Courtesy of Beyond Aero

Low-Speed Tunnel (LST)

The Development & Pre-testing Facility for Efficient Aerodynamic Testing

German-Dutch Wind Tunnels

www.dnw.aero

Low-Speed Tunnel (LST)

Key Aspects at a Glance

Type of wind tunnel	Continuous, atmospheric, subsonic
Mach number	0 – 0.23
Test section size(s)	3.0 m × 2.25 m closed test section
Total pressure	Ambient
Reynolds number (max, $l_{ref}=0.1\sqrt{A}$)	1.39×10^6
Temperature range	Ambient
Contraction	9:1
Drive power	~700 kW
Auxiliaries	Air supply: ~5.5 kg/s at 80 bar
	Power supply up to 1000 VDC

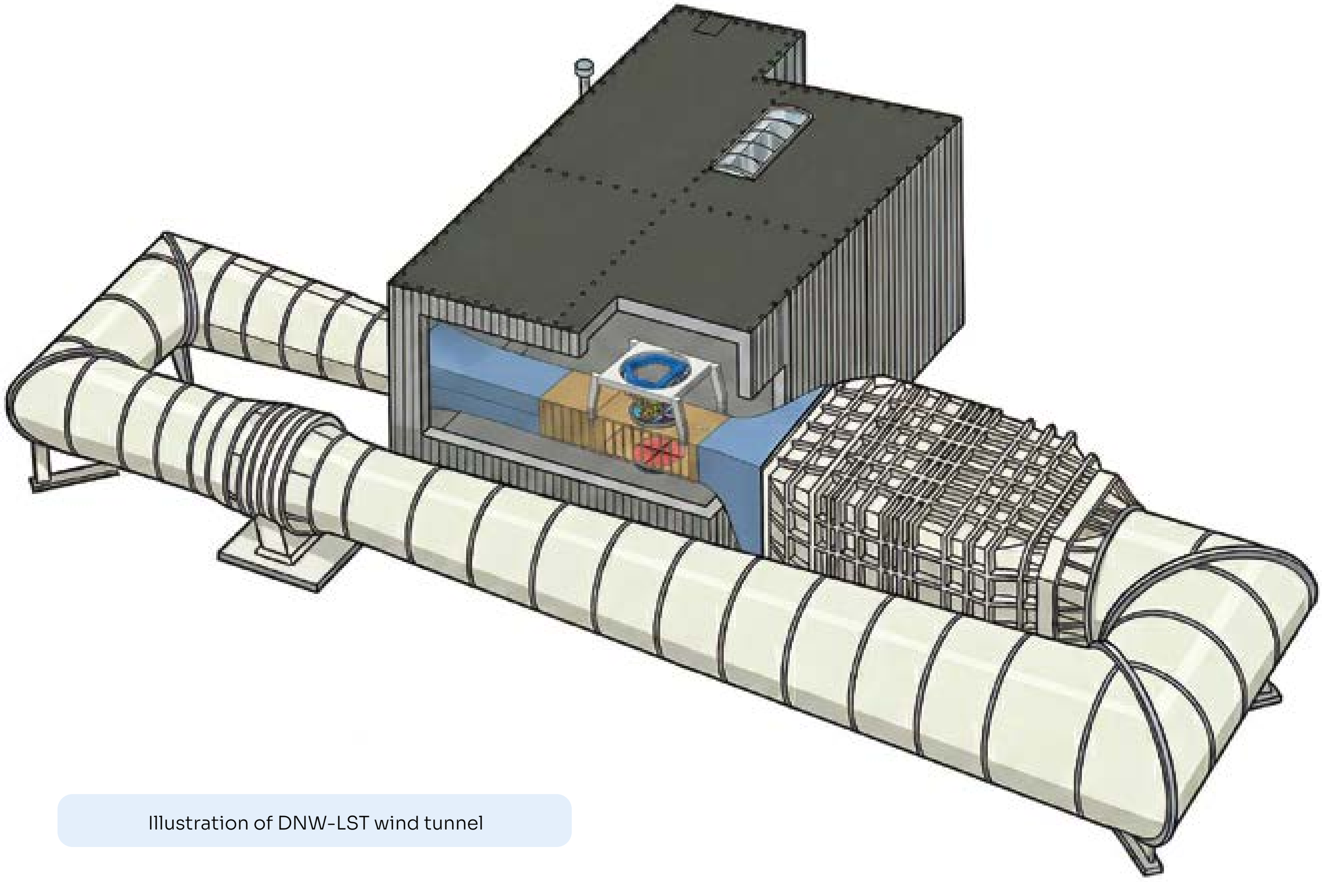


Illustration of DNW-LST wind tunnel

Within DNW's integrated portfolio, the LST serves as a readily accessible development and pre-testing facility for both the High-Speed Tunnel (HST) and the Large Low-Speed Facility (LLF).

Its role is to enable rapid iteration, early risk reduction, and test concept maturation before campaigns are transferred to larger-scale or higher-speed facilities.

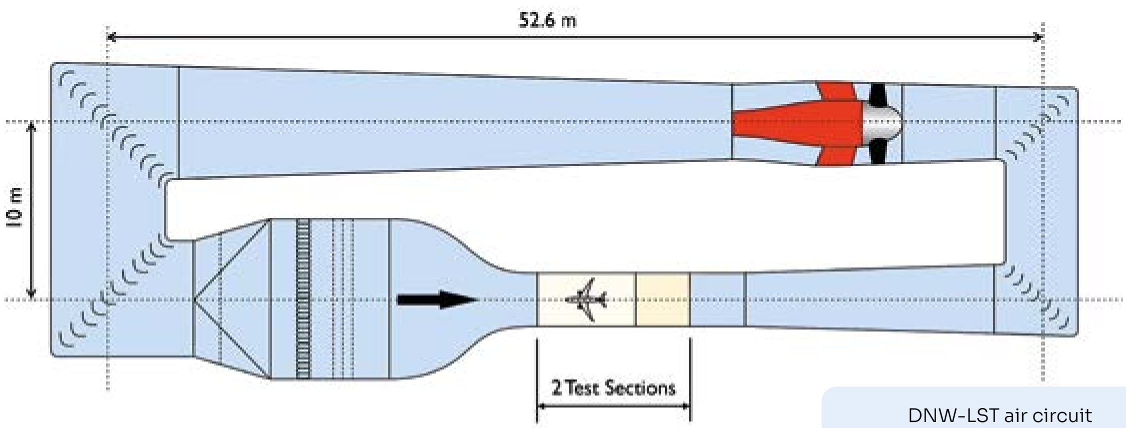
The LST is optimised for detailed flow-physics studies and early- to mid-stage aerodynamic development, offering a level of accessibility, adaptability, and turnaround speed that is difficult to achieve in large-scale tunnels. This makes it particularly valuable for exploring configuration changes, evaluating design alternatives, and validating measurement techniques.

The LST shares its operational philosophy, staffing infrastructure, and diagnostic ecosystem with the LLF. It has excellent optical access, access to the same compressed air infrastructure that supplies the LLF, and employs the same or closely related instrumentation systems. This ensures continuity in experimental methodology across scales and enables smooth transitions from development testing to large-scale validation.

While the LST supports both aerospace and non-aerospace applications, it is clearly differentiated from the NWB. The NWB is optimised for dedicated aero-acoustic and wind-energy-related investigations, whereas the LST focuses on aerodynamic development, sectional testing, configuration refinement, and pre-validation activities.

Wind Tunnel Configuration

The Low-Speed Tunnel (LST) is a closed-circuit, atmospheric wind tunnel designed for excellent flow quality, high repeatability, and rapid reconfiguration. A defining feature of the facility is that the test section is divided into two functional parts: an exchangeable forward aeronautical test section and a fixed aft industrial aerodynamics test section.

