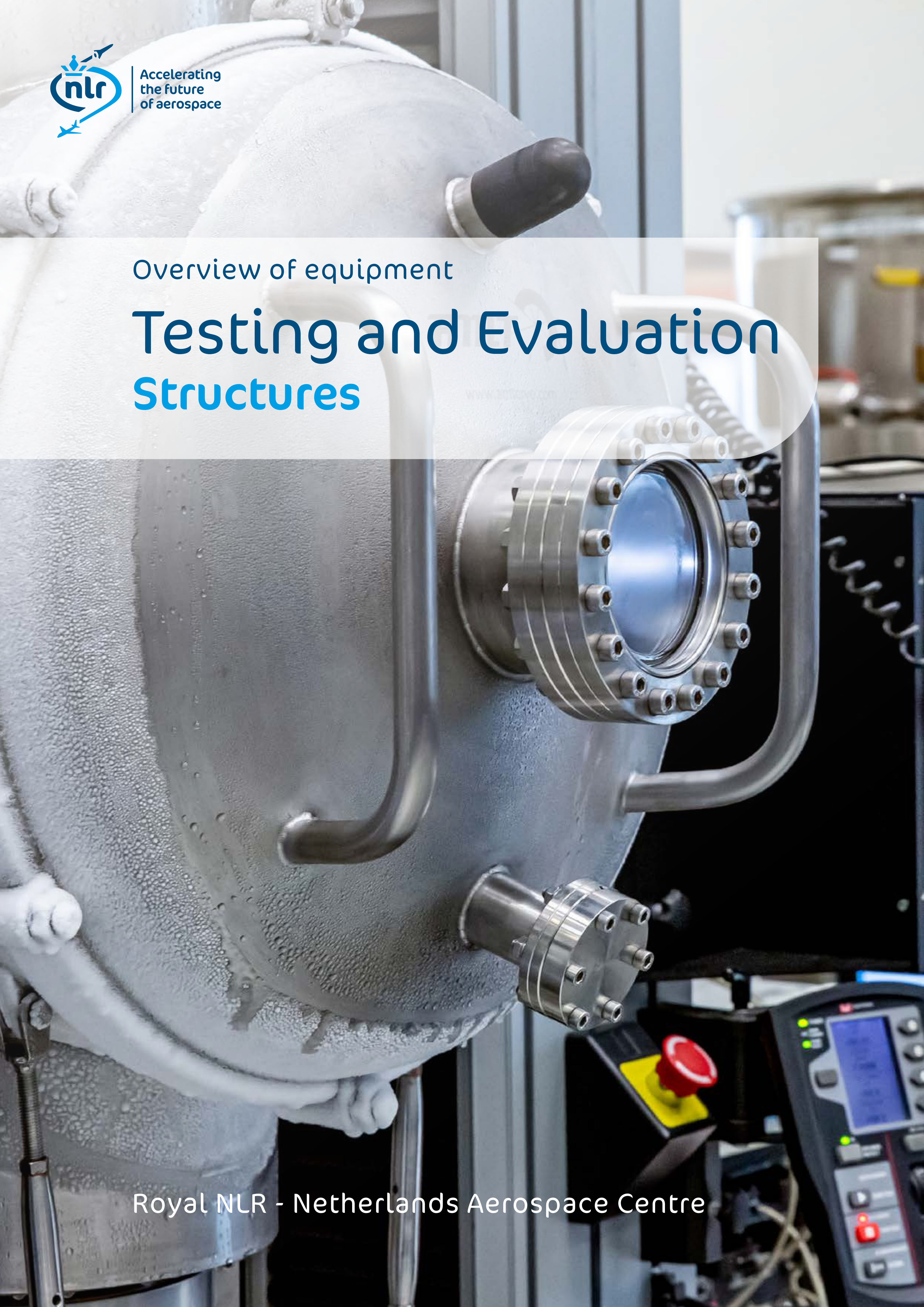
Accelerating the future of aerospace

Overview of equipment

Testing and Evaluation

Structures



Royal NLR - Netherlands Aerospace Centre

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NLR operates as an objective and independent research centre, working with its partners towards a better world tomorrow. As part of that, NLR offers innovative solutions and technical expertise, creating a strong competitive position for the commercial sector.

For over 100 years, NLR has been an ambitious applied research organisation, driven to keep innovating for the benefit of making aerospace more sustainable, safer, efficient and effective. Objectively and independently, we are now laying the foundation for a future meaningful, societal impact.

In a rapidly changing world, mobility and stability needs are constantly evolving. Aware of the social urgency, NLR helps pave the way for promising concepts to quickly see the light of day and transform into disruptive solutions or incremental improvements. We do this by combining a deep understanding of customer needs, multidisciplinary expertise and the use of our leading research facilities. In doing so, NLR plays a pivotal role between science, industry and government at home and abroad, bridging the gap between fundamental research and practical applications.

NLR is taking a leading role to achieve Dutch and European objectives. Together with our partners, we are working hard on a resilient and sustainable mobility system, and we support Dutch Defence in all military domains, with space and cyberspace playing an increasingly prominent role. From its headquarters in Amsterdam and Marknesse and our two satellite sites and in this way, NLR contributes to a safer and more sustainable society, strengthening the competitive position of Dutch industry.

For more information visit: **www.nlr.org**

This brochure is 1 out of a series of 4. It provides an equipment overview on

Testing and Evaluation of **Structures**

The other 3 topics are: Energy transition, Environmental and Electric & electronic

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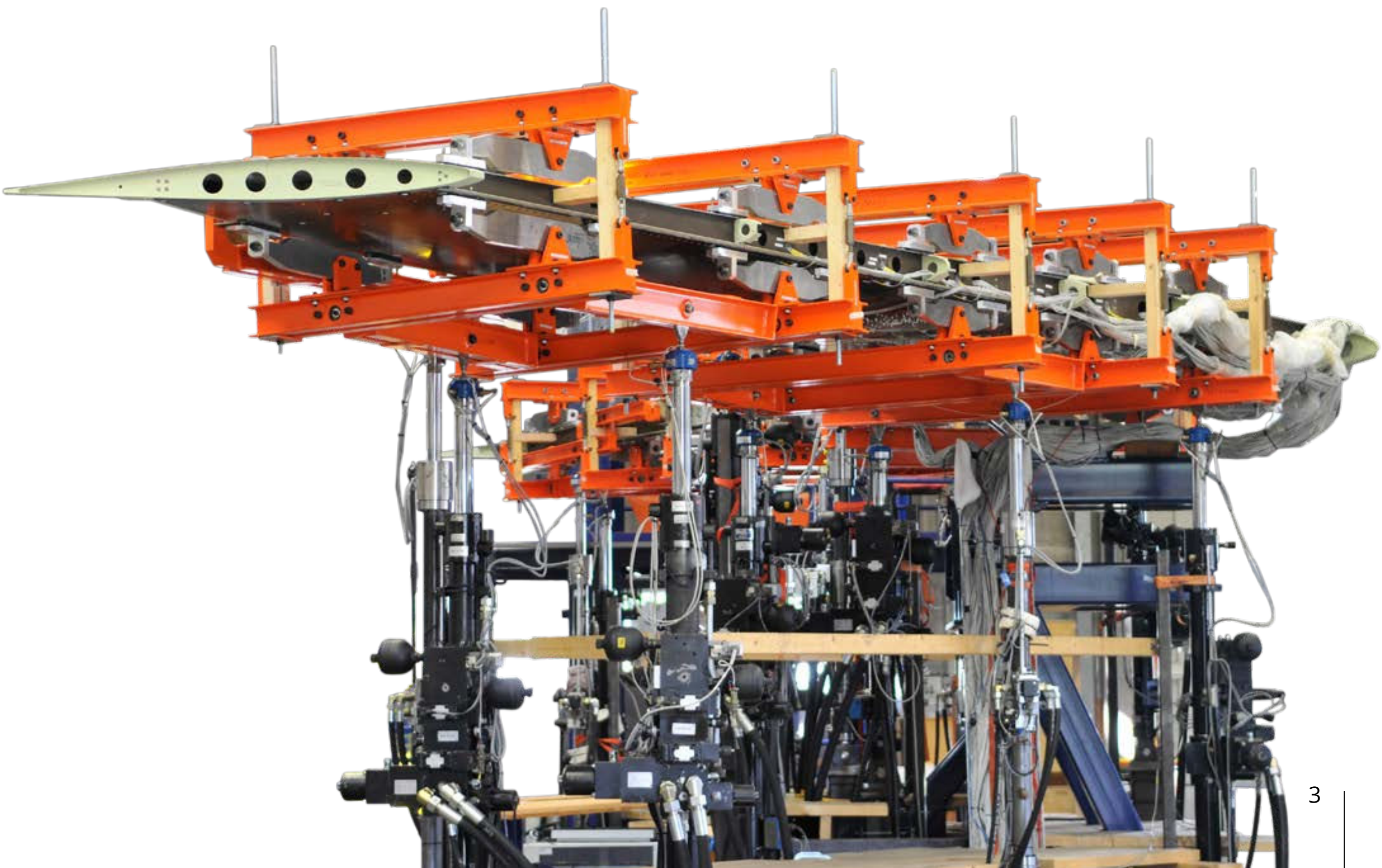


ACTIVITY AREAS

MECHANICAL TESTING

Coupon and materials testing

Static, fatigue and damage tolerance testing according to international standards or customer specifications. Materials testing, evaluation and qualification programs. Ambient, (deep-) cryogenic or elevated temperatures; dry, wet or chemically enhanced. Chemically enhanced ranges from (toxic) oil and gas related substances to (liquid) hydrogen

Panel and component testing

Large complex component testing, shear / compression buckling, fatigue and damage tolerance testing, curved fuselage panel testing. Ambient, cryogenic or elevated temperatures; dry or wet.

Full scale testing, certification or research

Load spectrum generation, rig design, testing and inspections of aircraft parts like moveables up to full wings or tails. Ambient, cryogenic or elevated temperatures; dry or wet.

ENVIRONMENTAL TESTING

Testing of materials and systems under various environmental conditions. High/low temperature, humidity, salt spray, decompression, altitude and waterproofness testing. Additionally, vibration, shock, acceleration, electric and acoustic environmental tests can be performed at NLR too, see specific brochure.

