Accelerating the future of aerospace

Wind tunnel modelling and testing

CS2/DEP-SFD - GA 945583

One Model. One Moment. Total Confidence.

When an aircraft model enters a wind tunnel, it's a decisive step in development. Years of development, simulation and numerical analysis are about to face measurable reality.

NLR ensures every campaign is carefully prepared and executed. Wind tunnel models are custom-made, combining aerodynamic fidelity, structural integrity, and measurement accuracy. NLR delivers high-quality models with decades of experience, refined processes, and multidisciplinary expertise. NLR enhances testing with advanced measurement techniques, such as flow visualisation and acoustics, precision custom load balances, and tailored remote control and data-acquisition systems. Its materials expertise spans composite components, metal 3D-printed parts, and propeller blade manufacturing. Smart test design and simulation reduce risks before testing begins. These models are not just built — they are built to perform.

NLR's services are independent of specific wind tunnels. We collaborate with DNW to execute campaigns efficiently. Our collaboration ensures smooth project execution and yields efficient programmes that provide valuable data for next-generation aircraft.

What sets NLR apart is the wealth of in-house knowledge and the unique combination of our specialists, our high-precision machining department, and the ability to utilise various testing facilities. Our expertise enables us to deliver high-quality models, making us a unique partner for wind tunnel testing.

WIND TUNNEL TEST PREPARATION

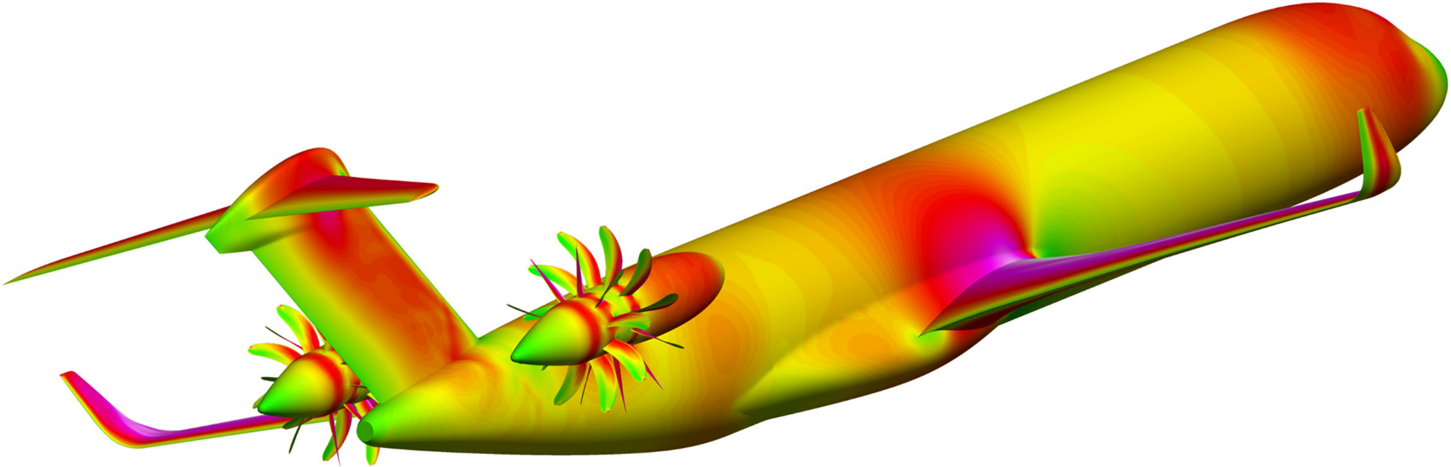
For wind tunnel testing, high quality wind tunnel models are essential. NLR specialises in designing and manufacturing the world's most advanced wind tunnel models. These models are required for complex tests, accurate measurements, and efficient testing. They often include sophisticated instrumentation and require precise manufacturing according to predefined geometries. The models must also meet strict safety regulations applicable to test facilities.

Numerical simulation of wind tunnel models and test set-ups

Structural numerical simulations are used early in the design process to ensure wind tunnel models can withstand aerodynamic loads during wind tunnel testing. This includes verifying the strength of strain gauge balance designs and drive trains with shafts, bearings, and gears under vibrations and dynamic loads. These numerical simulations help prevent model failure and potential damage to the wind tunnel facility, reducing costly downtime. Structural optimisation is also applied to improve designs, such as maximising the stiffness of strain gauge balances while meeting measurement requirements and safety factors for material strength.

Examples of structural simulation and optimisation supporting wind tunnel test design are:

- MODAL ANALYSIS OF A WIND TUNNEL MODEL WING VALIDATED BY MODAL TESTING
- PARAMETRIC DESIGN AND OPTIMISATION OF STING BALANCES
- TOPOLOGY OPTIMISATION OF A ROTATING SHAFT BALANCE
- CORRECTION OF UNDESIRED STING BALANCE BRIDGE OUTPUT DUE TO THERMAL EFFECTS USING THERMAL MODAL ANALYSIS
- ELECTRICAL CABLE MODELLING AND SIMULATION TO DETERMINE THEIR INFLUENCE ON STING BALANCE BRIDGE OUTPUTS
- WIND TUNNEL MODEL BLADE ANALYSIS
- AEROELASTIC WIND TUNNEL MODEL DESIGN
- ROTOR DYNAMIC ANALYSIS OF DRIVE TRAINS
- STATIC AND FATIGUE ANALYSIS OF GEAR AND SPLINE TEETH IN DRIVE TRAINS
- STATIC ANALYSIS OF WIND TUNNEL FLOOR DESIGN TO VERIFY ITS CAPABILITY TO CARRY HEAVY LOADS



Wind tunnel model design

Custom load balances

NLR specialises in developing customised load balances for wind tunnel models that require extremely high accuracies. These load balances are crucial for measuring forces and moments acting on the model during a test. Manufacturing a load balance involves several steps that can be time-consuming, costly, and risky. We design and develop custom load balances entirely in-house, from concept to commissioning, including calibration.

Together with our calibration facility we are able to optimise load balance sensors for various real-life measurement scenarios. This ensures precise data from test campaigns and allows us to help our partners generate accurate and reliable data from their wind tunnel tests.

REMOTE CONTROL

Some wind tunnel test facilities can be expensive to operate. To minimise time spent on model configuration changes, NLR can offer a solution using remote controls, which greatly improves test efficiency. Remote controls enable quick adjustments to control surfaces, tilting wings, and engines. NLR has a strong track record with remote controls and can advise on whether they will help reduce overall project costs.

Data acquisition systems for wind tunnel models

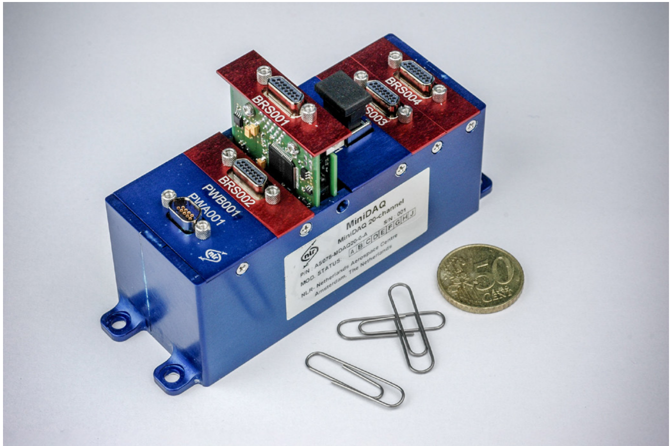
The increasing demands of customers drive innovation in Data Acquisition (D/A) systems for wind tunnel models. This includes delivering sensor data with higher spatial resolution, accuracy, and bandwidth. Wind tunnel operators typically see a doubling of data volumes every 18 months. To achieve optimal performance, D/A systems must amplify small electrical signals near sensors to maximise signal-to-noise ratio and buffer them for transmission to external measurement systems. Additional features like analogue filtering and analogue-to-digital conversion may be required. When mounting D/A systems onboard wind tunnel models, miniaturisation and mechanical integration are crucial due to limited space. NLR offers a range of solutions for embedded D/A systems based on proven precision electronic circuitry, tailored to specific applications and the available space inside the model.

Data from rotating A/D systems is typically combined with sensor data from other model locations and external measurement systems. This may include, for example, high-bandwidth signals from aerodynamic and aeroacoustic pressure sensors and dynamic strain gauges. The resulting datasets, which can exceed multiple terabytes per hour during wind tunnel tests, may require dedicated high-speed computer networks for processing, storage, and visualisation. NLR can provide these networks, which can include separate subnets for independent real-time data analyses. We also offer the necessary software and computer network infrastructure to support our customers' needs.

Fuselage mounted D/A systems for small wind tunnel models	**Small high-speed rotating D/A systems**	**Complex rotating D/A systems**	**Many high-bandwidth sensors in combination with high rotational speeds**

FUSELAGE MOUNTED D/A SYSTEMS FOR SMALL WIND TUNNEL MODELS

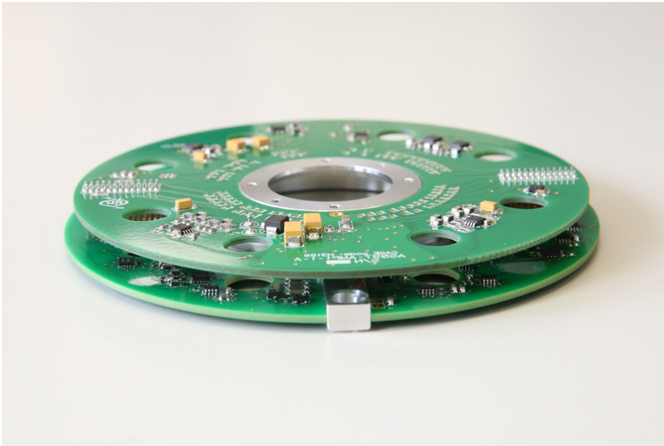
For small wind tunnel models, NLR offers MiniDAQ, a modular miniature D/A system. This is ideal when commercial systems are too large or offer insufficient performance. MiniDAQ has four sensor modules with five measurement channels each, supporting various sensors like strain gauges, thermosensors, and potentiometers. A sensor excitation voltage is available per module. The unit requires a 24V DC power supply and features a 100Mbps fibre-optic Ethernet data output. Its compact size (100x41x40mm) makes it especially suitable for small wind tunnel models.



