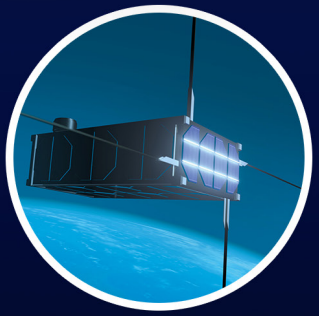
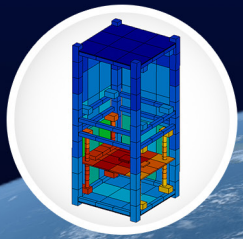
Dedicated to innovation in aerospace

Overview space capabilities





Royal NLR - Netherlands Aerospace Centre

Overview NLR space

SPACE APPLICATIONS

- Satellite navigation
- Earth observation
- Space Situational Awareness

SATELLITES & LAUNCHERS

- Concept development
- Space avionics
- Antennas
- Thermal control

SERVICES & FACILITIES

- Prototyping
- Research facilities

ENABLING CAPABILITIES

- AI on the edge
- Cybersecurity
- AR/VR
- Structures and materials

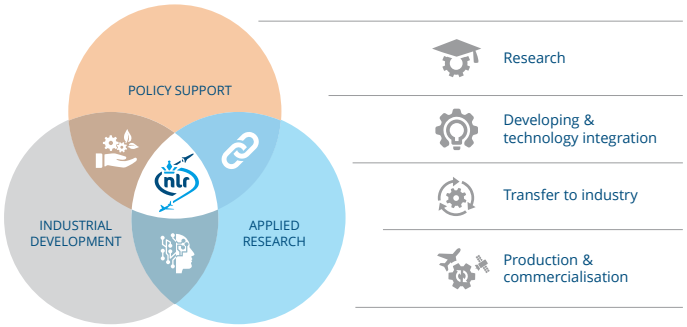
Space innovations for society

Royal NLR works closely with both industry and government on developing satellites, payloads and launchers systems and subsystems, such as thermal control systems, electronics and antennas. We also offer unique capabilities in the area of aerospace qualified light-weight composite structures and multi-metal additive manufacturing, and on the effective use of earth observation and satellite navigation data for both civil and military use.

As an independent R&D centre for aerospace we are known for our practical approach and innovative solutions. Based on our expertise combined with facilities we support companies and government in the whole development chain from concept development to prototype and small series production. We develop hardware from sensors to launcher components, up to software and information products derived from multiple source data. For these developments NLR has a wide range of test facilities available with which we can test, verify and validate products. This includes environmental and structural testing and also wind tunnel testing, up to (zero- and lowgravity) flight testing.

This booklet gives an overview of the broad spectrum of the knowledge, capabilities and facilities that Royal NLR is applying in the research projects and programs in the Netherlands and worldwide. We hope you will enjoy reading about our research and welcome you to contact us for more information.

Michel Peters, CEO
Royal Netherlands Aerospace Centre



Space applications

NLR supports developments on the effective use of space data and on solutions to generate reliable and robust systems that use these data. We are dedicated to harnessing the power of space-based technologies to support decision-making, by developing cutting-edge methods for extracting valuable insights from earth observation data, and applying these in the real-world contexts of safety, security, justice and defence domains. In the area of satellite navigation NLR focuses on the development of robust positioning, navigation and timing (PNT) solutions including mitigation methods for interference for mobility applications such as drones.

As space gets more and more congested the need for a traffic management system for space (STM) is growing and also systems to accurately monitor the space domain and alarm systems to prevent collisions. NLR works on solutions for these challenges as safe use of the space domain is essential for the future. NLR is developing a SSA tool with an automated alarm system and is exploring options for future STM concepts.

Space applications

Satellite navigation
Earth observation
Space Situational Awareness

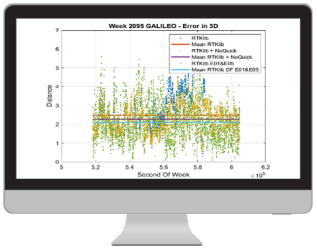
Satellite navigation

Robust and resilient PNT

Satellite Navigation is vulnerable to interference. NLR focuses on making PNT robust by designing new algorithms, antennas and procedures to detect and mitigate interference. When all else fails, we integrate and fuse other sensors to provide a reliable solution where satellite signals cannot be used.