MATERIAL EVALUATION

Failure analysis

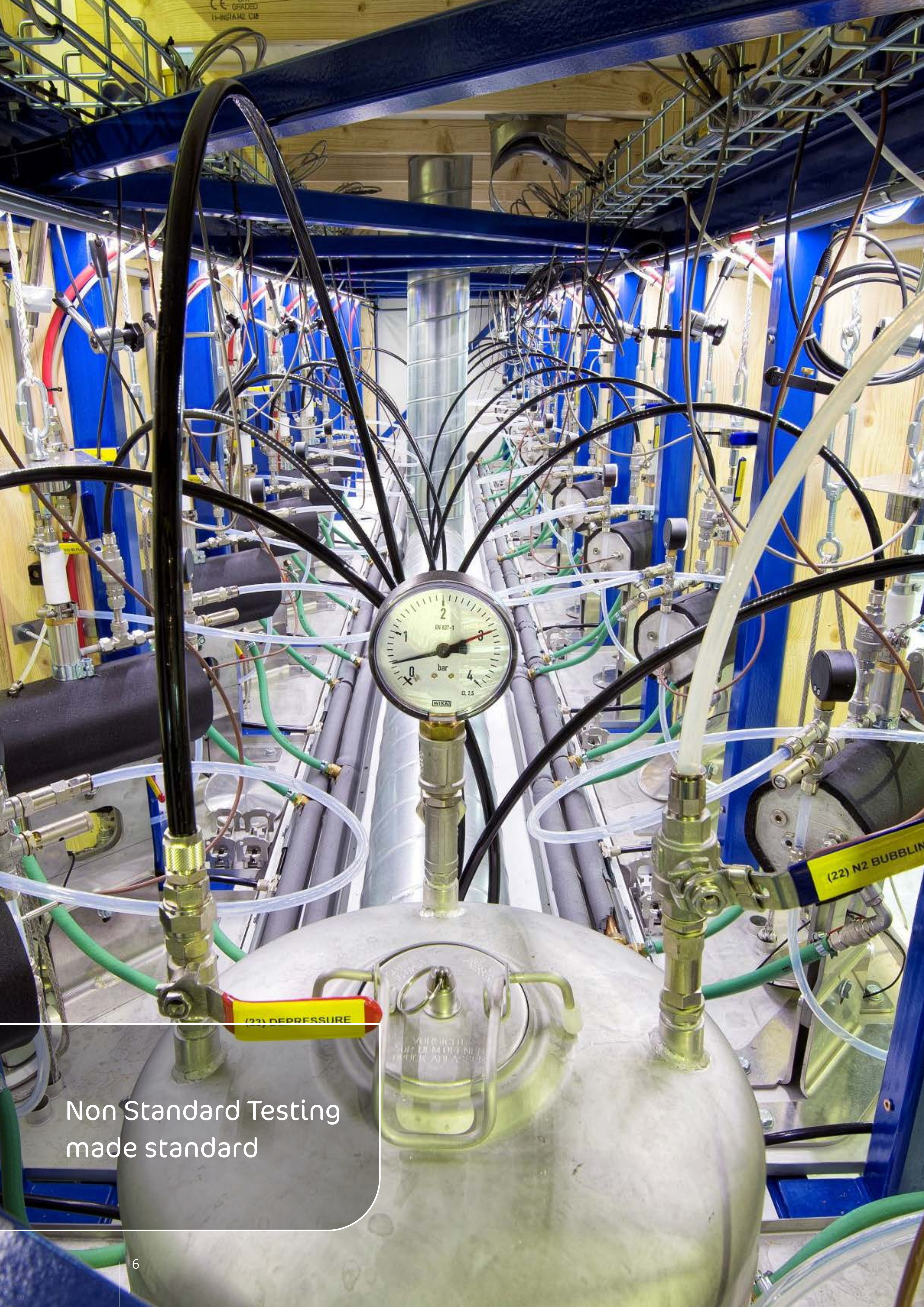
Materials failure and corrosion analysis, metallurgical services and forensic engineering. Material failure analysis is performed mostly both post-mortem but also in-situ.

Non-Destructive inspection

Fully automated C-scans, submerged and squirter mode, single beam and phased array, laser ultra sonics, Eddy current, ultrasound, dye penetrant, thermography, shearography, 3D structured light and magnetic inspection.

INTRODUCTION

NLR acts as a one-stop-shop for “Non-Standard” testing of aircraft parts, structures and materials. The traditional structural testing has evolved, it includes energy transition related testing: deep cryogenic, hydrogen, fuel cells, and hydrogen electric power trains (in full or its components).
We have the capability to offer you inspection, testing, characterization and fail- ure analysis. For structures, we can do that on material level, coupon level, component level or full-scale level. We can perform standardized tests, material qualification, certification tests, or tests made fit for your purposes. Energy transition related testing includes; mechanical testing to enable usage of liquid hydrogen (mechanical properties @20K, permeability) and energy related testing to enable the usage of hydrogen electric power trains (electrical performance, energy (heat) management, EMI, fuel cell health monitoring).
We can assist you in designing, manufacturing and machining your test articles and test setups and help you to set up a test plan. Our simulation, engineering, manufacturing and machining capabilities enable us to provide you with the best tooling and test setup structures. This document gives an overview of available testing equipment, including its specifications.



Non Standard Testing made standard

MECHANICAL TESTING EQUIPMENT

Standard Static test machines

Instron model 59R5882

Force range	:	200 N – 100 kN
Temperature range	:	-196 °C to +1200 °C
Humidity	:	70-95% RH / 50-90 °C
Testing speed	:	0.00005 to 500 mm/min
Horizontal test space	:	575 mm
Vertical test space	:	1235 mm

Instron 5882

Instron model 68FM-100

Force range	:	100 N – 100 kN
Temperature range	:	-196 °C to +1200 °C
Humidity	:	70-95% RH / 50-90 °C
Testing speed	:	0.00005 to 1080 mm/min
Horizontal test space	:	575 mm
Vertical test space	:	1906 mm

Instron model 5989

Force range	:	1200 N – 600 kN
Temperature range	:	-196 °C to +1200 °C
Humidity	:	70-95% RH / 50-90 °C
Testing speed	:	0.00005 to 508 mm/min
Horizontal test space	:	763 mm
Vertical test space	:	1790 mm

Instron 5989

All Instron machines are equipped with state of the art Instron controllers, combined with the latest Blue Hill test software, featuring:

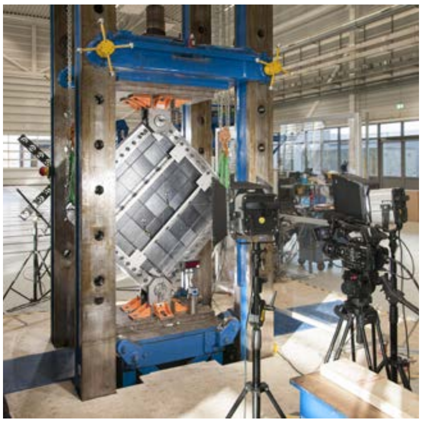
- 2.5 kHz or 5 kHz data acquisition (high sample rate for brittle specimen)
- 16 channel data acquisition system for external data logging of temperatures, pressure etc.
- 2.5 kHz control loop update

Avery

Force range	:	2000 kN compression 1500 kN tension (special tooling needed) Force and displacement controlled
Temperature range	:	-55 °C to +120 °C (+specials) Rel.
Humidity	:	controllable
Horizontal spacing	:	1040 mm between guides
Shear frames available	:	1000 x 1000 mm 800 x 800 mm
Max. specimen length	:	Compression without support: 630 – 3680mm Compression with support: 0 – 3680 mm Tension: 2470 mm (centre to centre)

Controlled by Instron ISRS 5500 controller, combined with Partner software, featuring:

- 2 channel data acquisition system for data logging of load and ram displacement



Avery with rectangular shear frame, video, online monitoring, DIC,

Standard Dynamic test machines

The dynamic test machines below are equipped with Instron 8800 controller, combined with WaveMatrix 2 software, featuring:

- Up to 5 kHz data acquisition
- 5 kHz control loop update
- LabVIEW programmable interface

Complete software package including Matelect®
Direct Current Potential Drop (DCPD).
KIC & CTOD fracture toughness / J-Integral / Flight spectrum loading.
Low Cycle Fatigue testing, strain controlled, high temperature.

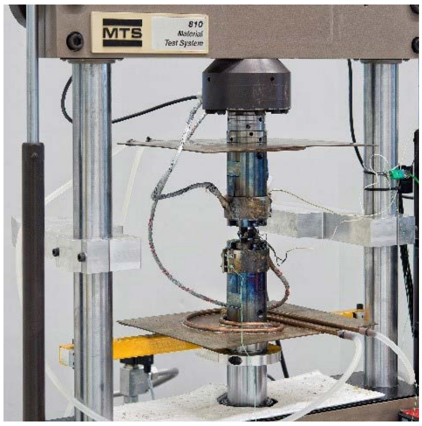
Instron E20000 All Electric dynamic test machine

20 kN (ElectroPuls E20000)

Full electric test bench
Max. specimen size : length: 850 mm excluding grips
width: 25 (standard pneumatic grips)
Horizontal spacing between guides: 515 mm
Other gripping options on request

20 kN (Minima)

Max. specimen size : length: 750 mm excluding grips
width: 25 (standard hydraulic grips)
Horizontal spacing between guides: 355 mm
Other gripping options on request



MTS, dynamic testing of coupons with heating and cooling devices

3 x 100 kN (MTS, Maxima and Schenck)

Load and displacement control
Max. specimen size : length: 600 mm
width 85 mm (standard hydraulic grips)
width 110/160 mm plate specimen mechanical grips

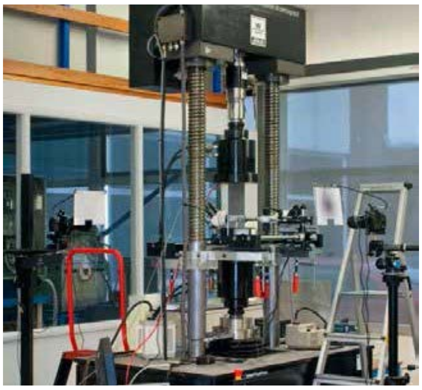
Temperature ranges : -80°C, RT, till +1300 °C
Horizontal spacing between guides: 700 mm

1 x 200 kN (Amsler)

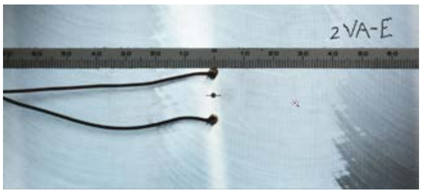
Load and displacement control

Max. specimen size : length: 1350 mm (max. 650 with hydraulic grips)
width: 50 and 160 mm (standard hydraulic grips)
width: 110 / 160 mm plate specimen (mechanical grips)

Temperature ranges : -80°C, RT, till +1300 °C
Horizontal spacing between guides: 600 mm



Amsler, crack growth sample, see below



Fully automated crack growth monitoring

1 x 250 kN (Instron)

Load and displacement control

Max. specimen size : length: 1350 mm (max. 650 with hydraulic grips)
width: 50 and 160 mm (standard hydraulic grips)
width: 110 / 160 mm plate specimen (mechanical grips)

Temperature ranges : -80°C, RT, till +1300 °C
Horizontal spacing between guides: 660 mm

1x x500 kN (MTS 500)

This dynamic test machine can be controlled by a MOOG SmarTEST control system, or a Perdok control system.

Force range : 500 kN tension
500 kN compression
Force and displacement controlled
Temperature range : -55 °C to +120 °C (+specials) Rel.
Humidity : controllable
Horizontal spacing : no limit (4 columns)
Shear frames available : 1000 x 1000 mm
800 x 800 mm
Max. specimen size :
- standard 500kN hydraulic grips length 1500mm, width 75
- standard 250kN hydraulic grips length 1600mm, width 160
- Wider specimens possible using non-standard mechanical grips

MTS 500

1 x 900 kN (WolpertAMSmsler)

Load and displacement control

Force range : 600 kN tension (100, 250, 500 and 1000 kN)
800 kN compression @ 210 bar (standard) pressure
1000 kN compression @ 280 bar pressure
Max. specimen size : Compression: Ø 190 mm x 1620 mm
(max. load 500 kN)
Beam: 600 x 180 mm, max 1220 mm
Plate: 600 x 920 mm
Plate: 600 x 1500 mm (< 250 kN)

Temperature ranges : -80°C, RT, till +1300 °C
Horizontal spacing between guides: 700 mm

▼ *WAMS*

Mechanical testing with enhanced chemical environments

Dynamic testing can be performed, not only hot-wet or cold-dry, but also in combination with speial (toxic, explosive) environments and/or saturations. For the energy industry material testing of composites saturated in Norsok has been performed, leading to the first certified DNV-GL F119 compliant material.
Temperatures up to 93°C, hence above boiling points, hence in pressuruzed contained autoclaves. Preparations are ongoing to enable testing with hydrogen and carbon-diaxides. Higher temperatures up to 120°C are under development

Coupon testing in dedicated autoclaves

For static, dynamic and creep testing in special (toxic) environments a autoclave solution in created. This enables in-situ testing within the (fluid/gas) environment at controlled pressures and temperatures.