SMALL HIGH-SPEED ROTATING D/A SYSTEMS

For wind tunnel models with very limited space in the rotating parts, NLR uses small circular printed-circuit boards with precision D/A circuitry. These boards are mounted around the rotating shaft and provide signal amplification, buffering, and excitation voltage for sensors. They also generate a synchronisation signal for sensor data and the propeller blade position.

The robust design allows for rotational speeds of over 10,000 rpm. These systems are typically used for measuring strain gauges on rotary shaft balances or propeller blades, often with temperature sensors for calibration and safeguarding. The analogue outputs are routed to external equipment via onboard slip rings for further processing.



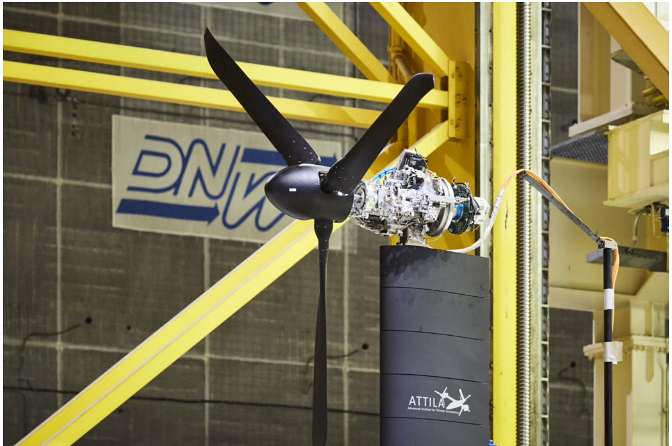
COMPLEX ROTATING D/A SYSTEMS

NLR offers sophisticated rotating D/A systems for larger wind tunnel models with more space in the rotating parts. These systems are ideal for blade deformation measurements, for example, tilt-rotor models, as well as other sensor data.

The system can acquire around 50 analogue sensor signals and data from six fibre-optic channels using fibre Bragg gratings. The data is time-stamped and aggregated into a single 100 Mbps Ethernet stream for external processing. Data transfer from the rotating to stationary domain can be done via a dedicated slip ring or contactless transfer module. A synchronisation signal is also provided for precise data alignment.

MANY HIGH-BANDWIDTH SENSORS IN COMBINATION WITH HIGH ROTATIONAL SPEEDS

For the most demanding wind tunnel model applications, NLR delivers dedicated D/A systems. These are highly integrated miniature measurement modules embedded in rotary parts, such as turbine rotors. They can withstand high rotational acceleration (>20,000 g) over a wide temperature range. The latest versions feature over 100 wideband sensors in the rotating domain. These D/A systems include NLR's patented contactless transfer mechanism for power and data, transmitting measurement data through a single 1 Gbps optical fibre. This solution is wear-insensitive, provides excellent signal integrity and electromagnetic compatibility (EMC), and eliminates ground loops.



Wind tunnel model design

Propeller blade design and manufacturing

Propeller blades must be strong enough for wind tunnel testing. Composite materials are often ideal for scaled blades, but metal blades may be preferred in some cases. It is crucial to understand the mechanical behaviour before testing. NLR's design process covers everything from conceptual design to detailed stress analysis of the final blade structure.

NLR has state-of-the-art facilities for working with composite materials, as well as high-precision machining or metal additive manufacturing (AM) of titanium and other high-strength metals.

- » MULTI-DISCIPLINARY DESIGN OPTIMALISATIONS, INCLUDING ACOUSTIC ASPECTS AND FLUID STRUCTURE INTERACTION (FSI)
- » FLUTTER SCREENING AND STUDY POTENTIAL VIBRATIONAL ISSUES
- » TESTING NEW (COMPOSITE) MATERIALS
- » INTEGRATION OF EXTENSIVE INSTRUMENTATION IN THE BLADES LIKE STRAIN GAUGES, KULITES, LED'S OR HEATING SYSTEM
- » GEOMETRY INSPECTION OF THE BLADES AND (NON-)DESTRUCTIVE ANALYSIS
- » ADVICE ON THE TRADE-OFF FOR THE MATERIAL OF CHOICE

Dynamically and aeroelastically scaled wind tunnel models

For dynamically scaled models, the mass distribution is designed to replicate the dynamic behaviour of the full-scale reference object. Aeroelastically scaled models require both the mass distribution and stiffness to be representative, whilst adhering to wind tunnel strength and safety requirements.

Typically, they consist of a load-carrying spar and skins with an internal foam core. Non-structural masses can be added to tune the mass distribution and centre of gravity. Detailed Finite Element Method (FEM) analyses are performed to determine stiffness properties and achieve the required values.

The models can be instrumented with embedded strain gauges and/or optical fibres to monitor bending and dynamic behaviour during wind tunnel tests.

Metal additive manufacturing

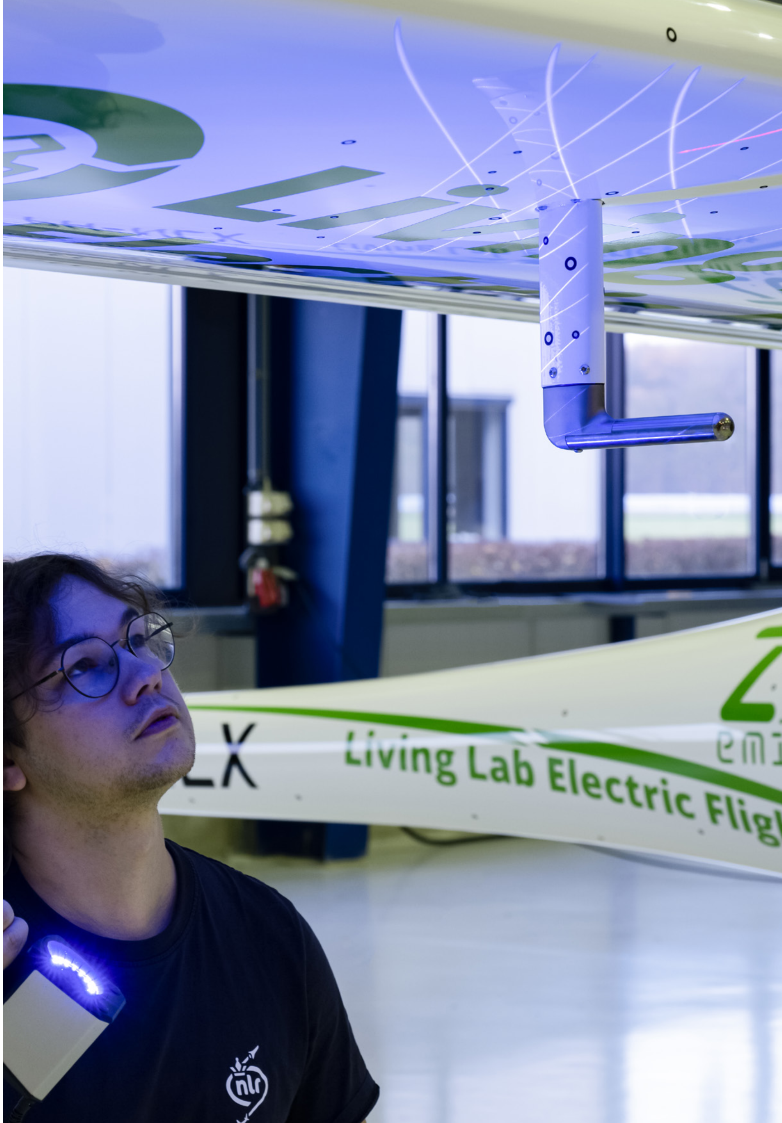
NLR-MAMTeC is the independent Metal Additive Manufacturing Technology Centre in the Netherlands. As part of NLR, it utilises over 50 years of materials experience in aerospace applications to drive technology development and product innovation. Metal 3D printing is useful for making wind tunnel parts. These benefit from the design freedom and reduced lead times that metal AM offers. Complex internal geometries can be made for sensor integration, air supply, lubrication or cooling. We use computer models and simulations to improve metal 3D printing. Design tools, including topology optimisation, are applied to maximise benefits. NLR's thermomechanical simulation expertise predicts thermal variations, residual stresses and deformations, enabling first time right production with high accuracy.