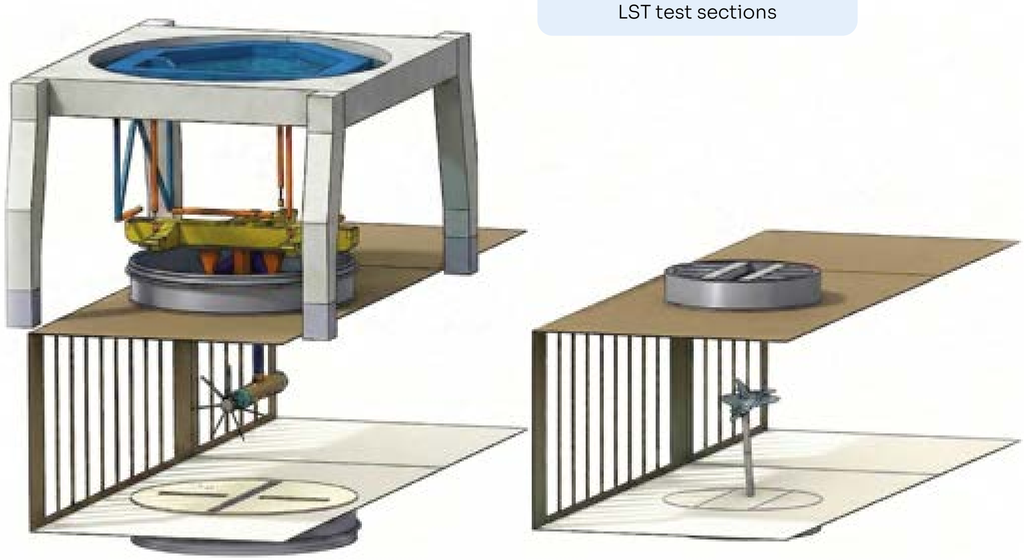


DNW-LST air circuit

The total test section measures 3.0 m × 2.25 m with an overall length of 8.75 m. The forward 5.75 m is dedicated to aeronautical testing and can be equipped with one of two interchangeable modules, allowing either two-dimensional or three-dimensional aerodynamic investigations in the same tunnel. The aft section is permanently installed and intended for non-aeronautical (industrial aerodynamics) testing.

The exchangeable forward modules can be prepared outside the tunnel and swapped into the circuit, minimizing wind-tunnel occupation time and improving facility productivity. Both forward configurations include turntables in the floor and ceiling, while the aft industrial section contains a floor turntable only.

LST test sections



Three-Dimensional (3D) Aeronautical Test Section

The 3D module is configured for complete configurations and complex installations. It features an external six-component overhead balance, integrated yaw-setting turntables, and model support via sting or strut connected to the balance. This setup is used for full aircraft models, semi-span configurations, and integrated propulsion concepts during aerodynamic development campaigns.

Two-Dimensional (2D) Aeronautical Test Section

The 2D module is optimized for high-accuracy airfoil and sectional investigations. It incorporates synchronized floor and ceiling turntables for precise incidence control, provisions for a tangential blowing slot to improve two-dimensional flow fidelity, and the possibility to install an arc-section cradle for strut-mounted models with an internal balance. Both forward test sections are compatible with wake rake traversing systems.

Industrial Aerodynamics Test Section

Behind the aeronautical section, the fixed aft test section is dedicated to non-aeronautical applications such as industrial aerodynamics studies. It shares the same cross-sectional dimensions but uses a simpler support arrangement with a floor turntable, allowing robust and flexible mounting of various test articles. All test sections provide excellent optical access, enabling extensive use of optical diagnostics and flow-visualization techniques.

Why Low-Speed Development Testing

Low-speed wind tunnel testing remains indispensable for the early stages of aerodynamic design, where configuration decisions are made, flow control concepts are evaluated, and critical sensitivities are identified.

At this stage, designers must explore large design spaces, understand the dominant flow mechanisms, and identify potential risks before committing to large-scale or high-Reynolds number testing. This requires a facility that combines high experimental fidelity with rapid configurability.

Low-speed development testing is particularly important for:

- Understanding flow separation and reattachment mechanisms
- Studying wake formation and interaction
- Evaluating control surface effectiveness
- Investigating high-incidence behaviour
- Refining airfoil and wing section designs
- Assessing installation effects at a local level
- Determining isolated propulsor performance
- Developing and validating advanced measurement techniques
- De-risk subsequent large-scale or compressible-flow test campaigns

Within DNW's staged testing philosophy, the LST enables rapid iteration, early risk reduction, and test concept maturation before proceeding to higher-cost, larger-scale campaigns.