Creep testing

NLR can carry out creep tests on several material types, e.g. high temperature engine materials or materials for energy industry (Fossil and Sustainable). A number of individual frames in a controlled room can be used for creep testing. Specific creep test setups, combined within a controlled environmental cabinet, are used for large creep test programmes, including low and elevated temperature possibly combined with toxic environments (e.g, NORSOK). Preparations for hydrogen of carbon-dioxide environments are on-going.

Tests in the setups within the environmental cabinets can be performed on the following samples:

- Cylindrical ASTM samples, M8, M6 and M4 interfaces are available
- 3 mm flat plate samples according ASTM
- Specials on request (temperature, humidity, flammable, toxic environment etc)

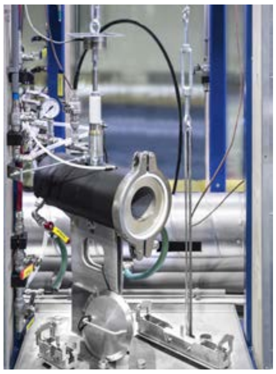
Maximum specimen length = 550 mm and width = 160 mm

Loads are applied by dead weight and a low friction hinged lever. Forces up to 100 kN can be applied on the test sample.
Samples can be manufactured by NLR out of bare material or extracted from a specific part according ASTM requirements.

For the individual test frames, ovens are available for testing at the following temperatures:

- Two induction ovens for temperatures up to 1600 °C
- Three resistance ovens up to 1100 °C
- One resistance oven up to 1200 °C
- Induction coils for heating and simultaneous strain measuring

Electric and hydraulic dynamic test machines with enhanced chemical environments



Dedicated Autoclave

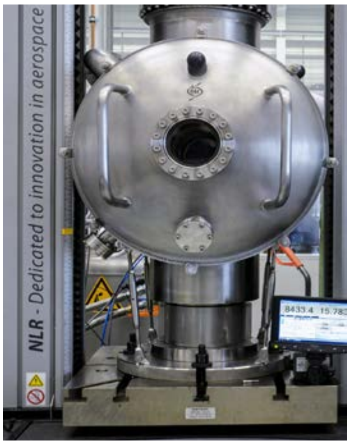
Creep frames combined within an controlled environmental cabinet

Series of creep frames within a controlled room.

Creep test with coil heating, strain measuring and grip cooling

Special mechanical test tooling

Special extentions of the standard test machines is one of the ways NLR tries to improve its possibilities.



Mechanical testing cryostat

This mechanical testing cryostat enables deep cryogenic (20K) material and structures testing. In a double walled vacuum insulated vessel, most static ASTM/AITM mechanical property testing can be performed at 20K.
The cryostat is used within a standard Instron test bench

Force range	: -100 N to +250 kN
Temperature range	: -253°C to +20°C
Testing speed	: 0.00005 to 500 mm/min
Horizontal test space	: 400 mm
Vertical test space	: 400 mm

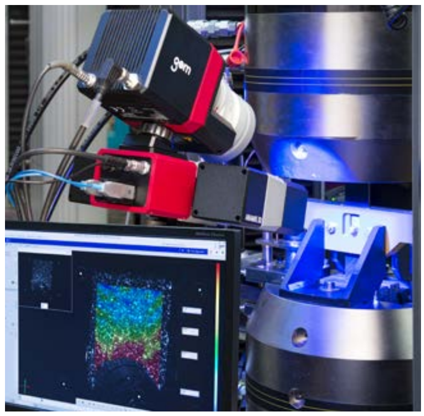
Cooling is performed using liquid nitrogen to pre-cool and liquid helium for final cooling. Cryo-pumps assist the cooling process in order to minimize helium consumption.
Currently only static testing at 20K can be performed. Developments are ongoing to enable long term (dynamic) testing, in a hydrogen environment at 20K. Commercial availability of long term testing is foreseen in 2026.

DCB-UBM

The standard double cantilever beam tooling has been replaced by uneven bending moment capabilities. The device is capable to test GI ,GII and mixed mode fracture toughness properties. Currently only static loads can be applied. An update to enable dynamic loading is under preparation. On top of the constant moment loading on the crack tip, this moment is also measured using an calibrated strain gauge instrumented load introduction device.

Bearing By-pass

In order to load the bolt/rivet in a loaded joint, with variable loading ratios, both in tension and compression, a bearing bypass extension on a standard Instron machine has been developed. Besides the hardware especially the master-slave steering makes this solution unique and innovative.

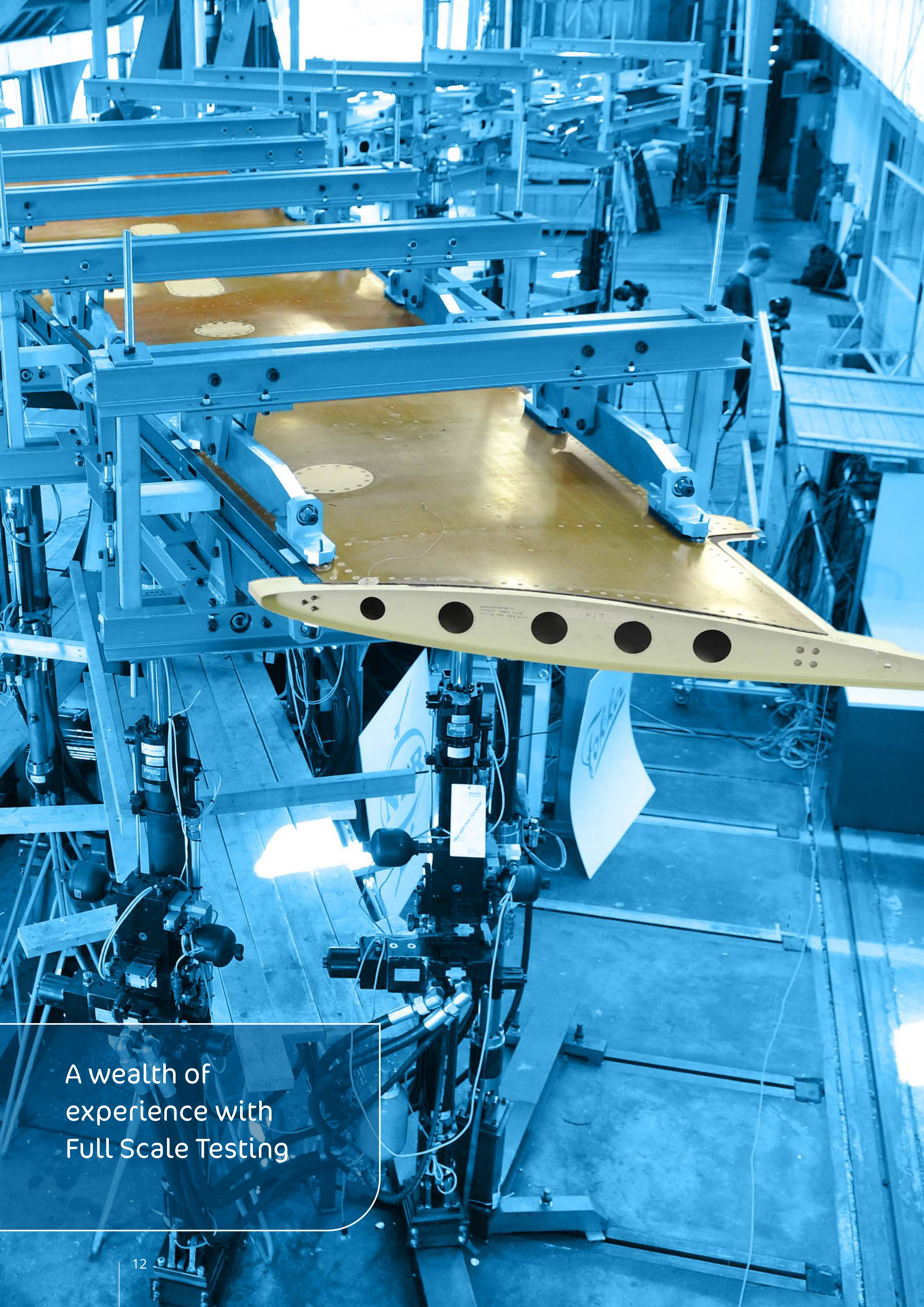


Automated 3D strain measurement

In several standard testing procedures the strain needs to be measured. This is traditionally done using strain gauges or clips. Alternatively NLR uses DIC optics, fully integrated into the Instron testing environment. After an initial calibration each strain measurement is just a simple click of the camera. Given the 3D optics also the strain (field) at the back end can be derived bases upon fronts train (fiels) and curvature (fields). For OHC testing this setup is very price competitive, since it makes 4 strain gauge per coupon obsolete.

Thermo-Electro-Mechanical testing

A special purpose testing machine has been developed within the EU-funded project DiDi. It enables testing of diode dies. It can dynamically test the diode, while a current (1600A) has been generated in one direction or a voltage (2000V) has been applied in the opposite direction. The whole testing is performed in a cyclic temperature regime (-55°C up to 150°C).



A wealth of experience with Full Scale Testing

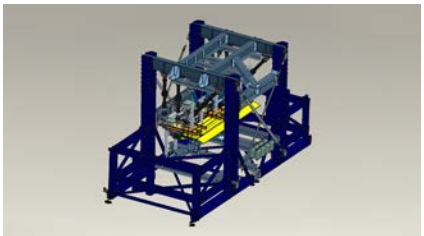
Multi-axial or Full-Scale Testing (FST)

Full scale multi-axial testing (FST) provides certification and customized demonstration of new structural technologies in aviation and aerospace. Typical projects are demonstration of innovative morphing flaps, multi-functional flap mechanisms, landing gears with complex kinematics and certification of full size wings with circular materials and optimized structures.

To optimize the tests, FST makes extensive use of structural and kinematic models, which are developed in house as part of the Virtual Aircraft Vehicle. FST is working on web based data presentation tooling to real life present test data on or near the test article and compare the test outcome with predicted data from the models.

A recent success is accomplishment of a significant smaller time to market by outlining and use of virtual test tooling in an early design stage before the test subject is fully developed. Another achievement is the integration of hydraulic actuator models in the tooling to be able to test and validate force fighting issues in multi axial actuation systems. Target is to further extend the tooling with Aerodynamic models to predict and optimize technologies with respect to fluid /structure interaction.