New GNSS signals

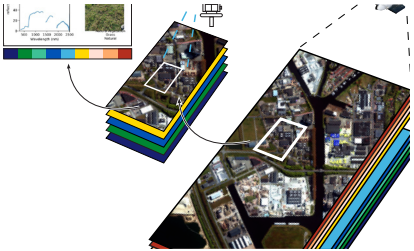
Both Galileo and GPS 3 offer new features over the classical GPS signals, such as secure, encrypted signals and high accuracy corrections. NLR researches and tests these new signals to enable customers to use them in an optimal manner. We provide support and advice to the Netherlands government on the use of new GNSS signals for a safer society.



GNSS performance monitoring

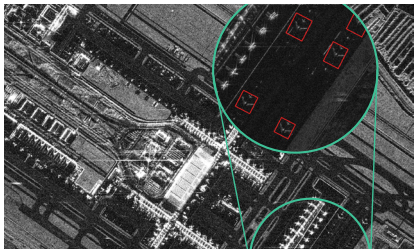
NLR monitors the performance of satellite navigation and correction signals. This is important for critical applications such as aviation and UAVs, where small deviations can cause serious accidents. NLR plays an expert role in the field of GNSS integrity monitoring for such applications.

Earth observation



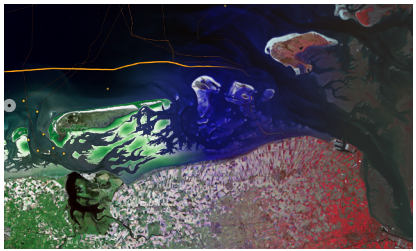
Hyperspectral sensor chain

NLR is driving innovation in Hyperspectral remote sensing to support security and safety operations. By researching advanced sensor processing chains, NLR enables the creation of algorithms that can detect subtle spectral differences, improving the identification of camouflaged targets and related phenomena. This technology has the potential to enhance monitoring and surveillance, providing crucial insights for decision-makers in the security domain.



SAR sensor Chain

NLR aims to advance the use of Synthetic Aperture Radar (SAR) technology to enhance detection and monitoring capabilities, leveraging the technology's ability to penetrate clouds. By developing SAR processing chains and algorithms NLR aims to utilise the power of Artificial Intelligence (AI), including foundation models, to improve interpretability of complex SAR images, enabling enhanced insights and more effective decision-making in critical applications.



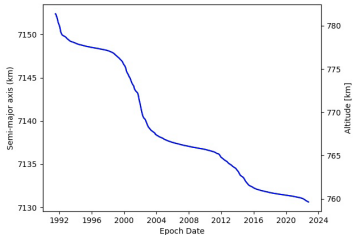
Actionable intelligence

NLR works on the conversion of Earth Observation data to actionable intelligence to in decision making processes, monitoring and inspection. This includes the development of robust Machine Learning algorithms for processing the ever increasing availability of data and the fusion of multi-source products with a range of spatiotemporal algorithms. NLR integrates workflows to reduce response times of end-users by improving the latency, data transfer capability, pre-processing and analytics of these information products.

Space Situational Awareness

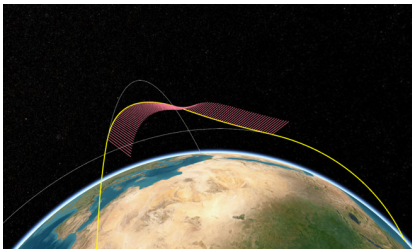
Information collection

NLR focusses on the understanding of SSA. This starts with accessing the publicly available object tracking data and object information sources to ensure a complete database. By collecting space object data on a daily basis, it is possible to investigate trends, procedures and anomalies. For this, NLR is developing the SSA tool “ARGUS”. ARGUS can monitor orbital events and will be extended with more advanced functionality such as Space Object Characterisation, Rendezvous- and Proximity Operations, an automated warning system and a 3D output capability.



Orbital calculations

With the gathered information in the form of Two Line Elements (TLEs), the orbital elements for each tracked object are calculated. By doing this, and by propagating the orbits for selected space objects, it is possible to get an insight in behavior and the space environment influences.