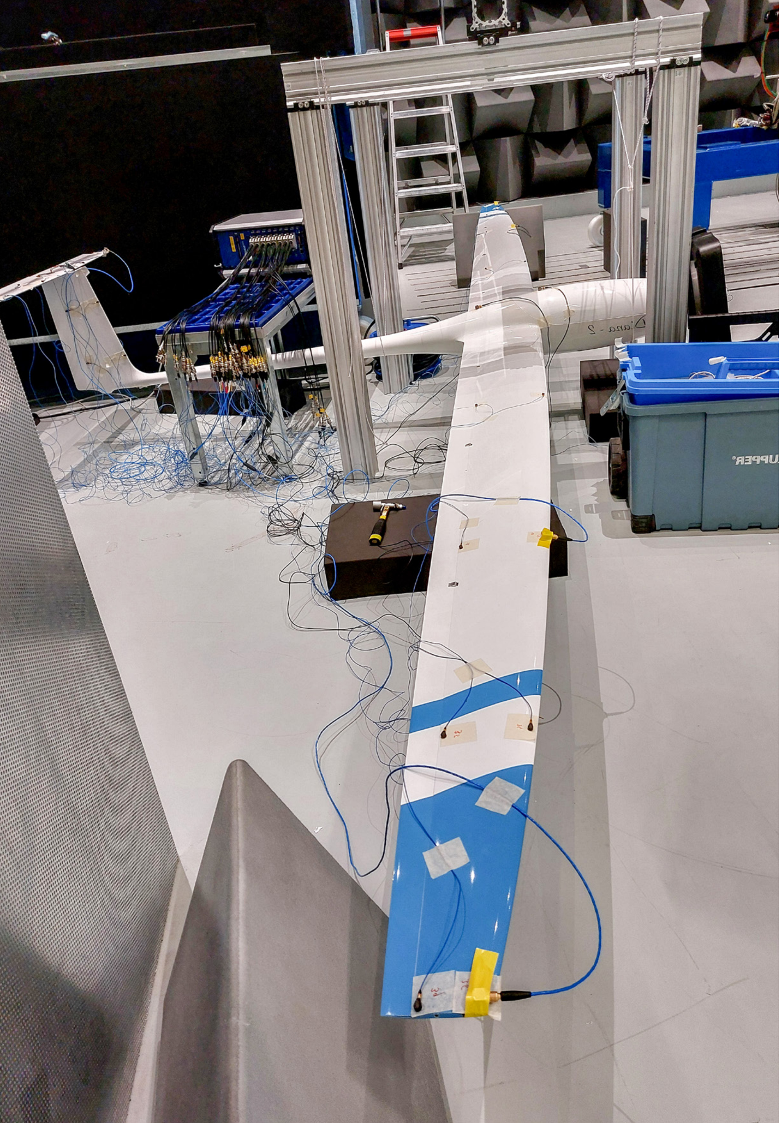
Model geometry inspection

NLR offers optical 3D scanning facilities for inspecting wind tunnel model geometry.

Our optical 3D scanning facility can:

- CAPTURE COMPLETE MODEL ASSEMBLY, INCLUDING INTERNAL AND EXTERNAL GEOMETRY
- ANALYSE AEROFOIL PROFILES FROM PROPELLER BLADES, ROTOR BLADES, AND WINGS, INCLUDING THEIR ALIGNMENT AND POSITION.
- PERFORM PROFILE FORM AND POSITION ANALYSIS OF WING SECTIONS AND PROPELLER OR HELICOPTER BLADE SECTIONS.

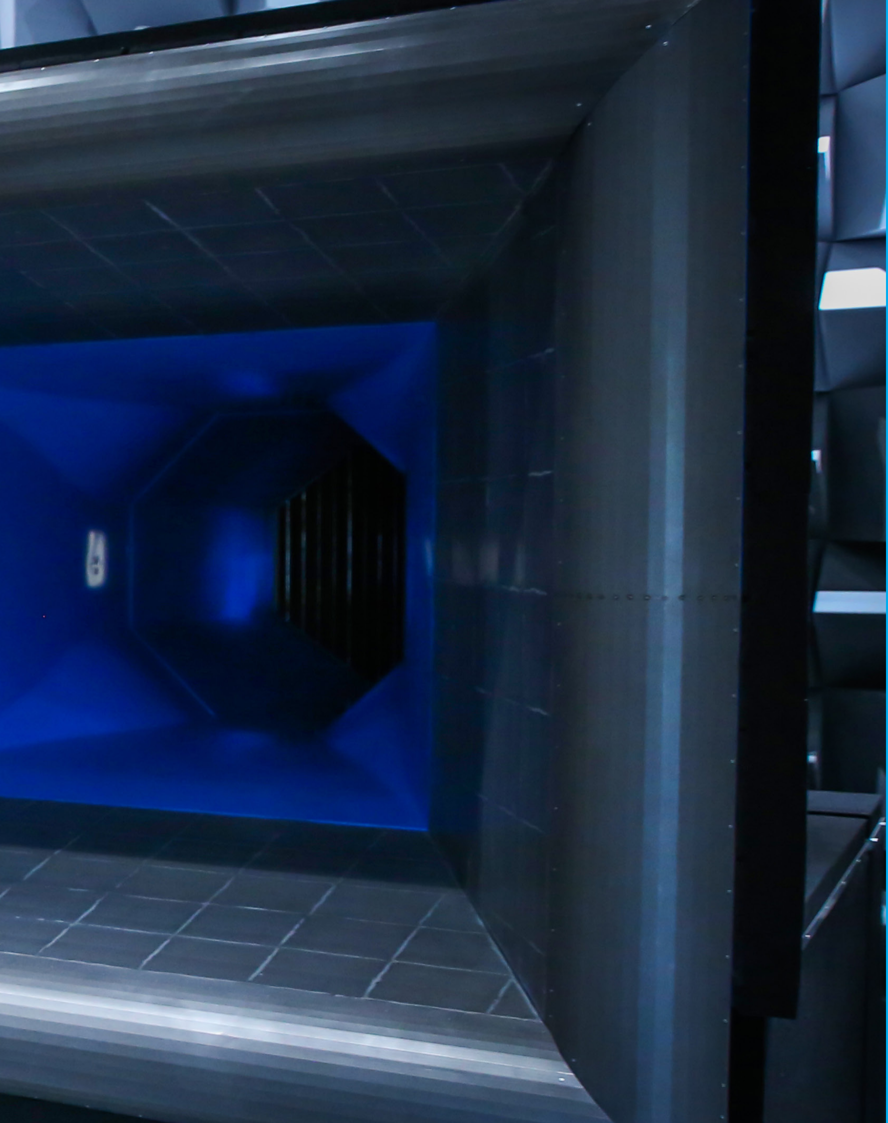




Ground vibration testing

NLR performs Ground Vibration Testing (GVT) on wind tunnel models to validate structural dynamics and flutter predictions. The goal is to identify natural frequencies, determining mode shapes, and calculate damping ratios. GVT ensures accurate model behaviour, validates computational models, and optimises design for safety and efficiency, reducing the risk of structural failure. GVT makes use of stick-on accelerometers and is a practical, non-intrusive approach that quickly measures modal parameters without significant model modifications.

NLR can also offer optical particle tracking methods, such as Digital Image Correlation (DIC). This is a highly effective method to accurately identify natural frequencies and reconstructing mode shapes. It provides non-contact, full-field measurements, overcoming issues with mass-loading effects.



WIND TUNNEL TEST EXECUTION AND ANALYSIS

This phase involves conducting wind tunnel experiments, data processing and analysing the data from test campaigns. NLR can support each step, leveraging its expertise in advanced measurement techniques and data processing capabilities.

NLR has extensive experience and a long track record in coordinating wind tunnel tests. We assist in defining test programmes, including the development of test plans and procedures, to ensure that the desired data is collected efficiently and effectively. Our expertise also extends to supporting model manufacturing, specifying the required wind tunnel equipment and instrumentation, and coordinating the wind tunnel test itself, ensuring that all aspects of the test are carefully planned and executed to deliver high-quality data. With experience in aerodynamic, aeroacoustic, and icing wind tunnel testing, NLR can also set up test programmes to demonstrate compliance with certification or qualification requirements.

Advanced measurement techniques

WIND TUNNEL CORRECTIONS

NLR can correct wind tunnel data for the effects of the wind tunnel itself, allowing the data to be considered as if measured in a 'free field'. This enables comparison with simulated results or other experimental data. NLR can apply these corrections to both aerodynamic and acoustic wind tunnel data.