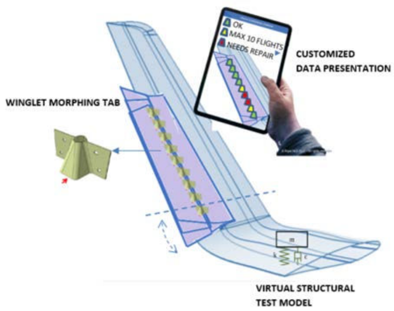
MANTA test setup used as basis for Morphing Flap



Modular Morphing Flap test rig development

CERTIFICATION

- Static limit load and ultimate load testing, dynamic testing & fatigue
- Damage Tolerance & Margin search
- Virtual model development & test optimization
- Data acquisition and customized data presentation, supply of data for stress calibration
- Testing under relevant environmental conditions, for instance temperature, ice or contamination



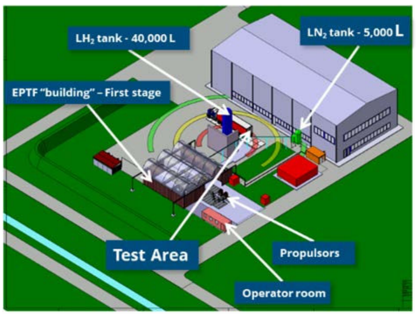
Customized data presentation

DEMONSTRATION NEW CONCEPTS

- Detailed design & manufacturing of new concepts
- Modular Test rig design
- Virtual model development for demonstration testing
  - Capability of modelling innovative, new technologies, such as Morphing structures with a relative complex deformation behaviour
  - Capability of modelling multi axial hydraulic actuation systems
- Physical full scale demonstration of new technologies and comparison with models
- Real life presentation of structural test data (displacements, deformations and strains) on the test piece

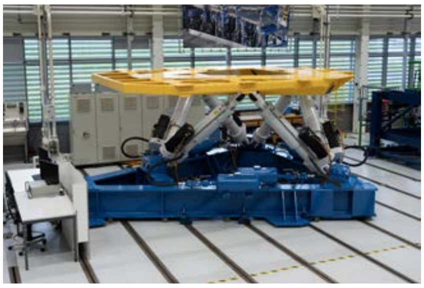
In the near future full scale testing (FST) will have close links to the Energy to Propulsion Test Facility (EPTF) at NLR. Our target is to model and perform multi axial structural tests on hydrogen storage and distribution systems for aviation and space under relevant environmental conditions.

The EPTF features a 40m3 liquid hydrogen tank, a gaseous hydrogen supply, sufficient liquid and gaseous nitrogen, 400kVA bidirectional power supply, AC/AD converters, hydraulics and pneumatics, a sound wall, free space, a shelter against wind and rain (which is equivalent to the open air) and last but not least; permits to operate. Formal opening November 2025.



Energy to Propulsion Test Facility (EPTF)

The first 110kW hydrogen electric fuel cell has already been tested. Complete powertrains up to multiple MW are under contract in the near future. Besides electric response testing also mechanical testing is to be performed. Mechanical testing implies; slosh testing of filled liquid hydrogen tanks, deformation testing of (superconductive) cryogenic piping and cables as well as attitude testing of complete power trains on the GRACE.



Multi axial positioning device GRACE

GRACE is a hexapod, a moving platform, able to mimic whatever movements of an airplane, schip or car. It can kick 7 tons of mass around with accelerations up to 9g. (Former F16 simulator moving platform). It can be operated outside at the EPTF or inside in the main building.

EXAMPLES

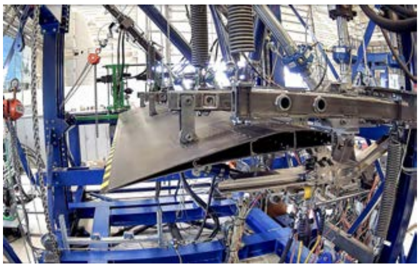
MANTA Morphing Wing Tab (WMT)

Detailed design, test and demonstration of a Morphing Winglet Tab under realistic wing bending and air load. The elastic behavior of the wing torsion box is mimicked by the orange metal dummy. Notice that the upper surface of the torsion box and the upper surface of the actual tab runs continuously. Structurally the upper surface of the tab and torsion box is a single piece.
No gap between tab and main wing implies superior aerodynamics.
The deflection of the tab is not a hinge rotation, there are no hinges only deformable load carrying connectors. The test showed superior long term resilience of the novel morphing structure.

MANTA Morphing Wing Tab (WMT)

MANTA Multi Functional Flap Mechanism (MFFM)

Detailed design, test and demonstration of a Multi Functional Flap mechanism with an additional degrees of freedom realize the combined function of aileron and flap within a single movable. The flap has at 3 spanwise stations prescribed deformations, representing wing bending and torsion. In deformed state the flap is rotated up to 60 degrees per second, while a linearly approximated air load as function of rotation angle, is applied. Several use case have been performed , including partial failures. Test showed promising results towards the feasibility of this concept.



MANTA Multi Functional Flap Mechanism (MFFM)

Algesmo Nose Landing Gear

An advanced optical-based landing gear load sensing and monitoring system was developed including the integration of optical fibres into a composite structure, an optical harness meeting aircraft installation requirements and a flight worthy interrogator. The system measures strains using optical fibre Bragg grating (FBG) sensor that are converted into loads and torque at the landing gear wheels and provides this data for use by the aircraft systems for integration with aircraft health monitoring, hard landing detection, flight management, flight controls and ground controls. A bespoke test rig was developed to rigorously test the whole sensing and monitoring system on an A320 main landing gear slider tube to validate the performance of the system. The system-level tests performed on the test rig showed a very good correlation with applied actuator loads and additional conventional strain and temperature sensors. It demonstrated that loads along all three axis of the landing gear and the torque about the wheel axle can be accurately measured. Tests performed at cold and elevated temperatures.

Algesmo Nose Landing Gear

Certification test of C-series commercial flap tracs at -55°C

The Airbus 220 (formely Bomabdier C-series) flap tracks, made by ASCO, are tested for certification at different environmental circumstances: ambient, -55°C, clean tracks and tracks inflicted with sand & dust. For NLR it was the first full scale certification test, where temperature was controlled down to -55°C. Several weeks (24/7) of full scale fatigue testing at -55ºC have been done. Full scale testing encompasses both elastic deformation testing as kinematic system testing.

C-series flap track testing at -55°C (24/7)

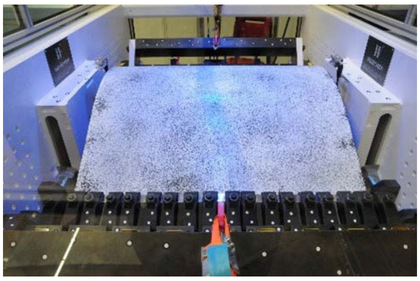
Damage Enhangement Test on an actual F16 wing.

In the period when the F35 was intended to replace the F16 within the Netherlands Airforce, there was an availability gap between the arrival of the F35 and the de-commissioning of the F16. Many of the Dutch F16's, according the maintenance manual, needed replacements of the wing. Due to NLR's long time commitment to the F16, it has build a lot of knowledge on the structure and the loading. Using a "Damage Enhancement Test" as the master piece of proof, NLR was able to convince the OEM and authorities, that the Dutch F16's, flying the Dutch spectrum and not the design spectrum, did not yet need the replacement of the wings.

F16 Damage Enhancement Test

Mini stretcher

Demonstration and improvement of a mini stretcher to optimize the stretch forming process of metallic aircraft components with fewer process steps and less material use. The improvement is measuring the strain field while deforming and adjusting the deformation load distribution in the load control process.



Mini strecher with optical feed back steering

Special test machines

Fuselage panel test facility (ROTOP)

Fuselage panels can be subjected to multi-axial loading conditions at room temperature. Internal cabin pressure is combined with longitudinal load introduction. Longitudinal loads are introduced using lugs that are bolted to the skin at each end and lateral load reaction at the frame ends and in the skin through a bonded interface. This bonded interface is a unique feature, providing a highly uniform hoop load, unmatched by any discrete bolted/riveted connection.

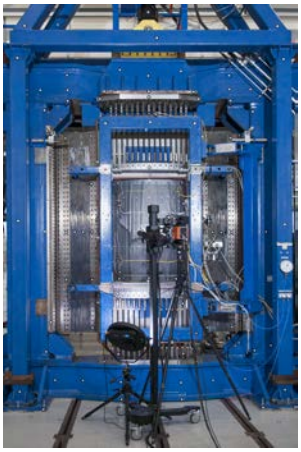
The design loads for the fuselage test facility were derived directly from the fatigue and static design loads of typical fuselage sections. This resulted in the following design loads for the test facility (the running loads per mm panel width or panel length are given between parentheses:

Static	: axial load	:	950 kN	(700 N/mm)
	ΔP / tangential skin load	:	1.2 bars	(340N/mm)
Fatigue	: axial load	:	450 kN	(334 N/mm)
	ΔP / tangential skin load	:	0.6 bars	(340N/mm)

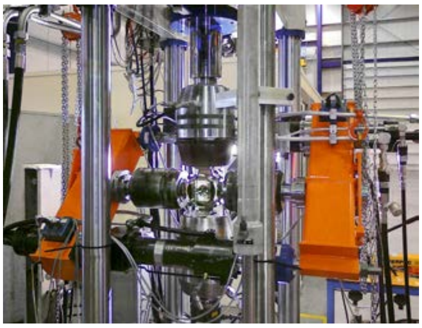
A range of different fuselage panels with different curvatures has been tested in the fuselage panel test rig. In the table below some typical examples of tested panels are given.

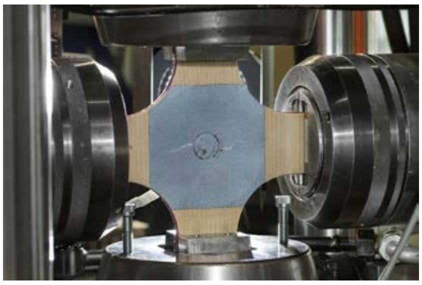
Panel lengths may range from 2800 mm to 1730 mm.

Aircraft	Fuselage diameter [mm]	Type of test	Type of loading	Goal
Shots Global Express	2693	Fatigue + Damage Tolerance + Residual strength	Flight simulation spectrum	Demonstrate technological feasibility of Glare side-wall fuselage panels
Alenia ATR 42	2865	Residual strength	Static + Constant amplitude	Verification of residual strength models with and without multi-site damage (MSD)
JAXA investigation	2880	Static + Fatigue	Constant amplitude	Natural crack growth in lap-joint
ACASIAS	3300	Static + Fatigue	Static + Constant amplitude	Integrating antennas in novel AFP orthogrid composite fuselage panels
Fokker 100	3300	Static + Fatigue	Flight simulation spectrum	Demonstrate feasibility of Glare and Glare stringers and structural health monitoring systems
STUNNING	3950	Residual strength	Static	Development of a progressive fracture method to predict crack arrest in thermoplastic fuselage panels
ANSA	3950	Fatigue + Damage Tolerance	Flight simulation spectrum	Fatigue crack growth + demonstrate bonded repair patch
Airbus A300	5640	Residual strength	Static	Verification of residual strength models with and without multi-site damage (MSD)
Airbus 380	3950	Static + Fatigue	Constant amplitude	Investigation of orbital joint and longitudinal joint at stringer

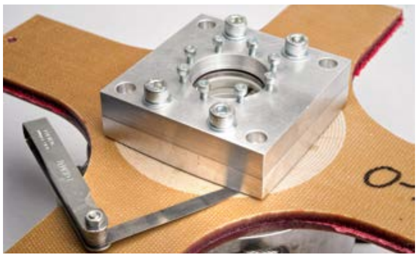


Rotop





Biax



Transparent Anti Buckling Guide for Biax

Bi-axial Test frame (Biax)

Static and dynamic testing in all four quadrants

Tension-Tension   Tension-Compression

Compression-Tension   Compression-Compression

Vertical load up to 500 kN, horizontal load up to 200 kN. Dynamic testing performed up to 5Hz for common specimen.

