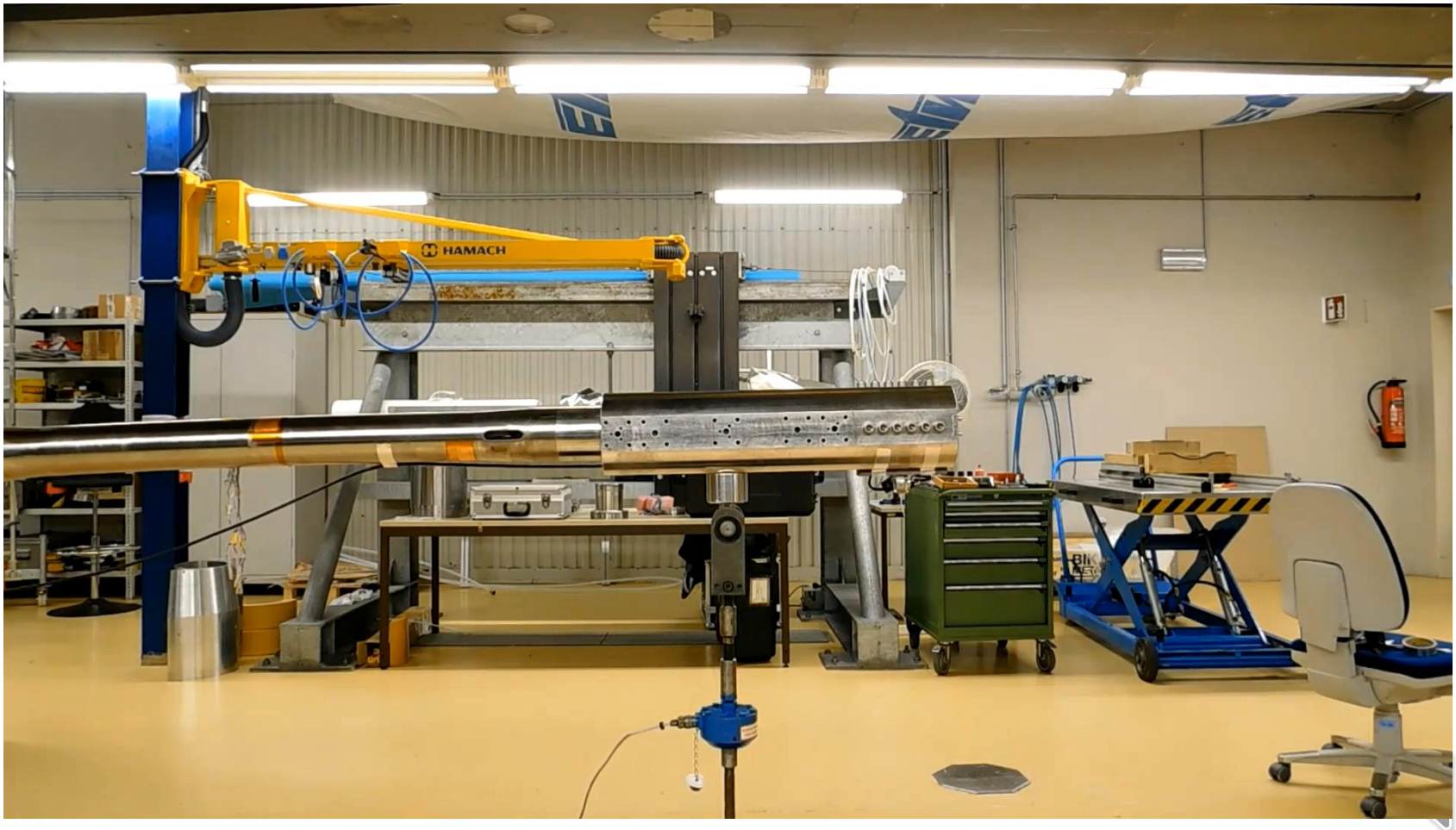
Normal force loading up to 29 kN



Balance B010

Dead Weight Loading

Pitching under normal force load of 29 kN



Summary

ETW enhanced its testing capabilities by new hardware components:

- ETW developed and already successfully tested the Lean Secondary Roll Mechanism (LSRM)

New capability: Wing level sideslip testing, allowing continuous sideslip polars

- The new balance B010 was designed, manufactured and successfully calibrated and is currently being validated in a final commissioning loading check

New capability: High-lift and edge of envelope testing in conjunction with the LSRM with load capacity reserve

- Next step is to combine LSRM and balance B010 for a high-lift full model test, to validate the overall performance of the two new hardware components to their full extent