Process comprehension

Understanding the outcome of the performed calculations and the limitations of the current propagation techniques allows for a deeper dive into space object characteristics. Trends in operation or deviations from normal procedures can be identified, from which rendezvous and proximity operations can be predicted.

Satellites and Launchers

NLR supports developments that help bring small satellites easier, faster and affordable to orbit. We can play a role from the very beginning of a rough idea up to the production of a prototype of a launcher structure or a satellite component or sensor.
With our experience and overall system knowledge of space avionics we work on sensor electronics, control units and processing boards for small and medium size high-end satellites.

NLR develops phased array antennas or beamsteering antennas for satellite communication and smart satellite navigation antenna's. Phased array antenna's utilise a series of elements that allow the antenna bundle to be controlled electronically instead of mechanically. This makes them less vulnerable and more flexible.

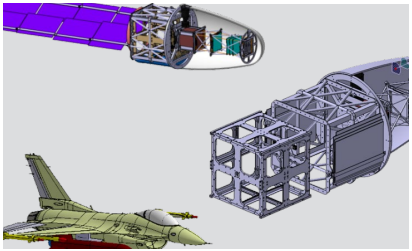
NLR has very broad expertise in developing thermal management systems for space applications and specifically pumped systems. Such systems are interesting in satellites with payloads that generate a lot of heat and need to be cooled in order to function properly.

NLR also works continuously on innovative space concepts like a new VLEO satellite concept, concepts for Space Traffic management (STM) and a circular system for food production in spac

Satellites and Launchers

Concept development
Space avionics
Antennas
Thermal control

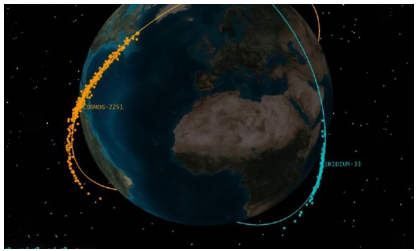
Concept development



Alternative satellite options VLEO concept

Following from a small-satellite air launch concept, a VLEO satellite concept has been developed in parallel. The concept incorporates:

- Fairing retention in orbit
- Integrated and standardised Sub-Systems
- Modular payload section
- Standardised mechanical and electrical connections
- Responsive launch capability with a dedicated orbit in VLEO



Space Traffic Management

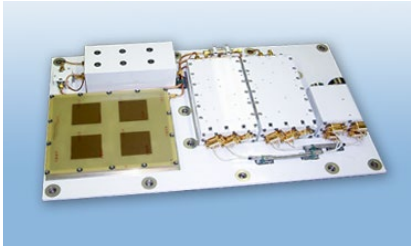
With the increase in number of launches and, subsequently, number of (small) satellites, a management system needs to be put in place as well – with quite some priority. Within STM, NLR has research potential in:

- ATM/ STM integration
- Orbital mechanics (collision avoidance)
- Re-entry procedures
- Material selection for design-for-demise and re-entry
- Technical assistance for regulatory decisions
- In-orbit recycling and refuelling

Space farming

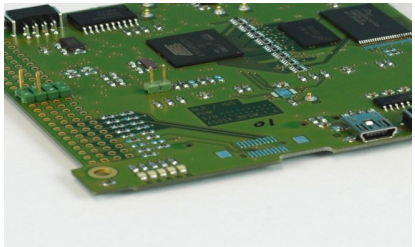
Producing food is essential to enable long term stays on the Moon and Mars. To this end a fully circular space habitat is required. Developing methods and technologies for food production in circular systems in space will require many innovative solutions. NLR is investigating how to enable such a system with its partners. The goal is to prepare for future space habitation, that at the same time will contribute to spin-off technologies for food production on Earth in challenging conditions.

Space avionics



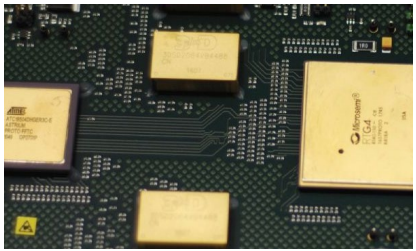
Sensor electronics

NLR's focus is on high-end space avionics for the small and medium size satellite market. High-end meaning increased reliability with respect to current SmallSat standards and space avionics offering very specific payload functions to support Earth Observation, ELINT and SIGINT.