Key Flow Parameters & Operating Envelope

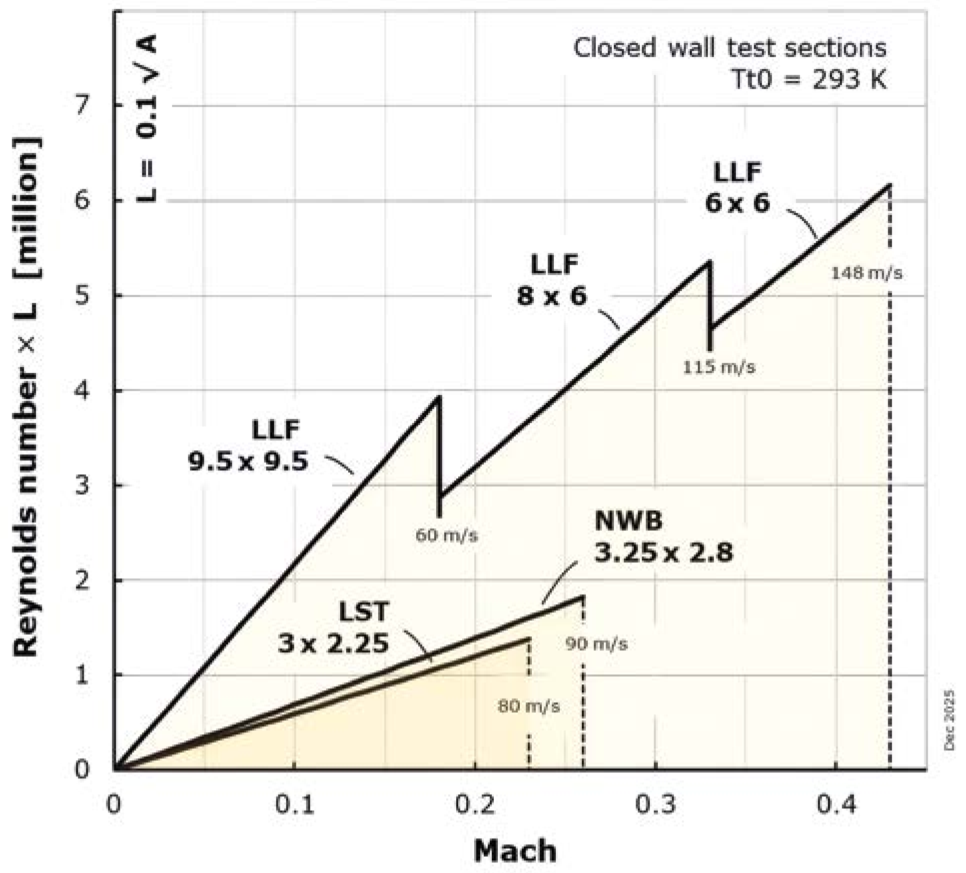
The Low-Speed Tunnel (LST) is designed to provide a highly controlled, low-turbulence flow environment for detailed aerodynamic development testing.

Key flow characteristics include:

- Velocity range: 1.5 – 80 m/s
- Reynolds number range (reference length 0.1 √A) up to 1.39×10^6
- Operating pressure and temperature: ambient
- Turbulence intensity: $Tu_x \approx 0.02\%$, $Tu_y = Tu_z \approx 0.03\%$
- Flow angularity: ≤ 0.1°
- Excellent flow uniformity and temperature stability across the test section

The LST is not intended to replicate full-scale Reynolds numbers. Instead, it is designed to support:

- Early-stage aerodynamic development
- Sensitivity studies
- Flow-mechanism investigations
- Isolated propulsion calibration
- Risk reduction (pre-testing) prior to large-scale testing



Mach-Reynolds envelope of DNW low-speed facilities

Model Support & Load Measurement Capabilities

The LST offers a wide range of flexible model support systems and load measurement concepts, enabling efficient testing of both two-dimensional and three-dimensional configurations.

The facility uses the same internal balance and half-model balance technologies as the HST, ensuring direct comparability of aerodynamic loads across speed regimes. This commonality allows models and instrumentation strategies to be transferred efficiently between facilities.