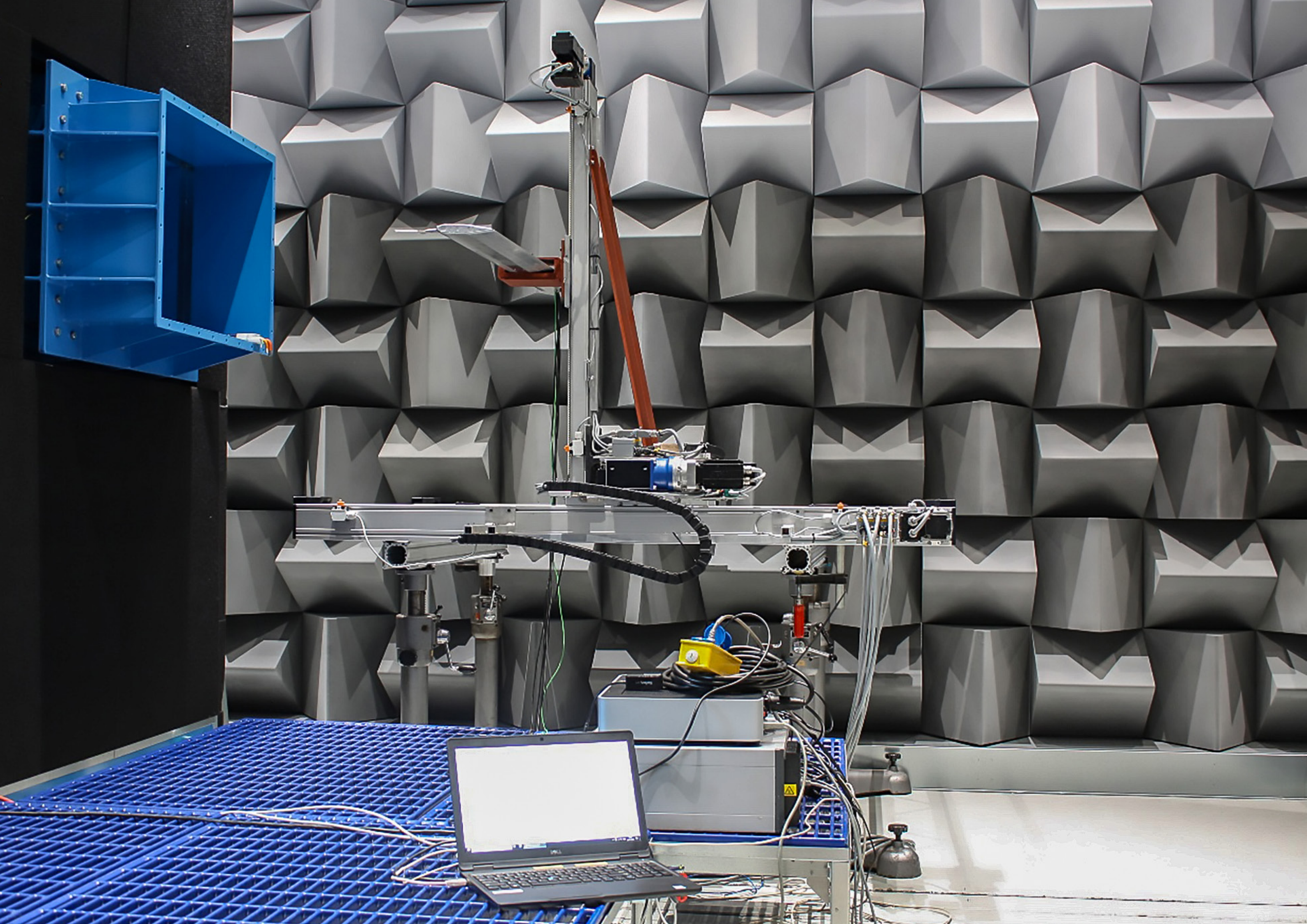
ADVANCED FLOW MEASUREMENTS

Tracer particle flow measurements provide quantitative information on multiple flow components, resulting in a vector flow field. This technique can yield results in either thin slabs or 3D volumes around wind tunnel models.

PARTICLE IMAGE VELOCIMETRY

Particle Image Velocimetry (PIV) is an optical technique that quantifies fluid flows by tracking particle movement within the flow. It enables flow visualisation and analysis of complex flow phenomena.

NLR uses High Speed PIV to capture flow dynamics with a field of view of up to 15cm x 15cm at an acquisition rate of 1kHz. Additionally, Large Scale PIV with Helium Filled Soap Bubbles allows analysis of flow patterns over larger areas (up to 1m x 1m), providing insights into complex flow phenomena. This technique is useful for studying flow topology over large models in commercial wind tunnels and investigating flow climates around ships for helicopter and drone safety.



SURFACE DRAG MEASUREMENTS

NLR uses a specially designed drag balance to directly measure the aerodynamic drag force of surface materials. This is used to minimise aerodynamic resistance of acoustic liner panels or to study the effect of surface adaptations and material roughness on drag. The balance can accommodate samples of 10-100cm long and is calibrated for loads at flow speeds of up to Mach 0.8 at the NLR Flow Duct Facility (FDF).

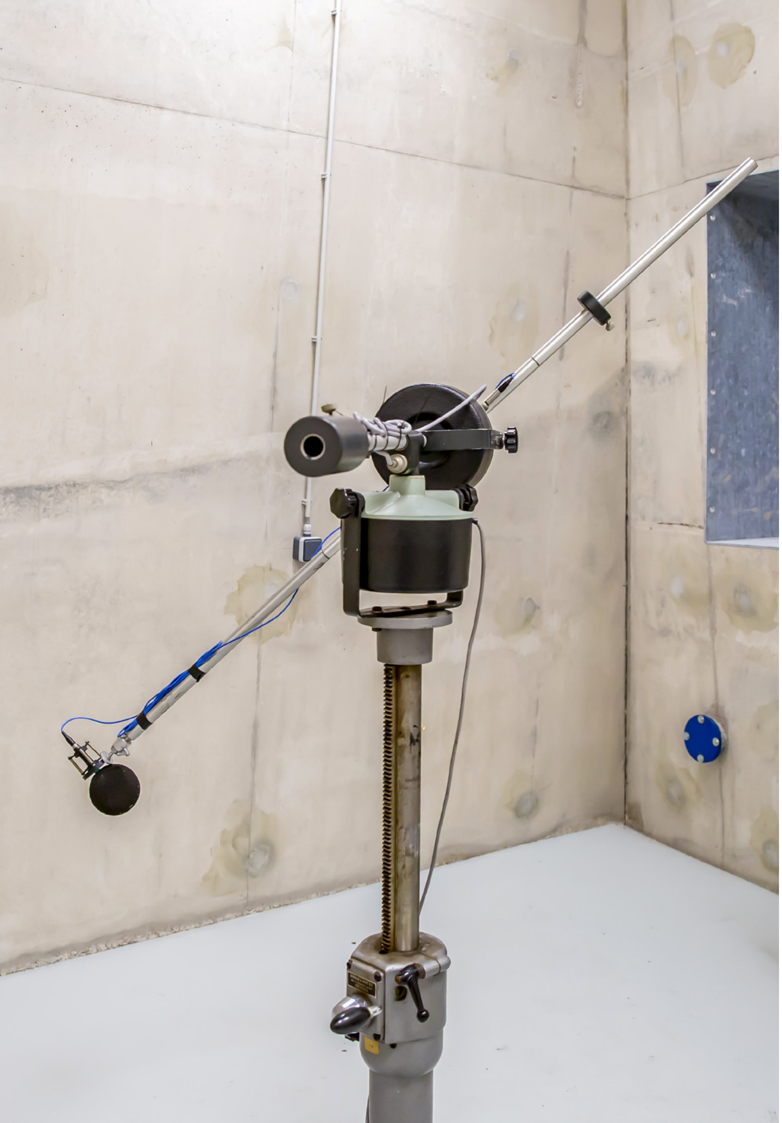
HOTWIRE MEASUREMENTS

Hotwire anemometry measurements allow for the evaluation of three-dimensional flow velocity fluctuations (x, y, and z) at frequencies up to 10kHz. This technique uses hotwire probes with extremely thin electrical wires (typically 5μm in diameter) positioned within the flow. By analysing the heat dissipation from these wires, the local velocity at the probe can be determined. The hotwire method is a well-established approach for measuring low turbulence levels, enabling the quantification of free-field disturbances even in empty test sections. It is commonly used to assess turbulence around models and within boundary layers.

Advanced acoustic measurements

ADVANCED ACOUSTIC SOURCE LOCALISATION

NLR specialises in advanced aeroacoustic measurements. Beamforming methods using phased microphone arrays allow for the localisation of acoustic sources on the wind tunnel model. We go beyond traditional beamforming methods by supporting advanced deconvolution techniques that can handle complex measurements, such as rotating source beamforming and distributed sources. Furthermore, NLR has developed a proprietary 3D deconvolution method using tomographic reconstruction, enabling precise 3D mapping of acoustic sources. We also offer methods to translate acoustic wind tunnel data into sound levels of airborne aircraft as perceived by an observer on the ground, which enables a more accurate understanding of real-world noise levels. We can also do this for prescribed certification envelopes.



Acoustic liner measurements

LINER INSERTION LOSS MEASUREMENTS

Acoustic liners are sound-absorbing materials used in aircraft engines to reduce noise pollution. To assess their performance, Insertion Loss measurements can be conducted in the NLR-FDF. Sound is generated in reverberant rooms, creating a homogeneous sound field. Sound levels are then measured in both upstream and downstream reverberant rooms, with microphones on rotating beams providing spatial averaging for low frequencies. Measurements are taken with and without the liner to evaluate its effectiveness, expressed as insertion loss, under various grazing flow conditions at speeds of up to Mach 0.8. These measurements support the development of more efficient acoustic liners for quieter aircraft.

LINER IN-SITU IMPEDANCE MEASUREMENTS

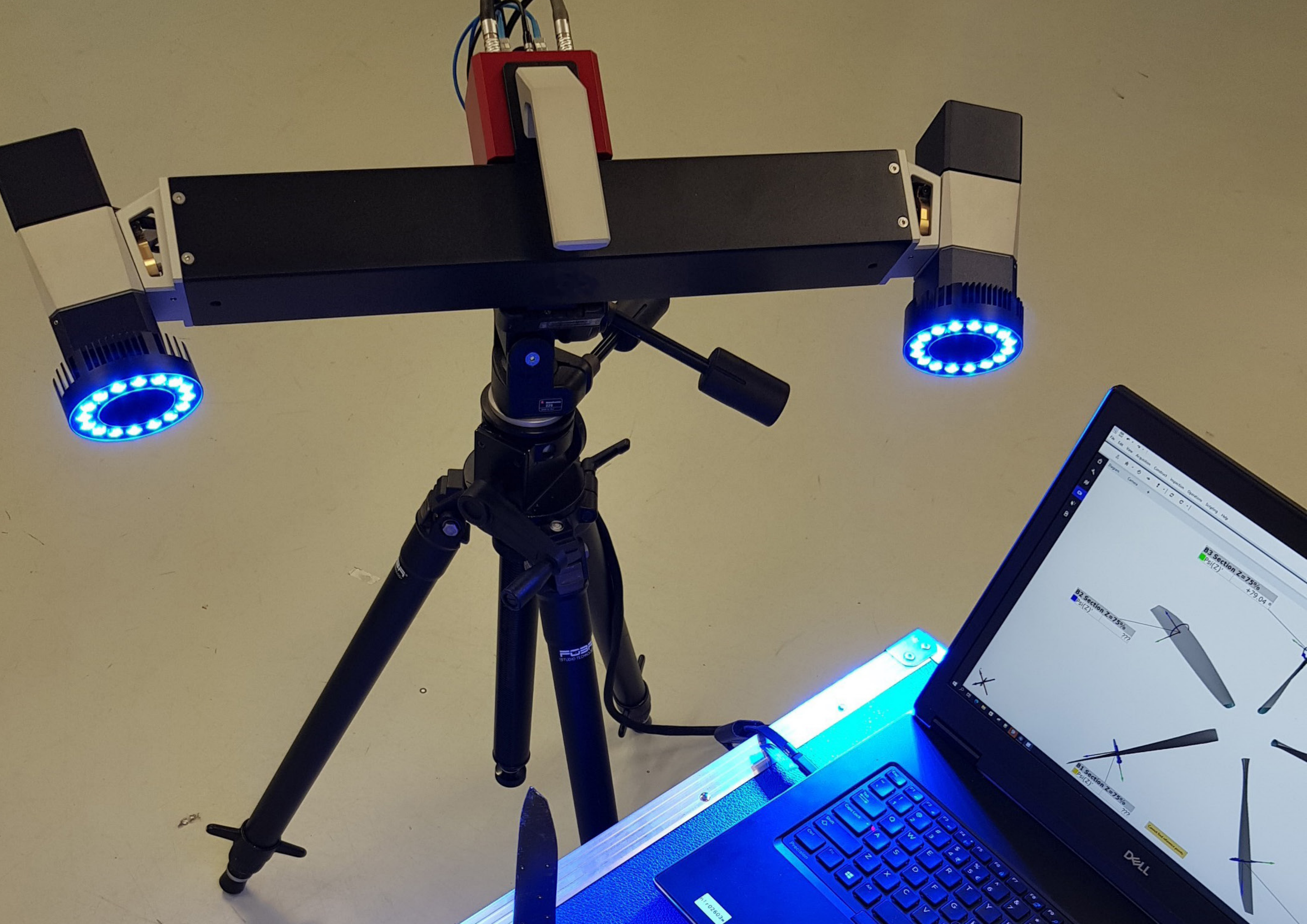
The acoustic impedance of liners determines their interaction with incident sound waves. This impedance can be measured using in-situ measurements, where microphones are installed in liner samples. The impedance can be measured at sound pressure levels (SPL) of up to 150dB and at flow speeds of up to Mach 0.8.