Control units

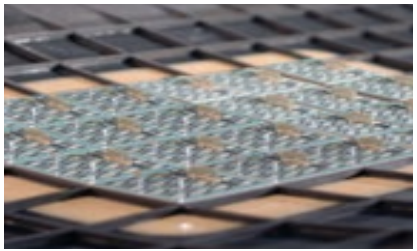
NLR develops Payload and Subsystem Control Units for CubeSat to GEO and ISS class applications with a proper balance between size, weight, power, reliability and cost. All covered by a proper level of quality assurance.



High-End Data Processing

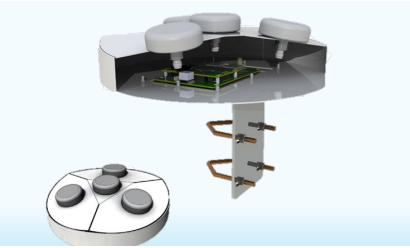
While mission demands become more stringent on low-latency feature detection and data delivery, there is a strong focus on advanced in-orbit data processing functions as edge-AI and algorithms for SIGINT and ELINT using state-of-art hardware and software technologies.

Antennas



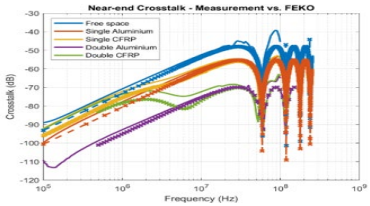
Phased-array SATCOM antennas

NLR develops phased array antennas for satellite communication. Such antennas utilise series of elements that allow the antenna bundle to be controlled electronically (beamsteering). Multi-beaming makes it possible to send information to different locations at the same time. NLR is strong in integrating these flat antenna elements in structures.



Smart SATNAV antenna

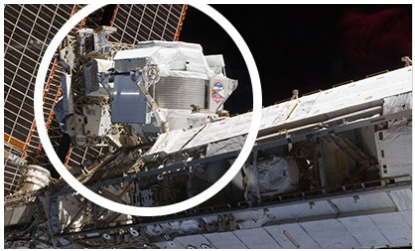
NLR also develops smart antennas, such as smart satellite navigation antennas that are able to compensate for the vibration and deformation and that can mitigate interference. NLR operates several test facilities to assess the performance of these smart antennas.



EMC modelling and analysis

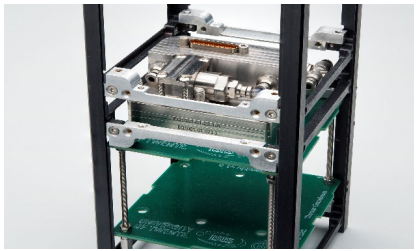
In order to predict the electromagnetic interaction of the antenna with the platform, NLR performs modelling and analysis of the installed antenna performance. For the EMC analysis of cables NLR uses several computational tools (such as the SACAMOS software). In the Electro Magnetic Compatibility (EMC) lab NLR can also test the real performance of a system.

Thermal control



Pumped cooling in space

NLR has a broad expertise in thermal management systems for space, specifically pumped systems. With our two-phase systems the temperature of a system can be kept very stable. For the AMS-02 instrument on the ISS for example the heat fluctuations are less than 0.3°C.



Thermal control of Cubesats

NLR has developed a modular cooling system for cubesats or small satellites, a mini pumped loop with a compact design. As cubesats get more powerful and their design is very dense, heat problems are foreseen in next generation cubesats.

Modelling and demonstrators

As the design of two-phase systems is quite complex NLR often builds demonstrators for customers. Besides NLR carries out thermal modelling and also assists customers in setting up realistic thermal models of their designs.

Enabling technologies

NLR has a wide variety of expertise area's that are relevant for space. Such as our AI expertise, which is relevant for the processing of space data on ground and more and more also for on-board (edge) processing. For this we work on the hardware and software side to develop suitable solutions for space.