Available support concepts include:

- Sting-mounted configurations for 3D models
- Strut and/or floor-mounted models
- Model support via suspension wires
- Sectional mounts for 2D airfoil and profile testing
- Inlet and propeller test rigs
- Traversing rake systems for wake surveys and flow-field mapping

The balance infrastructure supports:

- High-accuracy force and moment measurements
- Multi-component internal balances
- External half-model balances for semi-span and floor-mounted configurations

These systems enable:

- Global aerodynamic force and moment measurement
- Detailed load breakdowns
- Control surface effectiveness studies
- Installation effect assessments

The LST's mechanical infrastructure is optimised for rapid model installation and reconfiguration, minimising downtime between test phases and supporting highly iterative development workflows.

Business jet testing
(BYA-I model; courtesy of Beyond Aero)

Thrust reverser testing

Ground Proximity Simulation

The LST can be equipped with a dedicated ground board system, enabling realistic simulation of ground proximity effects.

This capability is essential for studies where near-ground flow interaction plays a dominant role, such as:

- Thrust reverser re-ingestion
- Jet–ground interaction
- Intake flow distortion under crossflow
- Ground-effect aerodynamics
- Installed propulsion studies close to the ground plane

The ground board can be configured to simulate various ground clearances and flow conditions, allowing controlled investigation of boundary-layer growth, ingestion phenomena, and re-circulation mechanisms.

This makes the LST particularly valuable for early-stage investigations of installed propulsion systems, where ground effects strongly influence performance and operability.

Propulsion Integration

The LST supports a broad range of propulsion-related and integrated aerodynamic investigations, with emphasis on concept maturation, installation effects and interaction phenomena at low speed.

The facility supports both powered and unpowered propulsion simulation, including:

- Nacelle–airframe interaction
- Intake distortion and recovery
- Exhaust–airframe interference
- Slipstream effects
- Crossflow sensitivity
- Flow ingestion phenomena

Key capabilities include:

- Dedicated isolated propeller test rig for low-speed aerodynamic testing
- Electrically driven or air-driven propulsion simulation
- Electrical power supply up to 1000 VDC
- Compressed air supply: up to 6 kg/s at 70 bar
- Suction-based intake simulation
- Interference-free thrust measurement using airline bridge technology
- Rotary shaft balances enabling 6DoF load measurements
- In-house calibration and validation of propulsion simulators in the Engine Calibration Facility (ECF)
- Compatibility with the rake traversing system for wake characterisation
- Helium Filled Soap Bubble, HFSB, flow seeding rake proving a seeding area of 1 m^3

The LST isolated propeller test rig is a dedicated facility, separate from installed propulsion simulation, and is used to pre-test propeller configurations in a controlled and efficient manner. These pre-tests are carried out before proceeding to installed propulsion and aeroacoustic investigations in the LLF, as well as high-subsonic and transonic performance testing in the HST. By following this step-by-step approach, technical risks are reduced and overall programme efficiency is improved.

The LST is particularly well suited for early-phase evaluation of propulsion integration concepts, where rapid configuration changes and detailed flow diagnostics are required.

Flow distortion measurements
(NIFTI Clean Sky2 project)

Propeller performance and aero-acoustics; Dowty's baseline propeller design undergoing checkout tests in LST prior to technology development testing in HST & LLF

Aeroacoustics

The LST provides limited aeroacoustic measurement capability within its closed test section environment.

While it is not designed as a primary aeroacoustic facility (this role is fulfilled by NWB and LLF), the LST enables:

- Relative noise assessments
- Source screening
- Installation-related noise investigations
- Qualitative comparisons between design variants

This capability is particularly valuable in early development phases, where the objective is to identify dominant noise mechanisms before moving to dedicated aero-acoustic facilities.

Measurement & Diagnostic Techniques

The LST employs a comprehensive suite of advanced aerodynamic measurement and diagnostic techniques. These systems are largely shared with other DNW facilities, enabling methodological continuity across the portfolio.