Model deformation measurements

During wind tunnel testing, models can deform under aerodynamic loads, making it essential to accurately register their position and shape. To achieve this, NLR employs 3D optical measurement techniques, including specialised 3D marker tracking and DIC. These non-contact methods use optical systems with multiple cameras to capture high-resolution measurements, either through phase-lock measurement with low-speed cameras or by providing time-resolved data of model motion with high-speed cameras.

These measurements are crucial for verifying FEM models, analysing model behaviour, and validating shape changes from hot to cold conditions. The optical techniques enable comprehensive monitoring of the model's structure, allowing for full-field structural analysis, complex motion tracking, component deformation analysis, and the assessment of mode shapes, relative motion, rotor track and balance, and blade torsion.

By applying point markers or a stochastic pattern to the model's surface, NLR can perform six degrees of freedom (6DoF) analyses to determine the model's translational and rotational motions in relation to each other or as absolute movements in three-dimensional space. NLR's 3D optical measurement systems can capture detailed information on model displacements, deformations, rigid body movements, and dynamic behaviour over time, supporting various applications, including full-field and point-based non-destructive measurements.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NLR Optical Blade Pitch Setting Tool

NLR offers a 3D optical blade pitch setting tool that allows for precise pitch setting of each individual blade on a hub. This active tool provides real-time feedback on the actual pitch setting during the setting process in the wind tunnel.

The process involves:

- CONTACTLESS MEASUREMENT USING A STEREO CAMERA SET-UP
- UNIQUE DOT PATTERNS ON HUB AND BLADES (PAINTED/PRINTED/ STICKERS)
- THE HUB SERVES AS REFERENCE POINT FOR THE ACTIVE BLADE PITCH MEASUREMENTS
- CAMERA IMAGES CAPTURE DOT PATTERNS
- COMPARISON TO CAD REFERENCE GIVES ACTUAL PITCH SETTING
- REAL-TIME FEEDBACK WITH < 5/SEC REFRESH RATE

NLR NOVAIR at DNW
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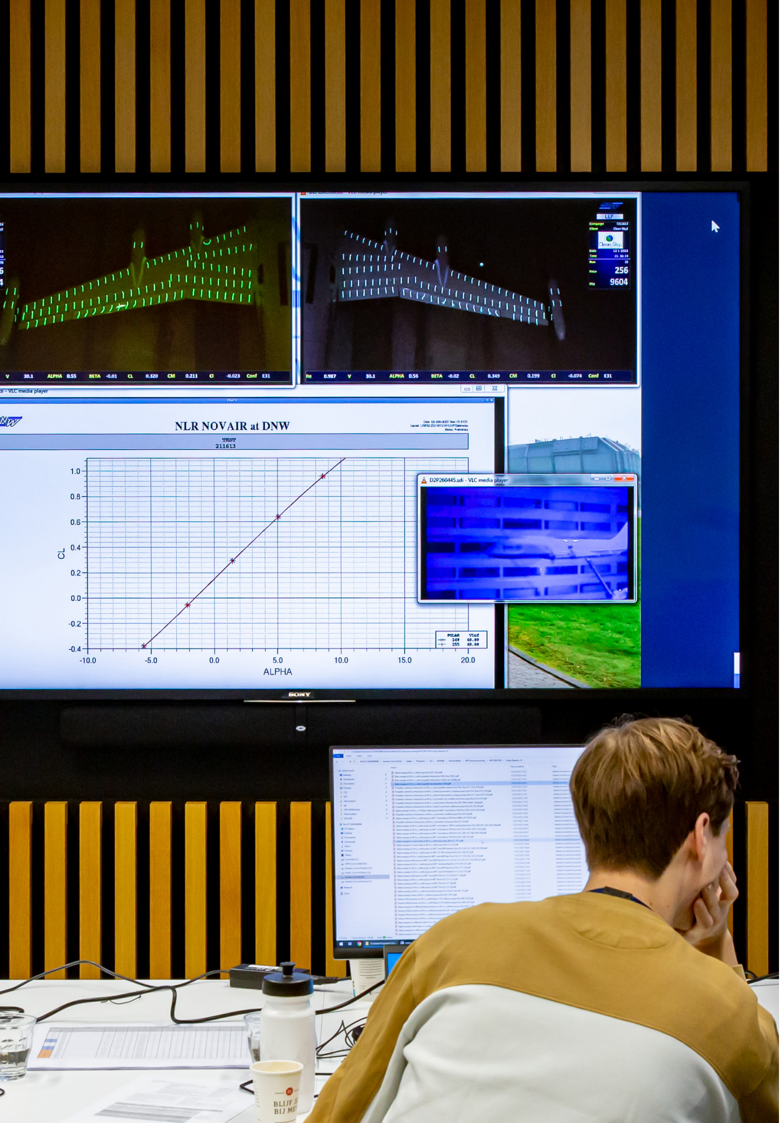
CL
ALPHA
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-10.0
-5.0
0.0
5.0
10.0
15.0
256
9604
Run W12; Rudder Effectivnes (W02 vs W12)
SONY

RESEARCH TOPICS

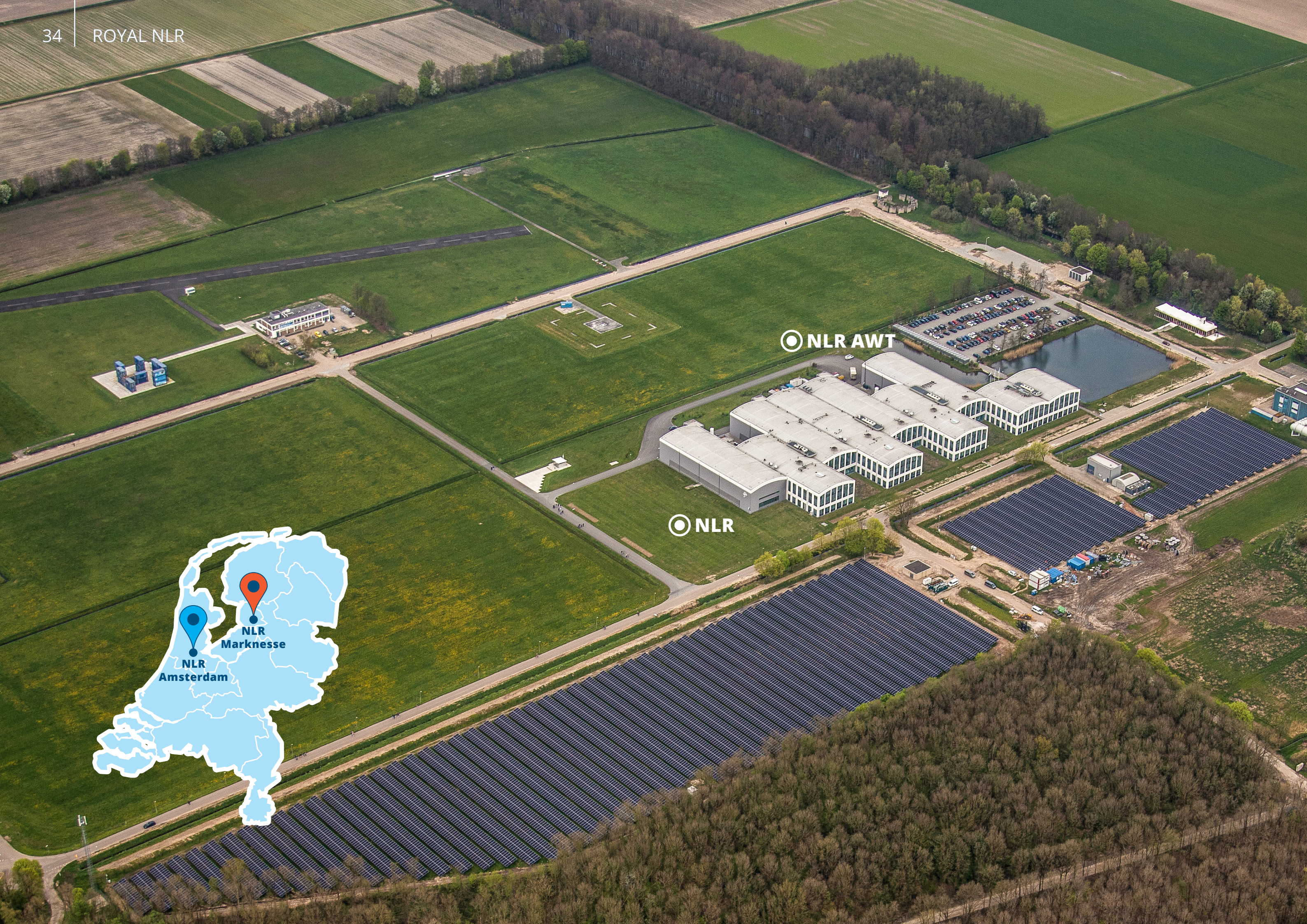
Measuring Flutter/ Fluid Structure Interaction

Elastic wind tunnel models deform under aerodynamic loads, changing the flow and aerodynamic loads. This deformation is more noticeable in thin and flexible aerofoils, leading to static or flutter behaviour. To capture this interaction, NLR uses an optical based method: tracing particles in the flow with particle tracking velocimetry (PTV) and tracking markers on the model surface. This allows us to capture the model's shape and modes and couple them directly to the measured flow around it.