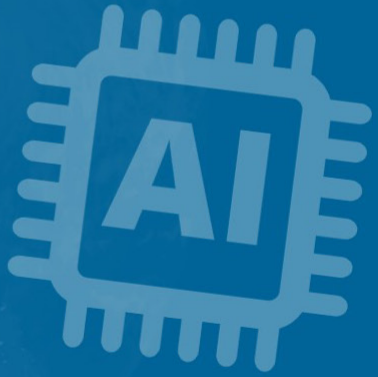
NLR supports small satellites integrators and governments in the development of safe and secure space systems. For this we work on (automated) cyber security assessments and solutions for small space systems.

Furthermore, in our NLR X-Lab we develop applications with immersive technologies such as AR/ VR for customers in order to improve communication on designs or missions, to support engineering processes or make remote handling possible.

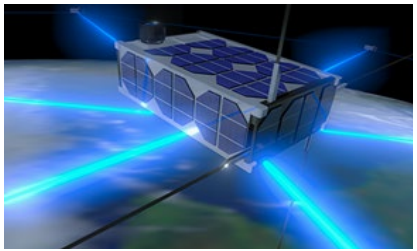
In the field of structures we focus on the development of light-weight structures based on composites and additive metal printing (AM). For composites NLR focuses on optimal design and use of composites in combination with automatization of production processes to realise space structures for attractive costs. NLR has extensive knowledge of Metal-additive manufacturing design rules, build preparations, production process and post-treatments, as well as certification and qualification processes.

Enabling capabilities

AI on the edge
Cybersecurity
AR/VR
Structures and materials



AI on the edge

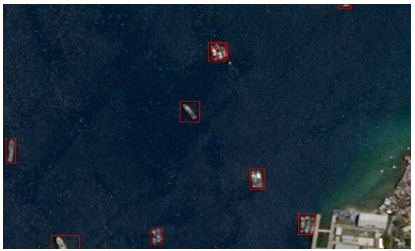


Efficient Computing

NLR has excellent expertise in efficient computing for space applications. Our expertise lies in selecting the optimal algorithms for edge devices, ensuring seamless AI-driven operations. We optimise processes to minimise latency, reduce computational load, and maximise data processing efficiency. By doing so, we enable real-time decision-making and enhanced performance in space missions.

Transfer to the edge

Our expertise in operating on the edge enables rapid deployment of AI-driven applications in space. We have established pipelines and extensive experience in training and preparing algorithms to run on edge devices, ensuring swift turnaround times. Our capabilities extend beyond development, as we also specialise in deploying and running edge applications, ensuring seamless operation in the most demanding environments.



Maritime surveillance

NLR successfully developed an on-board AI application for detecting ships at sea using optical sensor data on a small satellite. The innovative algorithm detected ships, cropped the relevant areas, and transmitted only the essential information back to Earth, significantly reducing data transmission costs. By optimising data efficiency, we enabled the transmission of a large volume of critical data, demonstrating the potential of on-board AI for maritime surveillance.

Cyber for safe and secure operations

Risk analysis and evaluation

NLR has the ambition to support the design of safe and secure space systems. One of the three cyber activity lines is 'Risk analysis and evaluation' of aerial systems and small satellites at platform as well as fleet level. We analyse the systems, pentest dedicated vulnerabilities and threat scenarios, and maintain a smart knowledge base on these scenarios with likelihood and impact indications.

Secure Command & Control

This research into 'Secure command and control' of air and space based systems includes assessment of (CCSDS) security standards for space systems and the tailoring of these to small satellites, development and testing of onboard solutions taking into account architectural separation, degrade modes and the use of trusted modules.

Automated cyber assessment

Future resilient space systems will have automated cyber assessment on board. Through continuous monitoring the safety and security state of the systems anomalies can be detected and smart decisions can be made on platform or operational level. NLR prototypes the monitoring capability and different (explainable) AI concepts.

Augmented and Virtual Reality (AR/VR) technologies

Immersive technologies

Information transfer is no longer confined to mouse, keyboard and screens. Immersive technologies like AR / VR make it possible to interact with information and be part of it. They are an added value for: – Engineering process (MBE) – Communication on designs, missions etc. – Training – Remote handling.

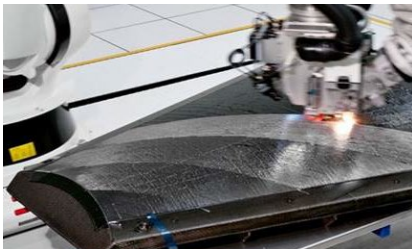
Engineering Process

AR/VR can be used to train engineers or astronauts. Immersive technologies can make training very realistic and effective and is affordable compared to a lot of current training means, such as high-end simulators or real-life training.