Application of a transparent anti-buckling guide is an option. This allows DIC measurements during compression tests.

Panel test rig

Horizontal test space 1400 mm ; Vertical test space 3000 mm

Force range 2300 kN tension ; 2300 kN compression

Impact testing

Instrumented impact facilities are available for high and low speed impact testing. Mass and velocity are measured using calibrated instruments. Energy prediction and measurement is embedded in software system. Digital and hard copy output with all relevant impact data.

Mobile impactor

Handy low speed device, instrumented, mobile impactor up to 150 Joule using elongated tube, including catching device

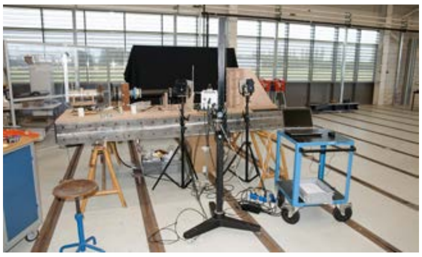
Mobile Impactor

Drop tower

7 mtr height with 10 kg weight. Incl. velocity sensor and load sensor. High speed DIC instrumentation possible.

High velocity impact gun

Ice or metal projectiles up to 2 inches. Speed up to 210 m/s

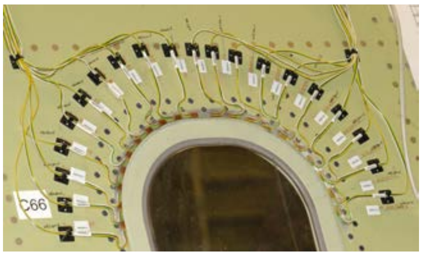


High Velocity Impact Gun

Measurement techniques

A broad range of transducers types is available:

- Strain transducers (strain gauges, extensometers, DIC, lasers, fibre optic)
- Displacement transducers (LVDT, linear encoders, SPR, lasers, capacitive, draw wire, etc)
- Temperature (pyrometry, thermography IR camera, thermal paint, PT100, thermocouples)
- CMOD clip gauges (displacement of the crack mouth opening
- Loadcell's from 0 up to 2500 kN
- Pressure, acceleration, flow



Strain gauges on window panel

Data-acquisition systems

- Dedicated (strain gauge) multi-amplifier Peekel Instruments systems
- (up to 2500 strain gauge channels; 7 x dynamic 1kS/s, 3 x multiplexer 10 S/s, 4 x seq. scanner systems)
- 3 x 250 KS/s multiplexer NI PXI systems
- 6 x 200 KS/s multiplexer IOtech systems
- Dedicated (strain gauge) multi-amplifier HBM systems
- Wireless MicroStrain systems for strain, temperature, DC and
- acceleration
- High speed and/or high accuracy

Data Acquisition System (288 channels)

Multi-Axis Control systems

- 6 MOOG Aerospace test systems, up to 500 channels
  - Loop update rate 2.5kHz
  - Centralized data base to access all tests and test data
  - Pseudo channels, special functions, mixed force modes etc. to meet the most challenging test requirements

- 1 "Next Generation" MOOG Aero Test Controller equipped with:
  - 10 Control channels and upgradable to 32 channels
  - Interface to 16 bridge type analogue sensors
  - Loop update rate up to 5kHz
  - Real time modular control system for static, dynamic or endurance testing
  - Wide range of transducer inputs and control outputs
  - Modular design allows easier upgrades
  - Capable of integrating and combining with the older MOOG systems into a test. "Add-on repair module"
  - Using the same, well known, Aerotest software as the older MOOG systems
- Wide variety of hydraulic actuators
- Support of electric, pneumatic and hydraulic test systems
- RvA calibrated controllers, load cells and data acquisition systems
- Fully integrated with acquisition systems

Single Axis Control systems

- Three custom made (Perdok/NLR) single axis actuator control systems
  - Control system for static, dynamic or endurance testing
  - Loop update rate 250 Hz
  - Position or load controllable
  - Linkable for multi axis testing
  - Modbus data system

Pyrometry

A pyrometer is a non-contacting device that intercepts and measures thermal radiation which can be used to determine the temperature of an object's surface

- Contactless
- Infrared radiation
- Emission coefficients

Types: Heitronics, Williamson, Keller, Optris

General specifications

- Temperature range .....-1500 °C
- Accuracy up to 0.5 °C
- Spot diameter min. 2 mm
- Optical viewfinders, display and laser aiming sight options
- Response time 5 ms – 600 sec

Potential Drop

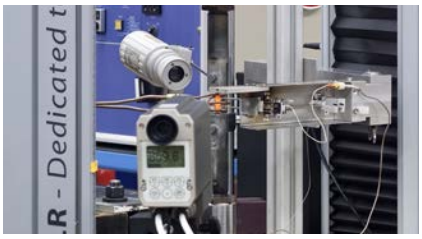
Potential drop instruments for the measurement of crack initiation and propagation in metals, also in the presence of stress corrosion effects.

Potential drop techniques rely upon the basic principle that a conductive specimen that carries an electric current will exhibit a voltage drop across its surface. If the resistance of the specimen is known, the voltage drop can be calculated for any particular value of the current. Specimen resistance can be altered by the presence of a defect such as a crack. Thus, by maintaining a constant current through the specimen, it is possible to detect the initiation and propagation of a defect by monitoring the value of the potential drop.In potential drop studies, it is not usually important to know the absolute value of the resistance or voltage since it is the relative change in poten- tial that is used to monitor crack growth.

Typical Moog Control system

MOOG Next Generation control system

Typical Perdok Control system



Pyrometry

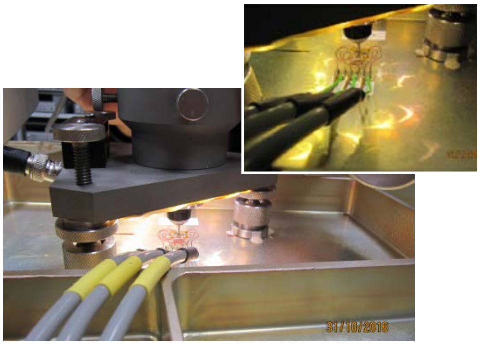
Potential drop

Residual stress measurements
(hole drilling method)

The strength behaviour of components is influenced by residual stresses existing in these components without showing any visible signs.

The most widely used practical technique for determining residual stresses is the hole-drilling strain gauge method described in ASTM Standard E837. With this method, a specially configured strain gauge rosette is bonded to the surface of the test object. A small shallow hole is introduced into the structure, through the center of the gauge, with a precision drilling apparatus. Strains in the immediate vicinity of the hole are measured, and the relaxed residual stresses are computed from these measurements.

System:
- Vishay RS 200



Residual stress measurement

Courtesy: Airbus Defence & Space Netherlands

Fibre Optic Sensors

Fibre bragg gratings (FBGs) appear to offer the best prospect for large scale commercial exploitation of fibre optic sensor (FOS) technology.
Main applications:

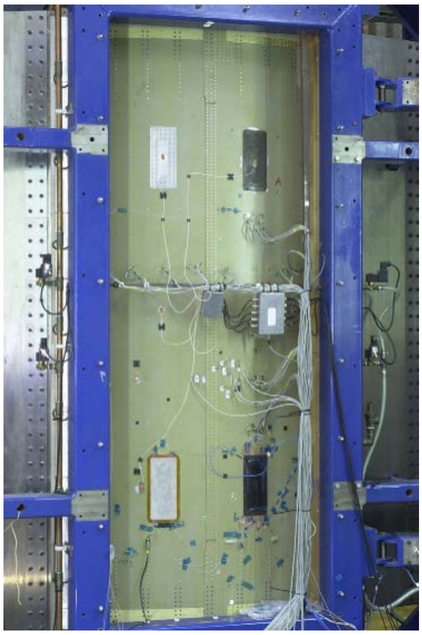
Structural Health Monitoring (SHM)
- load & usage monitoring
- impact detection
- damage detection

Process monitoring of composite materials
- state of cure during manufacturing
- internal strain after manufacturing

General attributes
- High spatial resolution, high sensitivity, low signal loss
- Small diameter, light weight, flexible
- Immunity against, i.e. applicable in
  - Electro-magnetic fields, high voltage, lightning
  - Explosive or chemically aggressive + corrosive media
  - High and low temperatures
- Read-out unit galvanically separated from object
- Ability to measure different parameters such as strain, temperature, pressure, acceleration, moisture, corrosion, chemical compounds (H2 level)

Measurement equipment
- PhotonFirst Gator, 1 CH, 8 FBGs, 20 kHz sample rate
- PhotonFirst XGator, 8 CH, 8 FBGs/CH, 0.1-20 kHz sample rate
- Smart fibres SmartScan Aero mini, 4 CH, max 16 FBGs/CH, 2.5-25 kHz sample rate
- FiSens FiSpec X1000-2, 1CH, 24 FBGs, 1-2 kHz sample rate

Main optical equipment
- Fujikura 90S Fusion Splicer
- Tools to install optical connectors
- VIAVI OLP-85 optical power meter
- FBP-P5000I Digital Probe



Demonstration of the feasibility of specific SHM systems on a representative structure (Glare fuselage panel with bonded and riveted repair patches

NLR Environmental test facilities

- **Climatic**
  - Temperature
  - Humidity
  - Salt Spray
  - UV Light
  - Fluid Susceptibility
  - Altitude, Decompression & Overpressure
  - Waterproofness
  - Icing
  - Tear Down
  - Thermal Vacuum
  - Fungus ■
  - Sand & Dust ■
- **Mechanical**
  - Vibration
  - Shock
  - Acceleration
  - Static Load
  - Bending Resistibility
  - Pull Force
- **Electric**
  - EMI/EMC
  - ESD
  - HIRF
  - Lightning
- **Radiation**
  - Total Dose ■
  - Proton ■
  - Heavy Ion ■
  - Californium Cf-252 ■
- **Acoustics**
  - Acoustic Noise
  - Transmission Loss

■ Tests performed externally under NLR responsibility

We do try to be a
Non Stop Shop

ENVIRONMENTAL TESTING EQUIPMENT

High/low temperature & humidity testing

The Testhouse of the Structures Testing & Evaluating Department operates four Climate Test Chambers for executing heat-cold tests in air conditions ranging from very dry to extremely humid.
Tests according to:

- RTCA DO-160
- MIL-STD-810
- IEC60068 Part 2-1, 2-2, 2-38, and 2-78

Specifications of climate chambers:

- Dimensions: 2000 × 2400 x 2400 mm (w x d x h)
  -10 to 80 °C and 20-90
- Dimensions up to: 910 × 1160 x 1110 mm
  -70 °C to +150 °C and 15-95%RH (between 10 °C and 95 °C).
  Maximum cooling rate is 3 °C/min.

Suitable for operational tests of electronic equipment. A complete range of power supplies can be used. Cable ports are available with diameters up to 100. In addition to testing of electronic components, NLR has a solid experience in testing composites and in accelerated corrosion testing.