Modular/reusable measurement instruments

Numerical simulations and experimental measurements do not always tell the same story. Differences arise from modelling assumptions, boundary conditions, measurement and manufacturing limits, or environmental effects. Both datasets have strengths and limitations. NLR's solution: combine them for a more accurate result. We integrate numerical and experimental data into one higher-quality dataset using advanced data fusion methods. Central to this approach is a digital twin of the experimental set-up that helps quantify effects like wall interference, structural flexibility and vibrations. This improves the test result interpretation. By creating digital twins beforehand, risks can be identified and mitigated early. This creates a seamless link between simulation and reality, turning separate datasets into reliable insights.


NLR AWT
NLR
NLR
Marknesse
NLR
Amsterdam

RESEARCH INFRASTRUCTURE

Modern aerodynamic research relies on various wind tunnel and propulsion test facilities to study low-speed, high-speed, and supersonic flow phenomena. These facilities enable controlled testing of aerofoils, aircraft components, and integrated configurations under precise flow conditions, supporting measurements of forces, pressures, flow patterns, and aeroacoustics. Specialised facilities, such as electric propeller test rigs and aeroacoustic set-ups, evaluate performance, efficiency, and noise characteristics of emerging propulsion technologies. These installations provide flexible, high-fidelity experimental capabilities for both fundamental research and applied design validation in civil and military aviation.

NLR's services are independent of specific wind tunnels. NLR and NDW are separate companies, and we collaborate frequently to offer comprehensive wind tunnel solutions to customers. Our collaboration ensures smooth project execution and delivers efficient programmes that provide valuable data for next-generation aircraft. The DNW and NLR wind tunnels are located near each other in Marknesse and Amsterdam.

Low speed testing

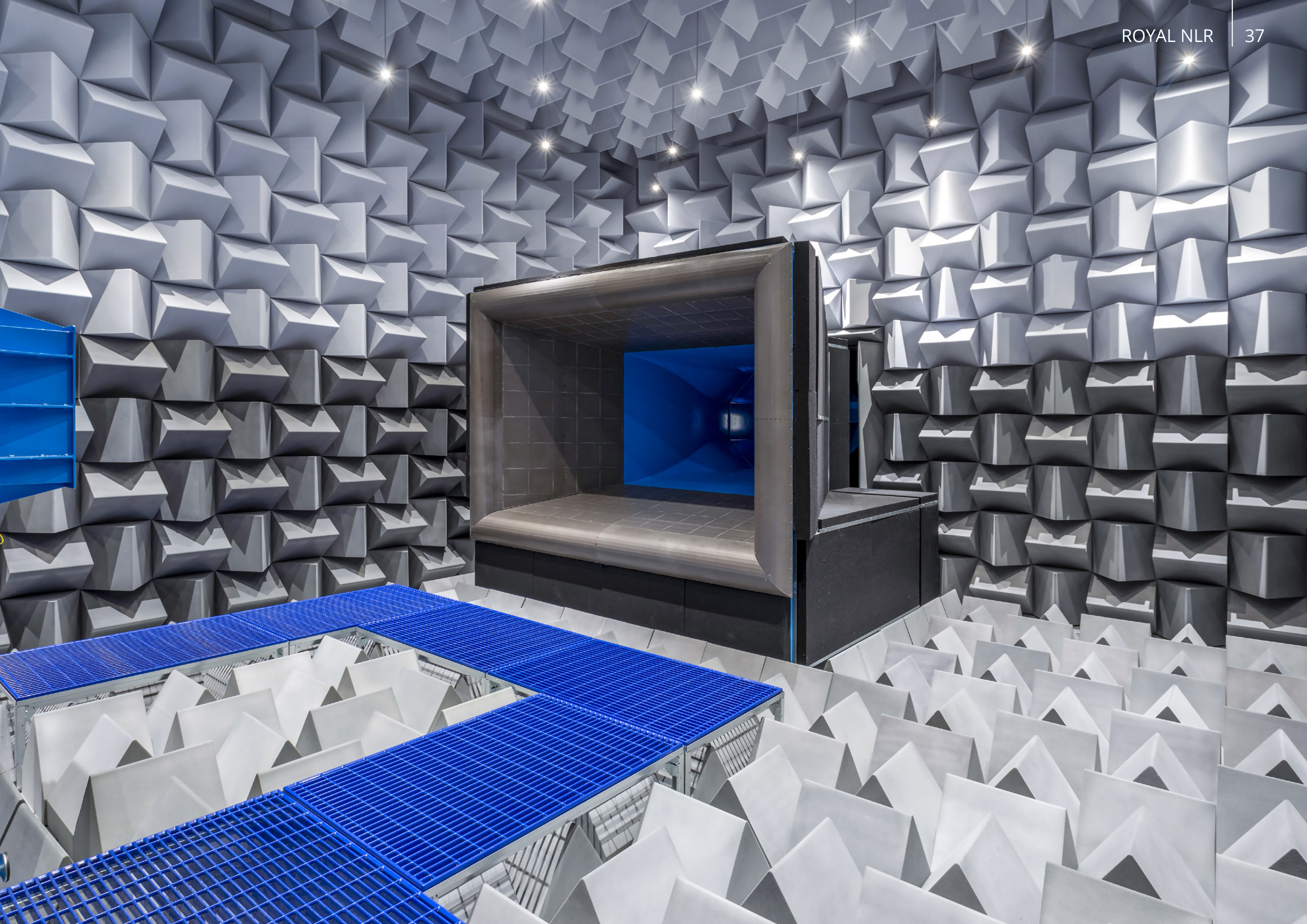
NLR Aeroacoustic Wind Tunnel

Marknesse

The NLR Aeroacoustic Wind Tunnel (NLR-AWT) is a state-of-the-art facility for researching aeroacoustic noise sources and developing noise reduction technologies for aircraft. In addition to its other capabilities, the facility also features a range of closed test sections with sizes between 95x95cm and 60x60cm, for wind velocities up to 65 and 150 m/s. These test sections are designed to provide low-turbulence flow, with a turbulence level of less than 0.2% flow (Tux< 0.2%), making them ideal for small-scale aerodynamic measurements.

The NLR-AWT is designed to study noise production characteristics of various materials and shapes. Its unique closed-circuit design features an anechoic chamber lined with foam wedges that absorb over 99% of sound waves above lower bass notes (200 Hz). The facility can accommodate a wide range of model sizes and configurations, from scaled-down versions to full-scale models and partial models.

Our research focuses mainly on early development phases (Low Technology Readiness level or TRL) or mid-TRL for small components. We develop advanced measurement methods to identify and quantify noise sources, and use flow measurement techniques like Particle Image Velocimetry (PIV/PTV) with Helium Filled Soap Bubbles and hotwire measurements to map airflow patterns qualitatively and quantitatively.

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DNW Low speed testing

Marknesse

The DNW Large Low Speed Facility (LLF) and Low-Speed Wind Tunnel (LST) are low-speed aerodynamic wind tunnels that operate under atmospheric conditions, offering controlled flow quality with low turbulence levels, ideal for low-Mach-number aerodynamic research and development.

DNW Large Low speed Facility

The LLF is a closed-return, low-speed wind tunnel with Europe's largest test section, accommodating large-scale models and integrated configurations at high Reynolds numbers. It supports investigations into aerodynamics, aeroacoustics, and unsteady flows for various applications, including aircraft, rotorcraft, propellers, wind turbines, and complex installations. The facility features advanced instrumentation, such as external force and moment balances, pressure measurement systems, and optical flow diagnostics, enabling high-fidelity testing, performance assessment, and design validation.

DNW Low Speed Tunnel

The LST is a smaller closed-return low-speed tunnel optimised for accuracy, repeatability, and efficient operation. The test section is 3.0 x 2.25 m. It is used for detailed aerodynamic measurements on small to medium-sized models, such as aerofoils, control surfaces, and simplified configurations. The LST supports force, moment, and pressure measurements, as well as flow visualisation, making it ideal for parametric studies, early design phases, and fundamental aerodynamic research.