Training

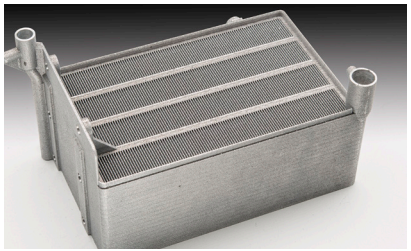
AR/VR can support the engineering process in various ways. It enables for instance engineers to observe and evaluate hardware components or systems collaboratively in a more interactive and immersive manner than traditional tools. This can help to foresee problems and possible challenges in an earlier stage and save time in the development process

Structures and materials



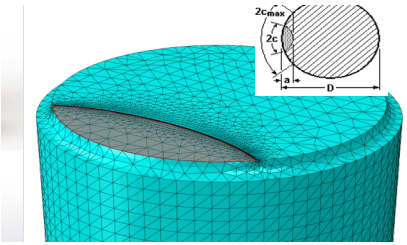
Carbon fibre placement

NLR has extensive experience with, and knowledge of, polymer based composite materials, including manufacturing processes. NLR focuses on optimal design and use of composites in combination with automatisation of production processes to realize space structures for attractive costs. NLR works with dry fibers, thermoplastics and thermoharders.



Additive manufacturing

NLR has extensive knowledge of Metal-AM design rules, build preparation, production process and post-treatments, as well as certification and qualification processes. We work with deposition and powder bed fusion techniques and focus on processing with titanium, nickel, aluminium and magnesium alloys and combinations of materials.



Crack growth solution developments

For ESA we continuously improve crack growth analyses of the ESACRACK software package. We do this through the analyses of different types of crack growth solutions. The input is integrated into the software package Nasgro due to the cooperation between ESA and NASA.

Space services & Facilities

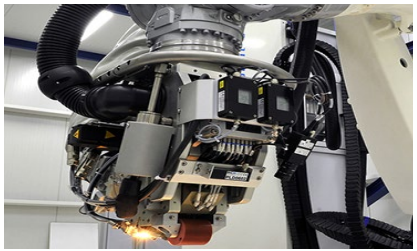
NLR has a wide range of facilities available for testing, verification and validation. This includes environmental and structural testing and also wind tunnel testing, up to (zero- and low-gravity) flight testing.

Besides we offer facilities to support companies to optimise their products and production processes such as composite structures in our Composites Field Lab and metal printed products in our Metal Additive Manufacturing Technolgy Centre (MAMTeC). We can also develop and realise avionics and sensor prototypes in house supported by our ESA-certified personnel. NLR also has extensive experience in wind tunnel modelling and production of high precision wind tunnel models.

Space Services & Facilities

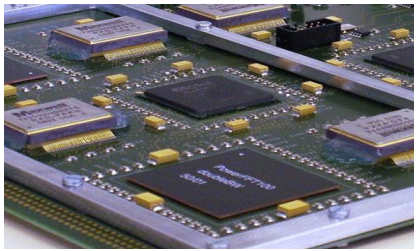
Prototyping
Research facilities

Prototyping



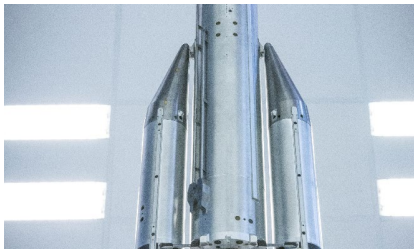
Composites manufacturing

In our composites field lab NLR supports companies in optimizing their products and manufacturing processes: prototypes can be build and even small pilots can be runs. We have several facilities: Automated Fiber Placement (dry, thermoplastics, thermoset), Autoclave and Out-of-Autoclave processing, Press forming, Braiding, Resin infusion, Robotic welding of thermoplastics



Electronics and sensor technology

NLR can perform all steps in the development process of avionics and sensor prototypes. Capabilities include high-speed design, support of many programmable logic brands, PCB assembly including BGA package placement, precise mechanical machining and 3D printing. ESA certified personnel is available for the assembly of flight electronics.