Climate test chamber

Salt spray testing

The Testhouse of the Structures Testing & Evaluating Department operates two Salt spray cabinets for corrosion testing. Standard and customized tests can be executed on avionics, coated and non-coated materials and structures. Solutions can be acidified or Sulphur dioxide can be injected periodically to simulate acid rain.

Test according to:

- DIN 50017
- ASTM B117-07
- ASTM G85-02 Annex A1, Annex A2, A3, A4 (and Annex 5 (Salt/SO2) for cabinet 1 only)
- RTCA DO-160
- MIL-STD-810
- IEC 60068
- Other specific requirements

Temperature range between room temperature and +55 °C.
Maximum dimensions of Salt spray chamber 1:

- 1300 × 980 x 1320 mm (w × d x h)

Maximum dimensions of Salt spray chamber 2:

- 1010 × 640 x 1140 mm (w × d x h)

Cyclic tests can be executed with freely programmable spray, purge and soak periods.

Salt spray cabinet1

Salt spray cabinet 2

Fluid susceptibility testing

To perform fluid contamination tests on materials and equipment.
Tests according to:

- RTCA DO-160, MIL-STD-810
- Spray and Immersion tests
- Contamination with pasta like substances possible

Spray test facility specifications:

- Dimensions testbox: 750 × 700 × 500 mm (w × d × h)
- Fluid temperatures up to 80 °C (depending on flashpoint)
- Temperature controlled testbox
- Programmable spray intervals

Immersion test facility specifications:

- Dimensions testbox: on request

Fluid susceptibility cabinet

Icing test

Tests according to RTCA DO-160 Category C.
Controlled with a climate chamber and cooled spray bottle

Icing test

Waterproofness testing

Various test facilities for executing Condensing water proof test, drip proof test, spray proof test and continuous stream proof test.
Tests according to:

- RTCA DO-160
- MIL-STD-810

UV-testing

Tests according to:

- ASTM D4329, D4587, D4799, D5208, G151, G154 (Cycle 1-6)
- DIN EN 12224, 1297, 13523-10
- DIN EN ISO 4892-1
- SAE J2020

Fluorescent UV lamps:

- UVB 313; UVA 340; UVA 351

Specimen holder dimensions:

- 3 x 6 inch 4 x 6 inch Other dimensions on request

Waterproofness test and UV Tester

Climate cabinet with UV Tester

Decompression testing

As part of the NLR's 'One-stop shop' for Environmental test facilities, the NLR operates a Rapid Decompression test facility. This facility is developed to test the performance characteristics of avionics or materials during and after decompression. The main components of the Rapid Decompression Facility are two vacuum vessels, the decompression vessel (blue) can be evacuated to cabin pressures equivalent to 6000 to 8000ft. The big vacuum buffer (green) can be evacuated to pressures well below operation altitude. After opening a valve between both vessels, complete decompression of the small vessel can take place in 2 or 15 seconds to a maximum flight height of 52.000ft.

Determined during decompression tests are: leakage, deformation, rupture or explosion of (gasket sealed) containers, or a change in physical properties of low density materials.

In the past NLR has tested Avionics, Night-vision cameras, an AED, Pantry equipment like Bun warmers, Convection- and Steam-ovens, and all types of iPad's used as Electronic Flight Bag (EFB).

Decompression test specifications:

- Decompression test can be performed according:
  - RTCA DO-160G section 4
  - MIL-STD-810G Procedure III
  - Customized test-profiles upon request
  - Min. decompression time: 2 seconds
- Altitude testing
  - Altitudes up to 15.800 meters (52,000 feet)
- Overpressure testing:
  - Can be performed in our autoclave up to 200kPa
- Test Article dimensions 700x700x700mm
- Data acquisition (up to 20hz)
- Signal feed troughs for:
  - Power supply (3phase, Neutral & ground)
  - 9 thermocouples channels for K- or T-type
  - Video system
  - 19 Pins connector for test article data
  - Cooling water
  - 3 x USB

Brazing and heat treatment

NLR is equipped with several high temperature furnaces for the brazing, heat treatment and the testing of materials.

Torvac Vacuum Furnace

In the full metal vacuum furnace, specimens with a maximum diameter of 280 mm and a height of 350 mm can be heat treated and/or brazed at a temperature up to 1250 °C. The furnace is automatically controlled and operates in vacuum mode or in a protective gas mode.

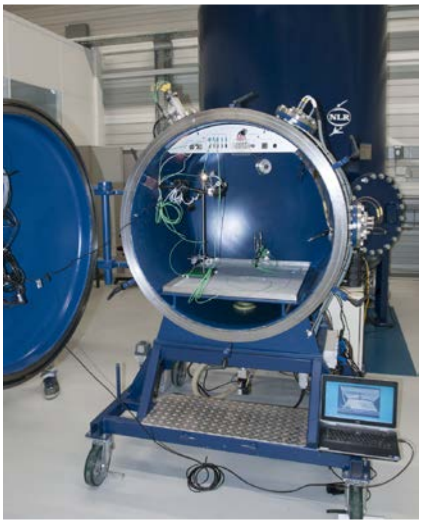
Air circulation furnaces

For the standard annealing and tempering of materials up to 750 °C with a maximum dimension of 350 x 350 x 350 mm.

Heat treatment furnaces

For the high temperature applications up to 1400 °C with a maximum dimension of 320 x 320 x 320 mm these furnaces are used for heat treatment and/or testing materials. Two furnaces are specially equipped with an installation to simulate a shock effect on the material and/or coatings.

Together with the 'Avionics Technology' department (ASAQ) an extensive set of environmental test capabilities is available, see specific brochure.



Rapid decompression test facility

Torvac Vacuum Furnace

Furnaces

▼ *Large furnace*

Where questions about materials are answered

FAILURE ANALYSIS EQUIPMENT

Scanning Electron Microscope

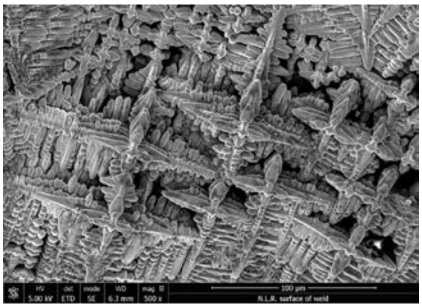
The Netherlands Aerospace Centre NLR of the Netherlands has a wide experience in the area of failure analysis and forensic engineering.
In the past 40 years, more than 400 service failure related investigations were performed under contract to industry and aircraft operators, in the following application fields:

- Aerospace
- Aircraft power plants and structures
- Energy supply (gas turbines and wind turbines)
- Mechanical, chemical and industrial engineering
- Manufacturing processes
- Offshore structures
- Automotive
- Shipping

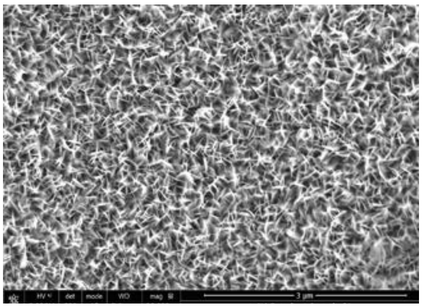
For failure analysis the NLR uses standard and advanced equipment, including;

- Optical microscopes, magnification up to 1000×, including high definition image capturing and image analysis
- Digital Binocular, magnification up to 1000×, including 3D reconstruction
- Scanning Electron Microscope FEI NovaNanoSEM450, magnification up to 500.000×. The microscope operates at high and low vacuum and has a large chamber for samples up to 150 × 150 × 150 mm. Conductive and non-conductive materials can be analyzed in the SEM. This SEM is equipped with EDAX Trident analysis system (EDX, WDX and EBSD).
- Energy Dispersive X-ray analysis (EDX) for the general analysis and X-ray mapping. This analysis method is used for qualification up to boron and quantification up to sodium
- Wavelength Dispersive X-ray analysis system (WDX) for the analysis of ultralight elements (up to boron) and trace elements present at 0,05 weight % or lower.
- Electron BackScatter Diffraction analysis system (EBSD) for crystal-logographic information, the determination of the local deformation near a crack tip and/or the influence of a mechanical/chemical process on the structure from a cross-section of a material. The analysis method can be used in combined with the information of the EDX analysis system.
- Micro-mechanical tensile, compression and three/four point bending tests up to 5 kN,
- Digital analysis system for the quantification of micro-structural
- features such as grain sizes, pores in anodised layers or particle
- distribution.
- 3-D analysis, 3-D quantification and reconstruction and/or charac-terisation of areal surface texture roughness
- Various non-destructive testing techniques
- Component analysis by FEM

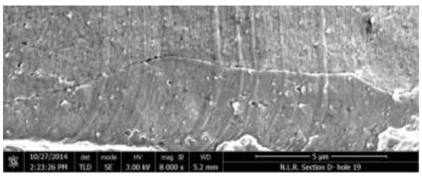
Scanning Electron Microscope



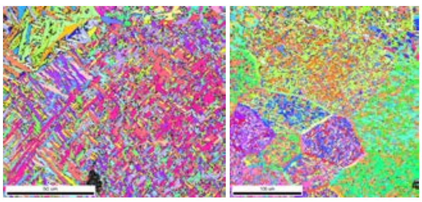
Dendrite structure in a welded sample



Oxidized surface of aluminium



Severe flights on glare fracture surface



EBSD image of SLM part and powder particles

Material characterization

NLR offers a multi–level approach in material science for the essential feedback to design, manufacturing, material/failure analysis and maintenance.
For the material characterization the NLR uses a fully equipped material testing and investigation laboratory:

- Cutting machinery for rough and precision cutting of components
- Grinding and polishing machinery for the preparation of cross section for metal, coating, composite material, etc.
- Metallographic imaging equipment for microstructural examination and material characterization, magnification up to 1000x, including high definition image capturing and image analysis
- Portable microscope and replication kit for filed investigations, magnification up to 1000x, including 3D reconstruction
- Advanced photo equipment, including high speed camera and video
- Scanning Electron Microscope (SEM) for fractographic and metallographic analysis equipped with a material analysis system.
  - Bulk and micro hardness capability
  - Environmental testing equipment
  - High temperature environmental testing equipment

Cutting and Grinding/polishing machinery

Light microscope for material characterization

Micro-mechanical testing

For testing small test items or for the validation of FEM models the Netherlands Aerospace Centre NLR has 30 years of experience in the area of micro-mechanical testing, in the following application fields:

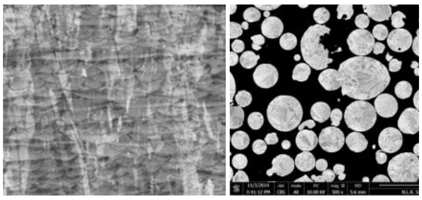
- Aerospace
- Mechanical and industrial engineering
- Manufacturing processes
- Product development

Advantages of the micro-mechanical test modules are:

- Flexible specimen geometry and sample design possible
- Flexible in use under binocular, light microscope, in the Scanning Electron Microscope (SEM) and/or as standalone system.