Visit the DNW website:

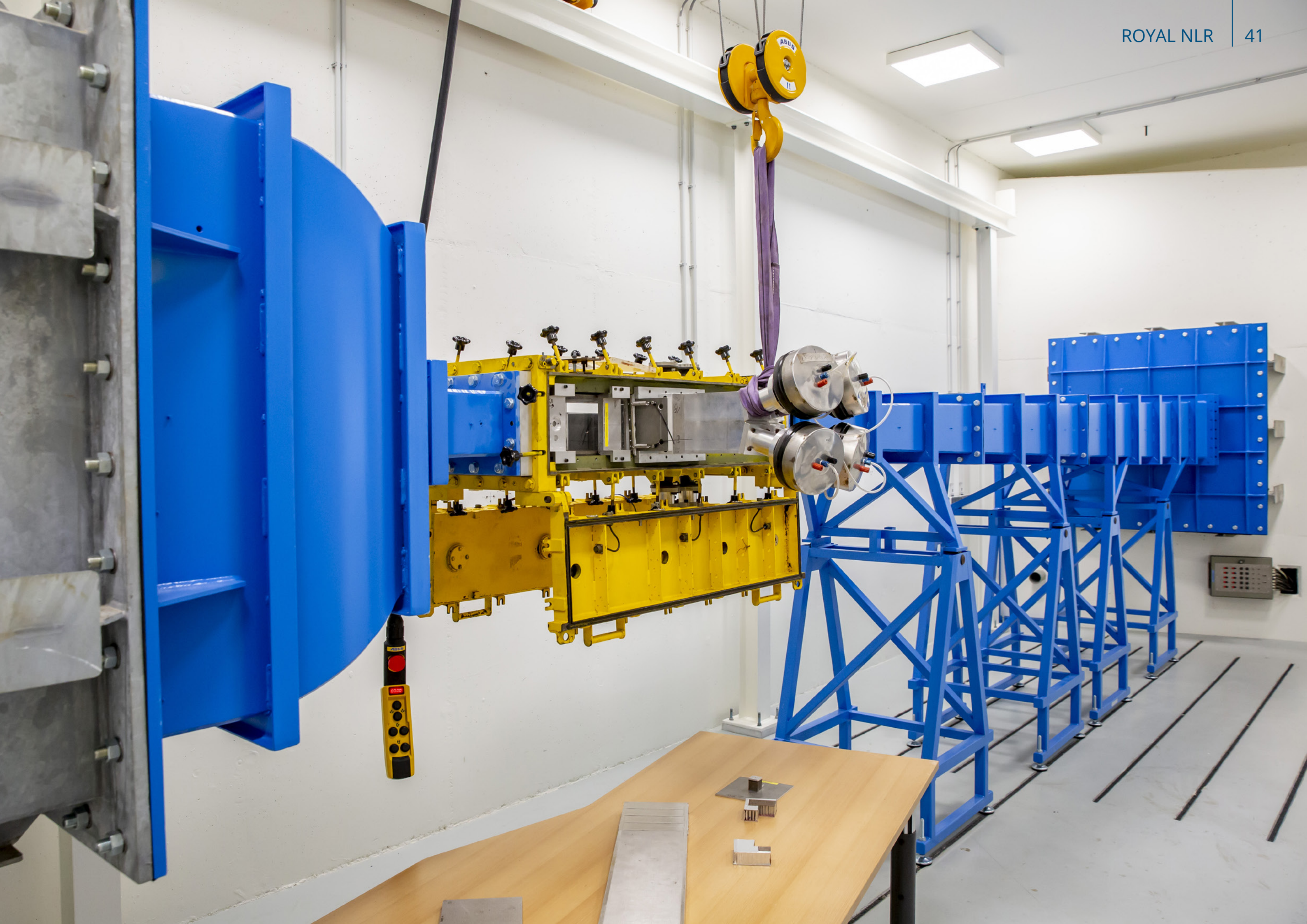
High speed testing

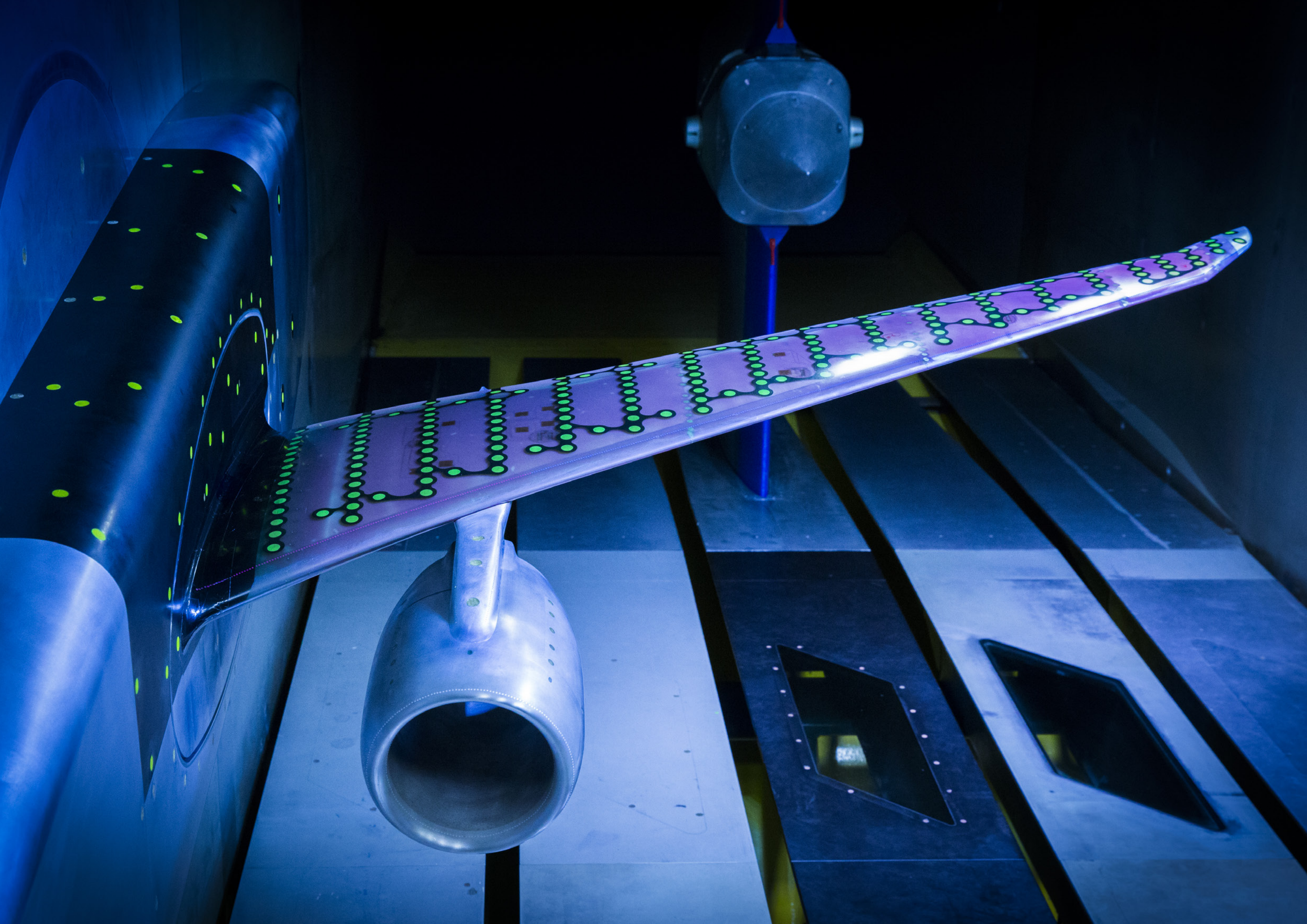
NLR Flow Duct Facility

Marknesse

The Flow Duct Facility (NLR-FDF) contributes to research on noise reduction techniques for aircraft. The facility is used for testing during the early to mid-development phase (low TRL). The FDF is a closed-loop wind tunnel that simulates turbine conditions, with $50m^3$ reverbant chambers upstream and downstream of the test section for accurate sound level measurements. The FDF is suitable for measuring sound absorption, insertion loss, and small-scale high-speed aerodynamics. NLR has developed advanced measurement methods to determine properties of sound-absorbing materials, such as acoustic impedance and sound absorption of liners, as well as the drag of liners.

The facility also uses various flow measurement techniques, including particle visualisation (PIV), scanned pitot tubes, and hot-wire measurements, to map qualitative and quantitative complex air flows. The NLR-FDF serves aircraft manufacturers, their suppliers, wind tunnel operators, and small to medium-sized enterprises. Research projects focus on the dynamic interaction between sound, (liner) materials, and air resistance measurements of various substrates and sound-absorbing materials.





DNW High speed wind tunnels

Amsterdam

The DNW High-Speed Tunnel (HST) and Supersonic Tunnel (SST) provide controlled flow at high subsonic, transonic, and supersonic Mach numbers, enabling research on compressibility effects, shock phenomena, and high-speed aerodynamic performance.

DNW High Speed Tunnel

The HST is a closed-circuit, variable-density wind tunnel for high-subsonic, transonic, and supersonic testing. The maximum test section is 2.0 x 1.8m. It allows for independent control of Mach number and Reynolds number, facilitating detailed studies of compressibility effects shock–boundary-layer interactions, and aerodynamic characteristics of aircraft components and configurations. The wind tunnel supports various measurements, including force, moment, pressure, and optical flow diagnostics. It is used for performance assessment, buffet studies, and design validation at transonic speeds.