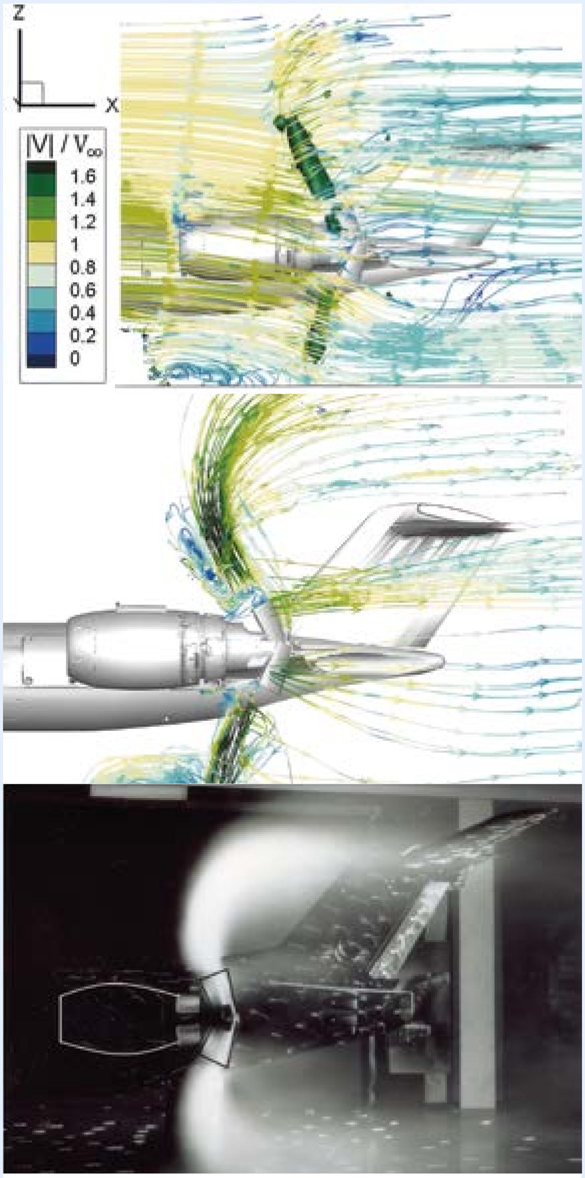
Available techniques include:

- High-accuracy force and moment balances (internal and external)
- High-density static and unsteady pressure measurement systems
- Stereoscopic pattern recognition (SPR) for model deformation and attitude measurement
- Infrared thermography (IRT) for transition detection
- Wake and boundary-layer surveys using rake traversing systems in both 2D and 3D test section configurations
- Particle Image Velocimetry (2C and 3C-PIV)
- 3D Particle Tracking Velocimetry (by NLR)
- Laser light sheet visualisation
- Pressure-Sensitive Paint (PSP) and Temperature-Sensitive Paint (TSP)
- Tufts and smoke visualisation
- Tracer gas concentration measurement

The LST offers exceptional optical access, supporting high-quality application of optical diagnostics.

These tools allow customers to move beyond force and moment data toward a detailed, physics-based understanding of flow behaviour.