Mechanical design and manufacturing

NLR is specialised in design and manufacture of high quality, high-precision wind tunnel models. Our models can incorporate smart features such as remote controls, advanced instrumentation, balances, rotating systems.

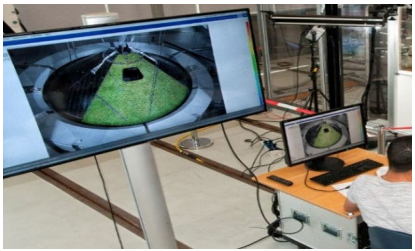
Research facilities

Coupon testing

NLR has a wide range of test facilities for mechanical testing, material evaluation and measuring control and calibration. From material, coupon, component to full-scale level. Under extreme conditions (from -250 and up to 1200 degrees C) and within specific environment (wet, dry, toxic).

Cryogenic component testing

NLR can test all different kinds and sizes of components, even under extreme conditions. Like for example the Ariane 6 component that has been tested under cryogenic conditions (picture)



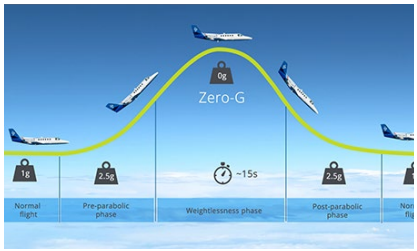
Inspection

NLR develops and applies appropriate inspection methodologies for all kind of structures including Non-Destructive Inspection (NDI) methods. We offer amongst others visual, ultrasonic, liquid penetrant, acoustics emission, lock in thermography inspection techniques.

Research facilities

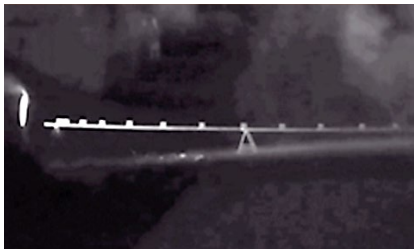
Satellite navigation lab

NLR has a number of facilities to test the robustness and reliability of GNSS systems. We have a GNSS various GNSS recievers, software defined radios and antennas available for testing. Besides bothe of the NLR offices are equipped with permanent GNSS antenna installations that can be connected to indoor test setups. Indoor tests can be performed over the cable or in the available testing halls, for example an EMC chamber or a large indoor hall suitable for indoor drone tests. For outside testing the NLR drone center and DigiCity support UAV test in non-FRI conditions on our premises.



Low gravity flight testing

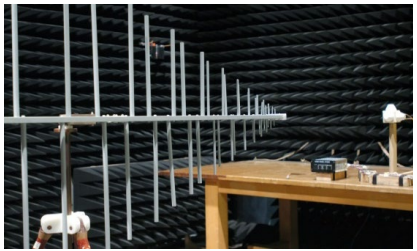
Ace2space is the partnership between Royal NLR and Delft University of Technology for performing parabolic flghts for testing space equipment before launching it (free fall tower, sounding rocket, space station). You can expose your application to in-flight-zero- or low gravity conditions (e.g. moon or Mars), perform a customer-required number of parabolic maneuvers. No implication to take more parabolic maneuvers and associated costs than really needed. Flights are performed with oumodified and instrumented Cessna Citation II research aircraft.



Rockt engine test facility

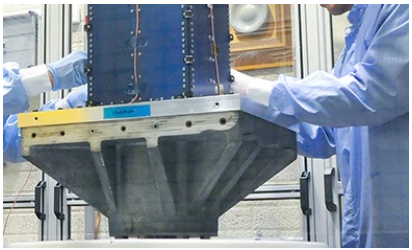
The Rocket-engine Test Facility Marknesse (RTFM) was developed and used several decades ago to test rocket engines. It has recently been reinstated to continue testing and allow for new concepts to be tried. This allows for customers, student teams and NLR-internal projects to rest rocket engines is a safe an controlled environment. Various propellant and rocket engine types can be tested at a small scale, within a flexible and low-costs set-up. The facility will be continuously developed to offer more comprehensive and professional support.