For the micro-mechanical testing the NLR uses standard and advanced equipment, including;

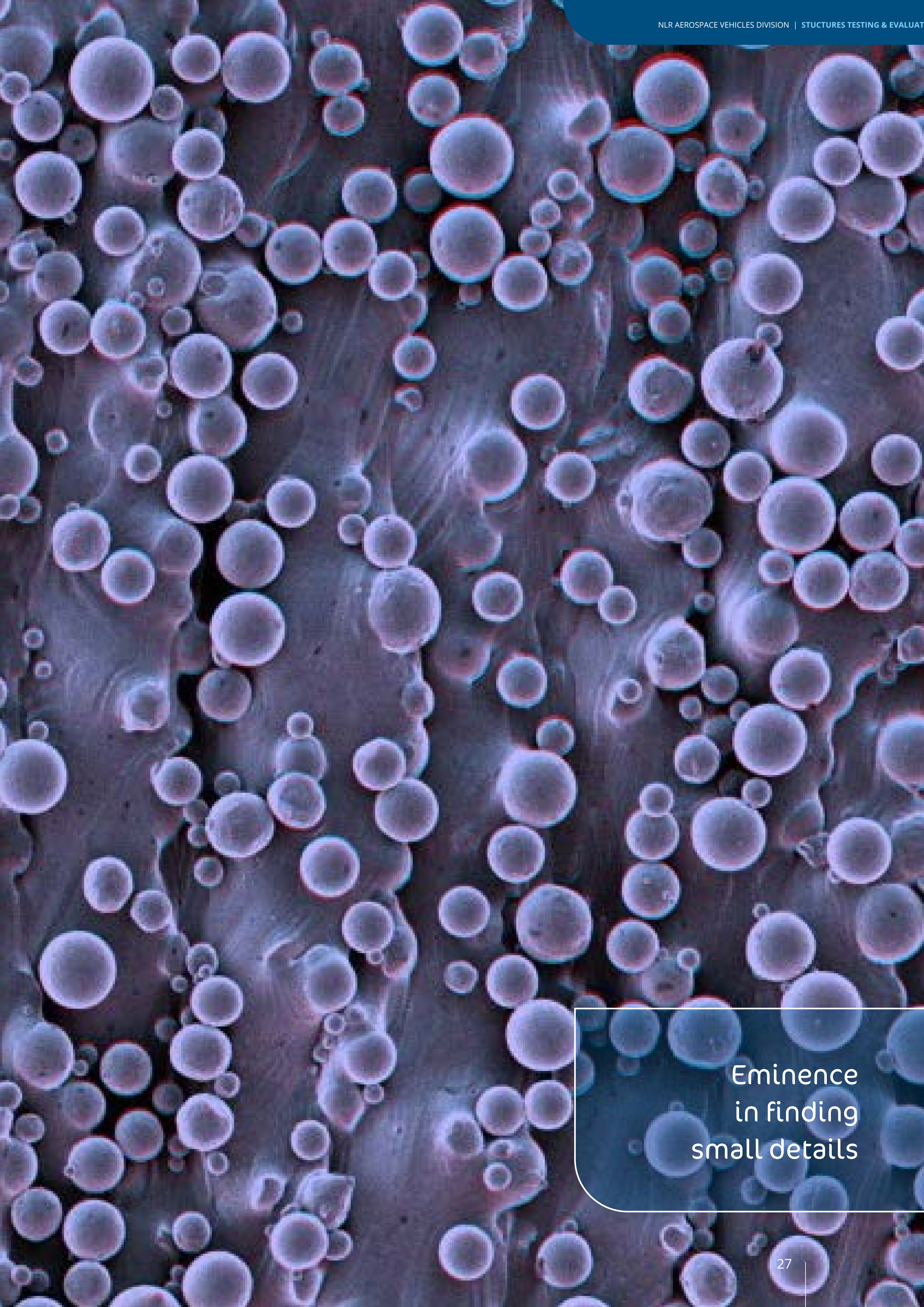
- Tensile and compression module, for tensile, compression, horizontal three and four point bending and DSB tests, load up to 5 kN
- Three and four point bending module, for vertical three and four point bending tests, load up to 2 kN
- Digital Binocular, for the visualisation at low magnification and/or samples that require a better depth of field
- Optical microscopes, for the visualisation of defects and/or crack at a magnification up to 500 x.
- Scanning Electron Microscope (SEM) NovaNanoSEM450, for the visualisation fine details and/or cracks at higher magnification
- Digital analysis system, for processing and analysing the data.
- Digital Image Correlation for processing and analysing the data
- Various non-destructive testing techniques, for combining the visualization techniques with the micro-mechanical testing and the non-destructive testing



LM image of SLM part (welds and grains) and SLM powder particles

Micro mechanical test setup (fout point bending)

Digital binocular for visualisation



Eminence in finding small details

Effective NDI solution for composite components and other lightweight aircraft structures

NON-DESTRUCTIVE INSPECTION EQUIPMENT

The Non-Destructive Inspection (NDI) group carries out a complete range of NDI services. Assistance is provided to airlines, air forces and aircraft component manufactures. Activities of the NLR include:

- NDI R&D studies (EU and Defense programmes)
- Development and Evaluation of new NDI techniques
- Simulation of NDI methods
- NDI of composite, metals and FML materials
- In-service inspections / Teardown inspections
- Investigating the reliability of NDI
- Structural Health Monitoring (SHM) / Failure analysis
- Qualification of NDI methods

The NDI group has R&D specialists and novel facilities enabling the development of inspection procedures in many NDI disciplines.

Visual

Visual inspection is the oldest, most economical and widely used inspection technique. Difficult accessible areas can be visually inspected with state-of-the-art video inspection systems and large surfaces inspected with e.g. 3D optical structured light scanning. 3D test results of the asset can be stored on location and sent directly to the customer for evaluation.

Ultrasonic C-scan facilities

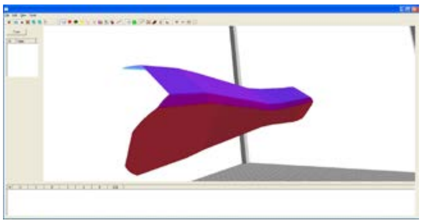
Automated ultrasonic inspection (C-scan) is an effective NDI solution for composite components and other lightweight aircraft structures. With this C-scan inspection the quality assessment of a material or structure can be determined without impairing its further use. In the development stage of components the C-scan test results are a significant input for adjusting production parameters to improve the overall quality. Further, the C-scan inspections guarantee a consistent quality during the production stage. Ultis software environment enables automatic defect detection and characterization. AITM requirement representations included. Reporting automated to a large degree. Uniform data processing over different devices.

3D C-scan facility

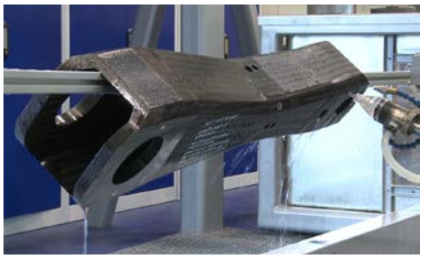
- Scan window of X 4.0m × Y 2.5m × Z 2.5m
- Immersion and squirter inspection mode
- Scanning of complex geometry components
- Complex scan profiles generated from CATIA or by Teach and Learn
- Turntable to inspect 3D circular components (max. diam. 1.9 m)
- Advanced 3D data acquisition and analysis system
- Integrated ultrasonic equipment with full wave signal capture
- Linear Scanning Array (LSA), cost effective scanning of large surfaces

2D C-scan facility

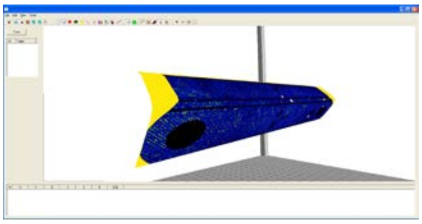
- Scan window of X 1.8m × Y 0.9m
- Immersion inspection mode
- Scanning of flat components in pulse-echo mode
- TomoView advanced acquisition and analysis system
- TomoScan LT ultrasonic equipment with full wave signal capture
- Linear Scanning Array (LSA), scanning of large flat surfaces



CATIA model



Complex 3D component



C-scan result projected on CAD model

3D C-scan facility

Squirter inspection large aircraft component

Phased array ultrasonics

Phased array ultrasonics (PA-UT) is a very promising technique for the in-service inspection of composite structures. An important advantage of phased array technique is the possibility of real-time imaging during scanning (amplitude or time-of-flight C-scans) on location. Sound beams can be steered, scanned, swept and focused electronically.

2D LSA C-scan facility

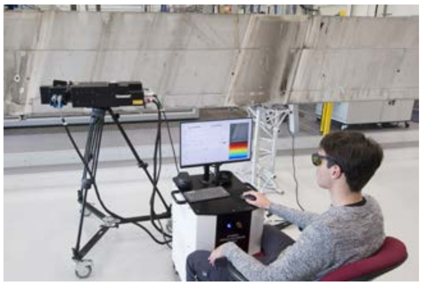
Laser ultrasonic testing

Laser ultrasonic testing is a fast and contactless technique to do ultrasonic pulse-echo inspection. Ultrasonic waves are generated and detected by lasers instead of transducers. This reduces inspection time by two orders of magnitude, it relaxes alignment constraints and negates the water coupling requirement. The inspection depth is limited by the laser energy the material can withstand and therefore laser ultrasonic inspection is well suited for thin composite components.

Curved and roller probe

Eddy current

Eddy current inspection (ET) is a primary technique for the in-service inspection of metallic aircraft components. The technique is based on the response of induced currents that are caused in a conductive mate- rial when the material is subjected to an alternating electromagnetic field. The technique is capable e.g. to inspect longitudinal lap-joints and circumferential butt-joints of a fuselage, but also rapid bolt hole inspec- tions are possible.



Laser Ultrasonic setup

Eddy current array

Eddy current array (ECA) inspection is a relatively new development in eddy current inspection. It implies the simultaneous use of a large number of EC coils which are integrated in a single probe. This application is typically for off-line EC inspection and allows wide-surface coverage of the inspection in a one-pass scan. Increases the scanning speed while maintaining a high resolution and allows real-time imaging (C-scan) of defects in the inspected part.

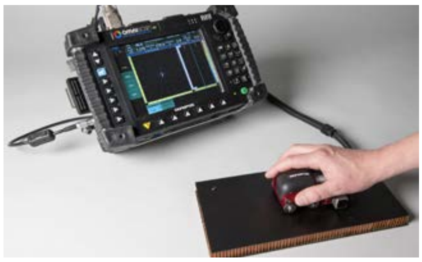
Resonance Testing

This technique is based on the resonance impedance technique. It can be used for test the cohesion quality of adhesive bonded joints and to detect delaminations and/or disbonds e.g. in composite and FML-materials. Material defects can be detected by a shift in the dominant resonance frequency. Both Olympus bond testing C-scan and Fokker Bondtester are available.

Eddy Current (Array)

Smart portable equipment

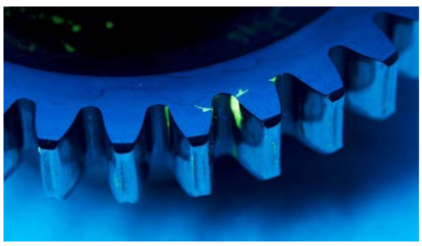
New generation of smart portable NDI equipment, tablet based, with multi-methods (UT, ET, resonance) in a single equipment. The equipment is equipped with 4G/Wi-Fi connectivity which enables "job cracking" which means remote assistance and therefore avoiding delays. The tool to manage the NDI staff capacity.