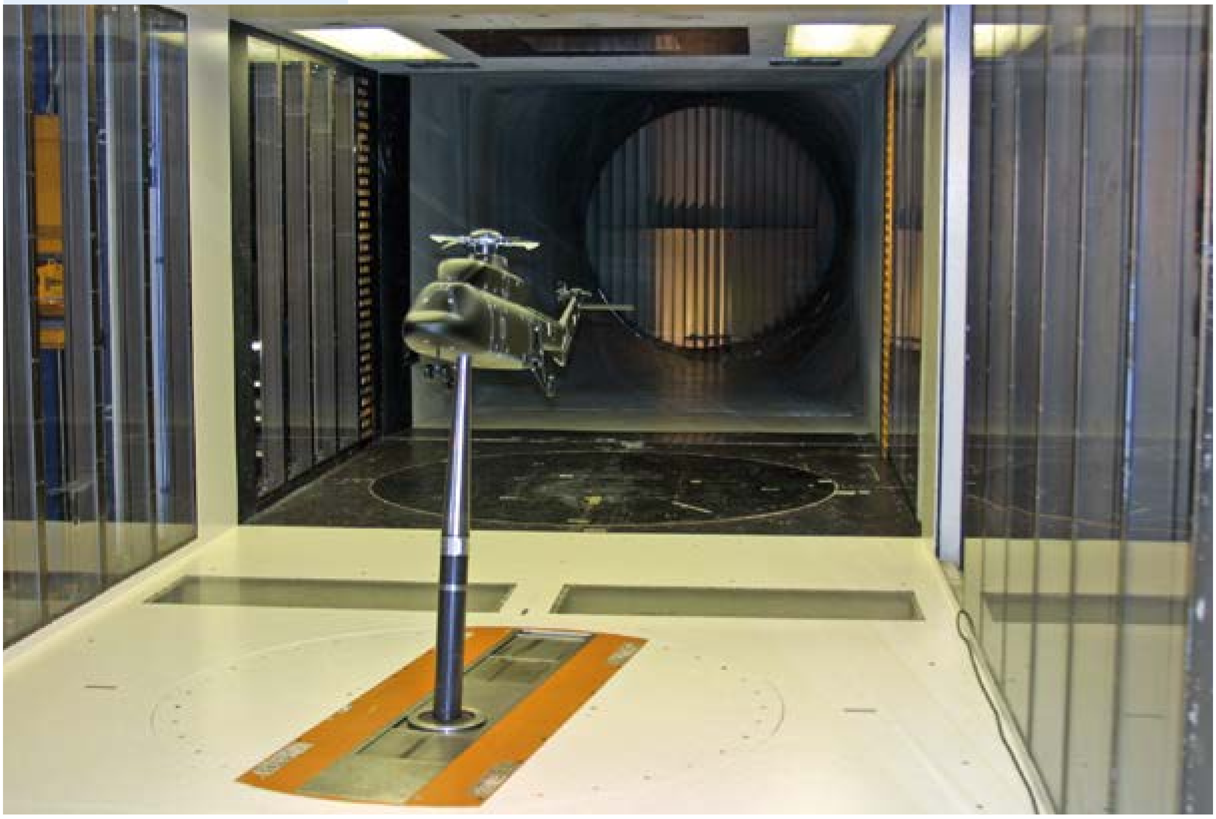
High testing productivity is enabled by DNW's GAIUS wind tunnel control, automation and data-acquisition system, which is deployed consistently across LLF, LST, ECF, HST and SST. GAIUS supports scripted test execution, continuous sweeps and synchronised data acquisition, ensuring data quality while reducing overall test time.



3D Particle Tracking Velocimetry on thrust reversers (courtesy of NLR)

2D airfoil testing (Richting RVO TSH project)

Helicopter testing



Typical Applications

Aerospace Applications

Typical aerospace applications of the LST include:

- Aircraft configuration development and optimisation
- Stability and control investigations
- Airfoil and section testing in the 2D test section
- Method development and CFD validation at low speed
- High-lift device optimisation
- Control surface effectiveness studies
- Flow separation and reattachment investigations
- Wake interaction studies
- Intake and exhaust flow behaviour
- Distributed propulsion concepts
- Boundary-layer control and flow control concepts
- Early-stage propulsion–airframe integration studies