Research facilities



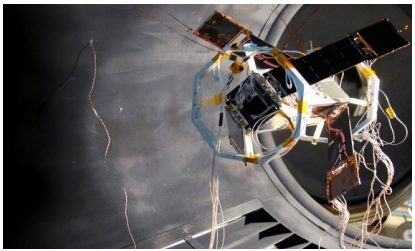
EMC Facility

The EMC Facility carries out testing and analysis concerning Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI) of electrical and electronic equipment. These EMC tests are usually carried out in the (semi-)reflection free space or Semi-Anechoic Chamber (SAR). The SAR is equipped with radio frequency absorbers, high-quality filters for main power, water supply and an exhaust gas extraction system. Testing can be done in accordance with most applicable aerospace standards.



Vibration & shock test facility

NLR operates a facility for vibration and shock tests. These tests can be done in accordance with any applicable standard including the RTCA DO-160F, MIL-STD-810F and IEC standards. Also dedicated test procedures can be applied. The VST laboratory is included in the Dutch Accredition Counsil (RvA) register of test laboratories under no. L220, for areas described in detail in the accreditation.



Thermal vacuum facility

The Thermal Vacuum Facility carries out research on aerospace-related thermal issues. The facility is equipped with various data acquisition/logging systems for different types of temperature and vacuum/pressure sensors, and 50 Hz infrared camera. Furthermore, single-phase and two-phase liquid/vapor heat transport systems can be developed and tested. To this end, a range of Coriolis mass flow meters, pumps, tubing and fittings are available. Fluid properties such as contact angle, surface tension and density can be measured with dedicated equipment.

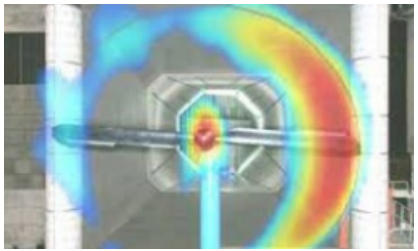
Research facilities

Metal Additive Manufacturing

The NLR Metal Additive Manufacturing Technology Centre covers more than 50 years of materials experience in aerospace applications, technology development and product innovation. NLR can help you develop the process more efficiently, from optimised parameters, post-processing approaches, evaluation of mechanical properties, design optimisation and process simulation through to the qualification and certification of metal–additive manufacturing (AM) products. NLR works on AM process optimisation, assesses material properties, designs components and builds parts up to the level of full-scale prototypes.

ACM³ Field lab

The ACM³ Field lab (Automated Composites Manufacturing, Metal Manufacturing and Maintenance) is a well-equipped, state-of-the-art field fact makes high-tech equipment available for the development of lightweight products. It serves to prepare the way towards automated manufacturing of advanced composite structures, largely in support of the 'composites' industry, but also of enterprises, which are new to this material.



Acoustic loading tests

Acoustic loading tests, simulating for example acoustic rocket launch conditions, can be performed in the reverberation room of the NLR Acoustic Flow Duct Facility (FDF) wind tunnel in Marknesse. The reverberation room is a closed room of about 50m³ with skewed walls to diffuse the sound in the room for frequencies of 150Hz and higher. The sound pressures are produced by acoustic speakers which are installed in the reverberation room, surrounding the test object. The sound levels can be equalized to a required sound spectrum, with a maximum overall sound pressure level (OASPL) of the test is 141dB.

About NLR

Royal Netherlands Aerospace Centre

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 find its way also into successful aerospace programmes of OEMs like Airbus, Boeing and Embraer.

NLR in brief

One-stop-shop

Global player with Dutch roots

100+
Since 1919

Amsterdam, Marknesse
Rotterdam, Noordwijk, Brussel

Innovative, involved and practical

For industry and governmental

For civil and defence

800+
staff

€ 110 M turnover

74% Dutch, 23% EU
and 3% worldwide

Active in 26 countries

Extremely high customer satisfaction

As an independent R&D centre for aerospace, NLR- Royal Netherlands Aerospace Centre 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 is the connecting link between science, industry and government. Based on our expertise combined with facilities we can support companies and government in the whole development chain from concept development to prototype and small series production.

Examples of our expertise fields:

- Active thermal control
- Space avionics and radiation hardness assurance
- Phased array antenna's
- AI enabled on-board data processing
- Space-based Intelligence Surveillance and Reconnaissance (ISR)
- Space Situational Awareness (SSA) and Understanding
- Metal additive manufacturing and composites

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