DNW Supersonic blow-down tunnel

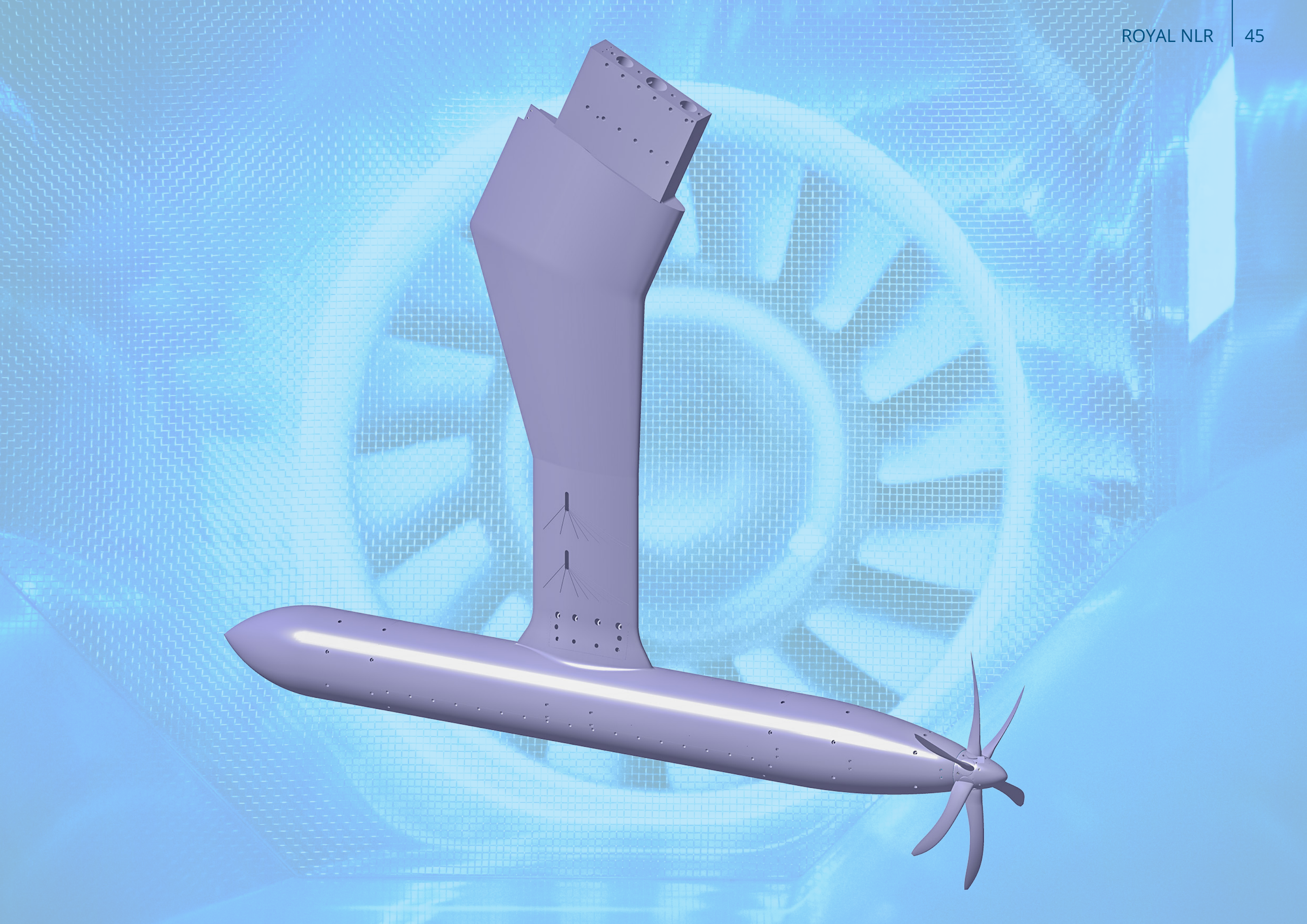
The SST is a blowdown-type supersonic wind tunnel that provides steady flow across a range of supersonic Mach numbers. It is used to study components like inlets, nozzles, and control surfaces, with a focus on shock structures, expansion effects, and high-speed flow phenomena. The facility supports measurements of force, pressure, and flow visualisation. It is suitable for research on supersonic flow phenomena, making it ideal for both applied and fundamental supersonic research.

Visit the DNW website:

High power propeller test rig

The high power propeller test rig is a facility for testing propeller models. It allows for various studies, such as propeller aerodynamic performance, hot-to-cold shape analysis, electromagnetic compatibility (EMC) effects on remote sensing and RSB signals, propeller-airframe interaction, and propeller noise. The propeller test rig has a 200kW power rating and can test propellers between 40-150cm. It also enables blade deformation measurements and contactless data transfer testing. The facility is useful for derisking propeller set-ups before they are used in larger wind tunnels.

Pressure measurements are made over the hull of the rig and at the pressure plate behind the hub to allow for thrust corrections. Dynamic data from strain gauges or a rotating shaft balance (RSB) can be routed via the slip ring. Dedicated time varying data from the rotating propeller can be routed via the built-in 48 channel slip ring. The rig can be easily integrated into wind tunnels, such as the NLR-AWT and DNW-LST.

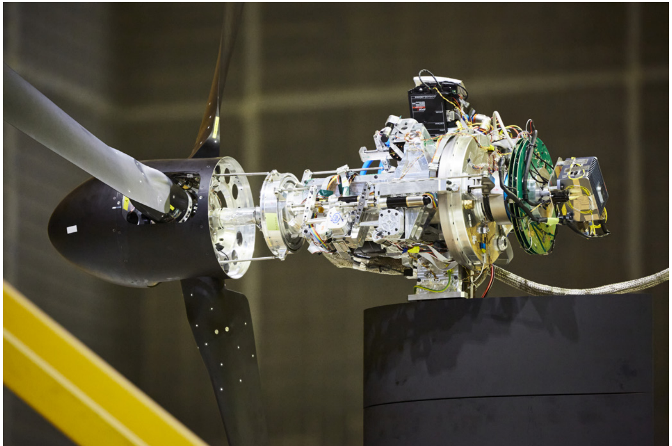


SHOWCASE PROJECTS

NLR has an extensive track record in wind tunnel modelling and testing. Some multi-disciplinary projects are presented on the following pages.

The ATTILA project

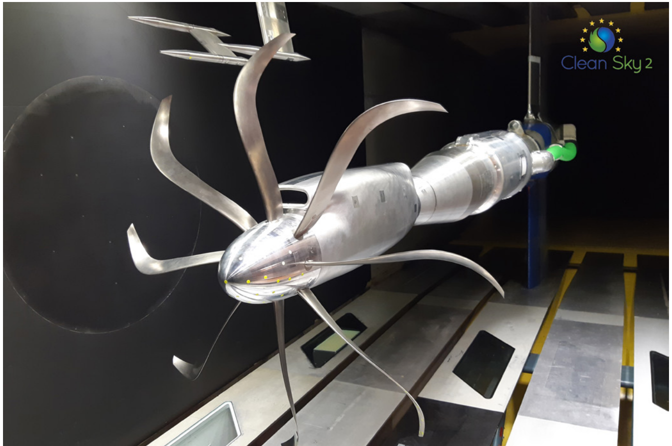
Coordinated by NLR, this European-funded Clean Sky 2 project involved developing a testbed consisting of an instrumented, aeroelastically scaled cantilevered half-wing with a powered nacelle-proprotor system, representative of the full-scale NGCTR-TD design. This included the use of advanced fibre-optic sensors and contactless rotating power and data transfer techniques. The design process was supported by detailed structural and aeroelastic simulations and was refined through testing. NLR led the model structural analyses, design, manufacturing, coordinated wind tunnel tests, and developed a patented Trim Excitation Device (TED) for precise whirl flutter testing.



CS2/ATTILA - GA 863418

The IRON project

In this European-funded Clean Sky 2 project, low-noise propellers were designed using computational optimisers for a next-generation regional aircraft. Two propellers were selected for experimental validation against a baseline design. NLR performed the structural analyses, designed and manufactured the wind tunnel model, and coordinated the tests of the propeller designs. The complex blade shapes generated by the computational optimisers posed a unique challenge for this project.



CS2/IRON - GA 945548

Aerion wind tunnel model

NLR designed and manufactured a high-speed wind tunnel model for the Aerion AS2 development. The model included extensive pressure instrumentation and custom-designed balances integrated in the control surface hinges.

About NLR

Royal Netherlands Aerospace Centre

POLICY SUPPORT

INDUSTRIAL DEVELOPMENT

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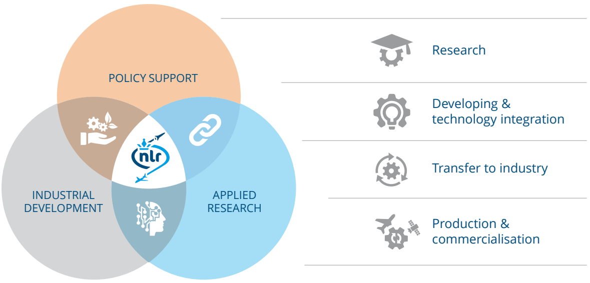
NLR is a leading international research centre for aerospace. Its mission is to make air transport safer, more efficient, more effective and more sustainable. Bolstered by its multidisciplinary expertise and unrivalled research facilities, NLR provides innovative and comprehensive solutions to the complex challenges of the aerospace sector.

NLR's activities span the full spectrum of Research, Development, Testing & Evaluation (RDT & E). Given NLR's specialist knowledge and state-of-the-art facilities, companies turn to NLR for validation, verification, qualification, simulation and evaluation. They also turn to NLR because of its deep engagement with the challenges facing our clients. In this way, NLR bridges the gap between research and practical applications, while working for both government and industry at home and abroad.

Royal NLR stands for practical and innovative solutions, technical expertise and a long-term design vision, regarding their fixed wing aircraft, helicopter, drones and space exploration projects. This allows NLR's cutting-edge technology to also find its way into successful aerospace programmes of OEMs like Airbus, Boeing and Embraer.

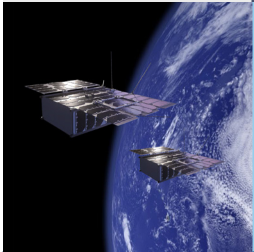


NLR in brief

AMSTERDAM, MARKNESSE, ROTTERDAM, BRUSSELS

1000+
STAFF

144M
TURNOVER



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Netherlands Aerospace Centre

As an independent R&D centre for aerospace, Royal Netherlands Aerospace Centre (NLR) is known for its practical approach and innovative solutions to the complex challenges of the aerospace sector. Our mission is to make air and space transport safer, more efficient, more effective, and more sustainable. NLR acts as a bridge between science, industry, and government. By combining our expertise and facilities, we can support companies and government throughout the entire development process, from concept development to prototype and small-scale production.

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Clean Sky 2 JOINT UNDERTAKING

Co-funded by the European Union

This concerns the research projects on pages 2 and 48.

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