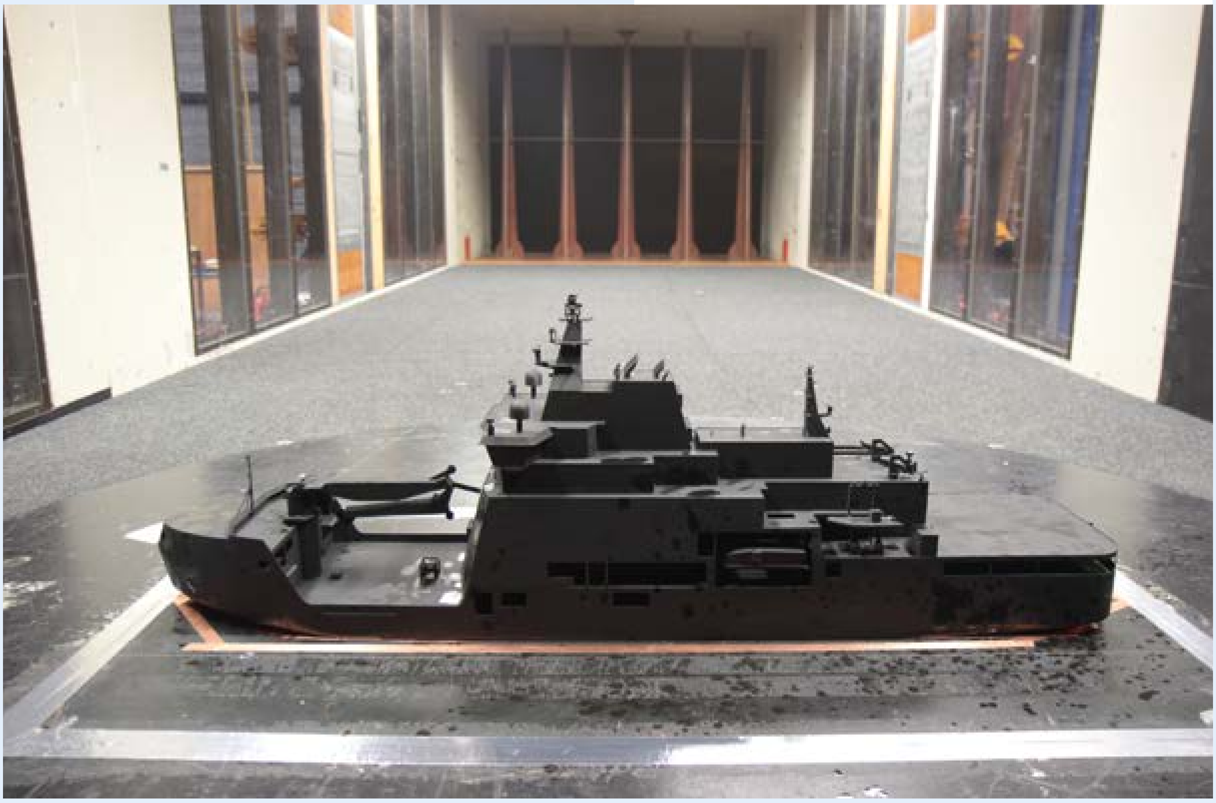
Industrial Aerodynamics Applications

While primarily supporting aerospace industry, LST also contributes to a range of non-aeronautical applications.

These include:

- Aerodynamic optimization for athletes (e.g. cyclist, speed skaters)
- Wind climate studies for buildings using atmospheric boundary layer simulation
- Wind load measurements for ships and offshore structures
- Exhaust gas dispersion measurements to access pollutant transport in complex flow environments
- Ship-Helicopter Operating Limit (SHOL) testing to evaluate safe helicopter operations on naval vessels under varying wind conditions

Wind load measurements on a ship



Investigation by TU Delft on jet-installation noise reduction using a blown-nozzle (IPER-MAN NWO project)

Investigation by FUTPRINT50 consortium on propeller-wing interaction (Horizon 2020 project)

Customer Value & DNW Portfolio Synergy

The LST enables customers to explore design spaces rapidly, reduce programme risk early, and enter large-scale testing phases with mature, well-understood configurations.

By combining flexibility, advanced diagnostics, and fast turnaround times, the LST allows customers to:

- Identify critical sensitivities early
- Reduce the number of expensive large-scale test iterations
- Validate numerical methods in controlled conditions
- Develop robust test concepts for subsequent facilities
- Explore and down-select preferred design concepts for further development

Beyond the LST itself, DNW operates a complementary portfolio of wind tunnel facilities in the Netherlands and Germany, covering subsonic, transonic and supersonic regimes. These facilities are managed as an integrated organisation.

Within this portfolio:

- LLF provides large-scale, multidisciplinary low-speed testing
- NWB enables dedicated low-speed aero-acoustic and multidisciplinary investigations
- HST delivers high-Reynolds-number transonic validation up to M = 1.3
- SST extends testing seamlessly into the supersonic regime up to M = 4
- TWG offers highly flexible, smaller-scale continuous transonic and supersonic testing up to M = 2.2

This synergy of scales and speed regimes allows customers to execute coherent experimental programmes across multiple facilities, from early concept studies at smaller scale to large-scale high-fidelity validation.

This integrated approach differentiates DNW from isolated single-tunnel providers and enables customers to move from concept-level testing to large-scale validation within a single coordinated experimental ecosystem.

LST serves as a readily accessible development and pre-test facility enabling rapid iteration, early risk reduction, and test concept maturation before campaigns are transferred to larger-scale or higher-speed facilities.

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