Bondmaster

Penetrants

Liquid penetrant inspection (PT) is used to detect small cracks or discontinuities open to the surface which may not be revealed by normal visual inspection. Penetrant inspection can be used on most airframe parts. The inspection is performed by applying a special liquid to the surface. This liquid has excellent capillary action and penetrates into very small defects. After a dwell time the excess penetrant liquid is removed. A suit- able developer is applied to the inspection surface to draw back the pen- etrant out of the crack. A visual indication is then obtained by colour contrast or by fluorescence under black light.



PT inspection of gear wheel

Lock in Thermography

Optical Lock-in thermography (OLT) is a non-contact NDI method that monitors the heat radiation pattern on the surface of a test part. OLT uses a low-frequency modulated heating which is imposed on the test part using two sets of halogen lamps, differences in surface temperature are caused by internal features (discontinuities/geometry). The inspection technique is non-contact, fast and with a large field of view (1m2) and well established for the characterization of carbon fiber reinforced plastics after manufacturing and under in-service conditions.

Thermography on wing flap

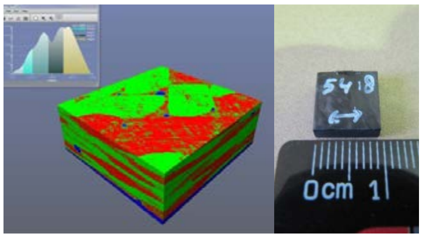
Shearography

Shearography is a non-contact NDI method that can determine gradient of the out of plane deformation of a subject under load by use of light interference. Excitation of the subject is done optically, using high power halogen lamps, causing a temperature increase and therewith expansion of the subject. Area's containing defects that change the stiffness of the material can be detected in this way, making the technique ideally suited to detect skin-to-core disbonds.

Shearography on wing flap

Computer Tomography

No NLR CT-scan hardware is available yet, but AVIZO software is available in order to perform analyses on externally scanned components.

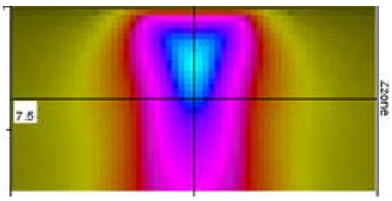


Fiber (green/red) and void (blue) CT-image of woven composite specimen

Modelling/simulation of NDI methods

CIVA is a software platform developed to simulate NDT imaging and signal processing. The platform consists multiple modules, the following are available at NLR:

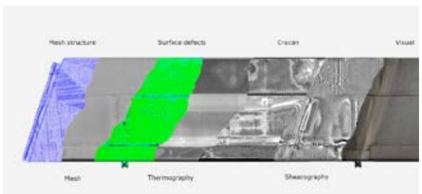
- Ultrasonic Testing (UT)
- Electromagnetic Testing (ET)
- Infra-Red Thermography (IRT)



Simulated Ultrasonic beam profiles in CFRP

Multi Domain Scanning

By combining NDI techniques with optical scanning a complete 3D representation of an object including the NDI-data can be made. Using this process, location information can be easily added to the NDI data allowing for easy comparison between different techniques and better differentiation of defects. Additionally, all data is stored on the surface mesh in a single file opening the possibilities of a Digital Twin.



Multi Domain result

Augmented Reality used in NDI

Augmented Reality is used to display NDO-images onto the hardware. Final goal is to guide the inspector towards the relevant information to be decided upon. This guidance can be computer assisted. The decisions can be discussed in a team effort.

AR using a hololens

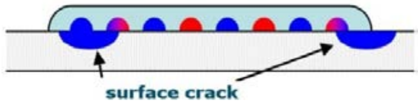
Acoustic emission

The acoustic emission technique (AE) is based on the principle that acoustic emissions are generated when defects initiate or grow in a material under stress. Acoustic emission is not a 100 % NDI method but can considered as a passive monitoring technique for the detection of dynamic defects such as crack growth and impact events.

Comparative vacuum monitoring

Comparative vacuum monitoring (CVM) is a relatively new technique that can be used for monitoring areas of a component where damage is expected to occur. The technique is based on the principle that a small volume maintained at a low vacuum is extremely sensitive to any ingress of air. The working principle is illustrated in the adjoining figure, the red lines represent the vacuum lines, the blue the atmospheric lines.

Acoustic emission



Principle of CVM

Passive Thermography
FLIR Thermovision A40 camera

- 76.800 pixels resolution
- Spectral range 7.5 to 13 µm
- Thermal sensitivity @50/60Hz 0.08 °C at 30 °C
- Accuracy (% of reading) ± 2 °C or ± 2%

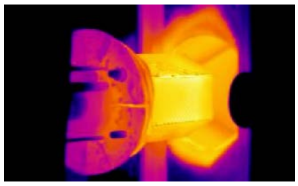
FLIR Thermovision A35 camera

Thermo-elastic stress analysis (TSA) is a technique that gives the stress field of dynamically loaded component of structure. TSA utilizes an infra-red sensitive (thermal) camera and the thermo-elastic effect, which describes a small reversible change in the temperature of an object as it undergoes an elastic deformation. TSA is ideal for:

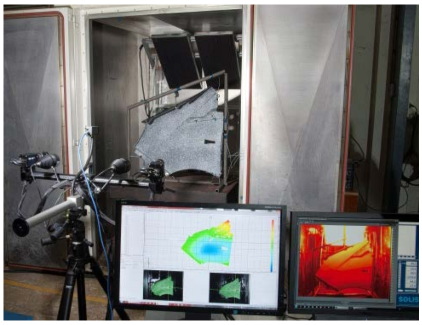
- Easy and fast evaluation of hot spots in components
- Crack detection
- Verification and iteration of Finite Element Models

Specifications:

- 86.016 pixel resolution (336x256)
- Spectral range 7.5 to 13 µm
- Thermal sensitivity @60 Hz 0.05°C at 30 °C
- MITE software



IR camera result

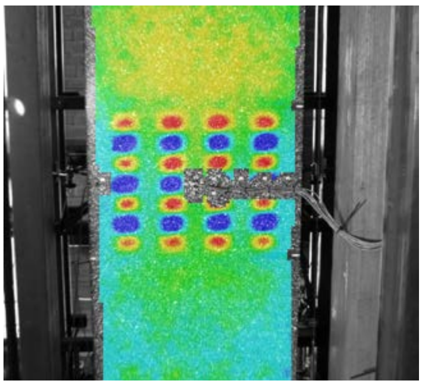


Thermo-elastic stress analysis combined with 12M DIC

Digital Image Correlation (DIC)

Optical 3D deformation field analysis for static or dynamically loaded components and structures is an effective, full-field, non-contact and material independent measurement solution; featuring:

- Visualization of strain gradients and hot spots
- Visualization of crack growth, crack tip opening and local/global strain fields/distribution
- Measurement of in-plane strains and 3D out-of-plane displacements
- Verification and iteration of Finite Element Models
- Verification of failure behaviour
- Investigation of fracture mechanics
- Design tool validation
- Tracking damage in (composite) materials



12M DIC displays a buckling pattern

GOM ARAMIS 12M

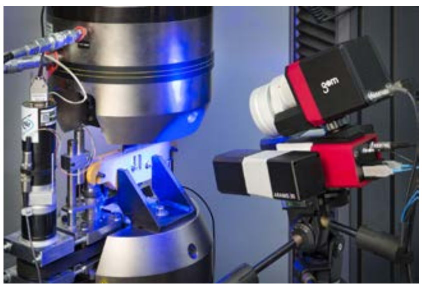
Specifications:

- Full-field analysis of small and large components
- 4000x3000 pixels camera resolution
- 58 images/sec
- High speed option with 2 high speed camera’s (up to 7000 fps at 1024x1024 pixels resolution)
- 3D point/marker target tracking function (PONTOS)

GOM ARAMIS 6M

Specifications:

- Camera frame with integrated cabling
- Camera frame length: 300 mm



DIC measurement using 6M camera

- Light Projector (Blue Light Technology,Light shaping, Revolver optics)
- 2x 6M pixel cameras, resolution 2750 x 2200
- Frame rate: 25 Hz (44 Hz with reduced resolution)

Stereo Pattern Recognition (SPR)
GOM PONTOS

The 3D point target tracking function PONTOS is based on the recognition and tracking of visible reflective markers on the object surface using stereo metric camera's and is based on Stereo Pattern Recognition (SPR) or more general on Digital Image Correlation (DIC) technology. Positions and movements of complex parts which cannot be measured directly (e.g. concealed components, etc.), are measured by means of adapters. With the use of high-speed cameras, the system is also suitable for measuring fast processes and motion sequences, e.g. for impact testing.
SPR is ideal for:

- Full field Structural Monitoring
- Complex motion tracking and analysis
- Component deformation analysis
- Mode shapes
- Relative motion
- Gap size changes


SPR system

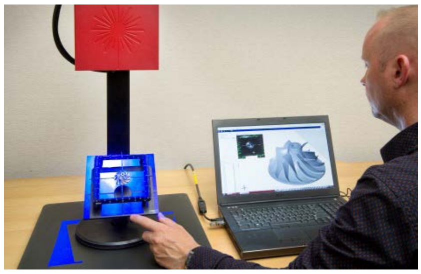

Reflective markers on the elevator surface, recorded by SPR cameras for SPR processing of 3D displacements

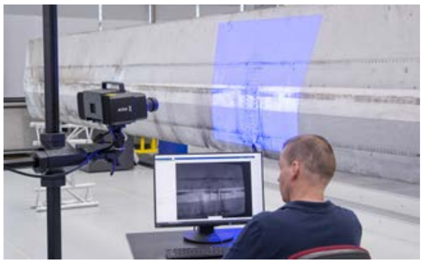
Optical 3D measurements
GOM ATOS 200

- Measuring area: 200 mm x 150 mm
- Working distance: 250 mm
- Point spacing: 0.08 mm
- Sensor dimensions: ca. 206 mm x 205 mm x 64 mm
- Calibration object for this sensor with certificate

GOM ATOS 5

- Measuring area / point spacing/ max length measurement error:
  - 320 x 240 mm / 0.068 mm / -0.002 mm
  - 1000 x 750 mm / 0.236 mm / -0.049 mm
- Calibration object for this sensor with certificate

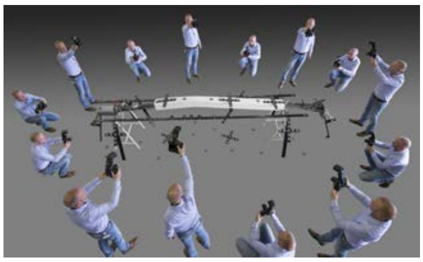

Optical 3D geometry measurement


Structured 3D Light Scanning

Optical 3D Photogrammetry
GOM Tritop

Optical 3d coordinate measuring system

- Measuring volume 1 x 0.5 x 0.5 m^3: 0.015mm accuracy
- Measuring volume 10 x 5 x 5 m^3: 0.2mm accuracy


Optical 3D coordinate measurement

High Speed Video
Photron FASTCAM SA5

- Monochrome sensor
- Synchronization with integrated DAQ units
- Recording memory capacity:16 GB (1.5 sec. with max. resolution)
- Multiple camera synchronization: possibility for performing ARAMIS optical 3D deformation (DIC) high speed measurements

Performance examples:

- 1,024 x 1,024 pixels @ 7,000 fps
- 1,024 x 744 pixels @ 10,000 fps
- 512 x 512 pixels @ 25,000 fps
- 256 x 256 pixels @ 87,500 fps
- 128 x 128 pixels @ 262,500 fps
- 128 x 24 pixels @ 775,000 fps


High speed video

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