Dedicated to innovation in aerospace

NLR Portfolio

Innovations for Military Applications

Royal NLR - Netherlands Aerospace Centre

Introduction

Adding value to the Military Domains

The Royal Netherlands Aerospace Centre – Royal NLR - has been an ambitious, knowledge-based organization for over a century, with a deep-seated desire to keep innovating. We are very proud that we have received the royal predicate and that we are now the **Royal Netherlands Aerospace Centre**. Our knowledge and expertise have made us one of the driving forces in the aerospace sector, both in our own country and abroad.

Royal NLR has over 100 years of experience in the defence industry and is supporting the Royal Netherlands Air Force in daily operations, lifecycle management and (virtual) training. In addition, Royal NLR is supporting Netherlands' Defence Technological & Industrial Base (NLDTIB) with research on new materials and optimization of various manufacturing techniques.

Royal NLR is proud to be a partner in several military programs starting from the early development phase and is committed to continue to support the Warfighter with Dutch excellence and innovations.

This document gives an overview of the broad spectrum of innovative tools, capabilities and facilities that Royal NLR has to offer.

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, Operation and Sustainment. 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. This allows NLR’s cutting-edge technology to find its way also into successful aerospace programmes.

NLR in brief

Centre of Excellence	Global player with Dutch roots	100+ Since 1919	Amsterdam, Rotterdam, Marknesse, Noordwijk
Innovative, engaged and practical	For industry and government	For civil and defence	658 employees
€ 92 M turnover	72% Dutch, 22% EU and 6% international	Active in 30 countries	Extremely high client satisfaction

NLR expertise for

Life Cycle of Military Applications

Smart Manufacturing Processes
Focus Today on the Technologies of Tomorrow

Factory of the Future
Making Industry 4.0 Business as Usual

Hangar of The Future
Contributing to Technology Innovation with State of the Art Facilities & Tools

Durable Sustainment & Repairs
Providing Durable and Affordable Sustainment Solutions

Multi-Domain Operation
Continuous Operational Improvement through Multi-Domain Integration

Operational Support & Training
Evaluating Concepts of Operations and Training for Excellence

Society
Perceiving the Sound of Freedom

Production

Smart Manufacturing Processes
Focus Today on the Technologies of Tomorrow

Factory of the Future
Making Industry 4.0 Business as Usual

Production

Smart Manufacturing Processes

The Netherlands is known for producing complex, high-quality, and high-performance products. Royal NLR supports NLDTIB in making innovations in their manufacturing processes, from testing of new materials to qualification and certification of products. By doing so, more affordable products with increased performance can be realized.

One of our latest test cell facilities called the Automated Composite Manufacturing (ACM) Pilot Plant allows NLR and partners to investigate novel materials and manufacturing techniques. In addition to experimenting with novel materials and manufacturing techniques, also Digital Twin and Internet of Things applications are demonstrated in the Pilot Plant.

The objective of our research is providing improved quality, higher performing, lighter, more affordable products with a more consistent quality and reliability.

These efforts also impact affordability in the sustainment phase. In addition to sustainment, research is performed on innovative repair solutions, which are elaborated later on in this document.

The following pages provide more information on collaboration opportunities with NLR regarding Smart Manufacturing Processes.

Additive Manufacturing

Focus and Impact

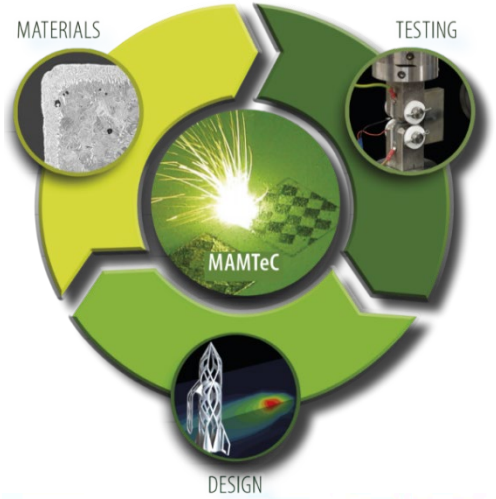
MAMTeC is the (Metal) AM Technology Centre in NL at NLR. This manufacturing technology is used to fabricate metal and high performance thermoplastic products with less weight, better performance and higher efficiency, certified to airworthiness standards. MAMTeC develops the technology to manufacture and certify (Metal) Additive Manufacturing components.

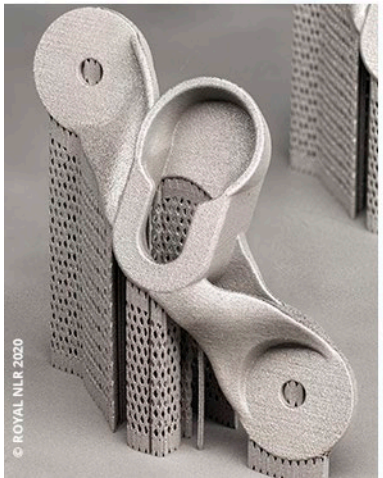
Technologies and Materials

- Laser Powder Bed Fusion
- Blown Powder Directed Energy Deposition (manufacturing & repairs)
- Sinter-based Fused Filament Fabrication
- High Performance Alloys (e.g. aluminium, titanium, nickel-based super alloys, magnesium)
- miniFactory for high temp/high performance thermoplastics (e.g. PEI, PEEK, PEKK, PAEK with Carbon / Glass Fiber variants)

Industry Partners

- KMWE
- Aeronamic
- Thales
- Oerlikon
- PPP (public private partnership)





Composites

Focus and Impact

A key objective for more efficient and sustainable aircraft is to make lightweight, durable and affordable parts designed for ease of maintenance. NLR takes care of the entire process, from calculation and design all the way through to manufacturing, repair and certification.

Royal NLR has extensive experience with, and knowledge of, polymer based composite materials, including manufacturing processes, the mechanical behavior of composite materials, and the structural response of composite structures.

Applications and Capabilities

- Automated Composites Manufacturing
- Autoclave and Out-of-Autoclave oven processing
- Press forming
- Braiding
- Resin infusion
- Robotic welding of thermoplastics
- Automated Fiber Placement (Dry, Thermoset, Thermoplastics)

Industry Partners

- GKN Fokker
- Specto Aerospace
- KAI

Thermoplastic Composites

Focus and Impact

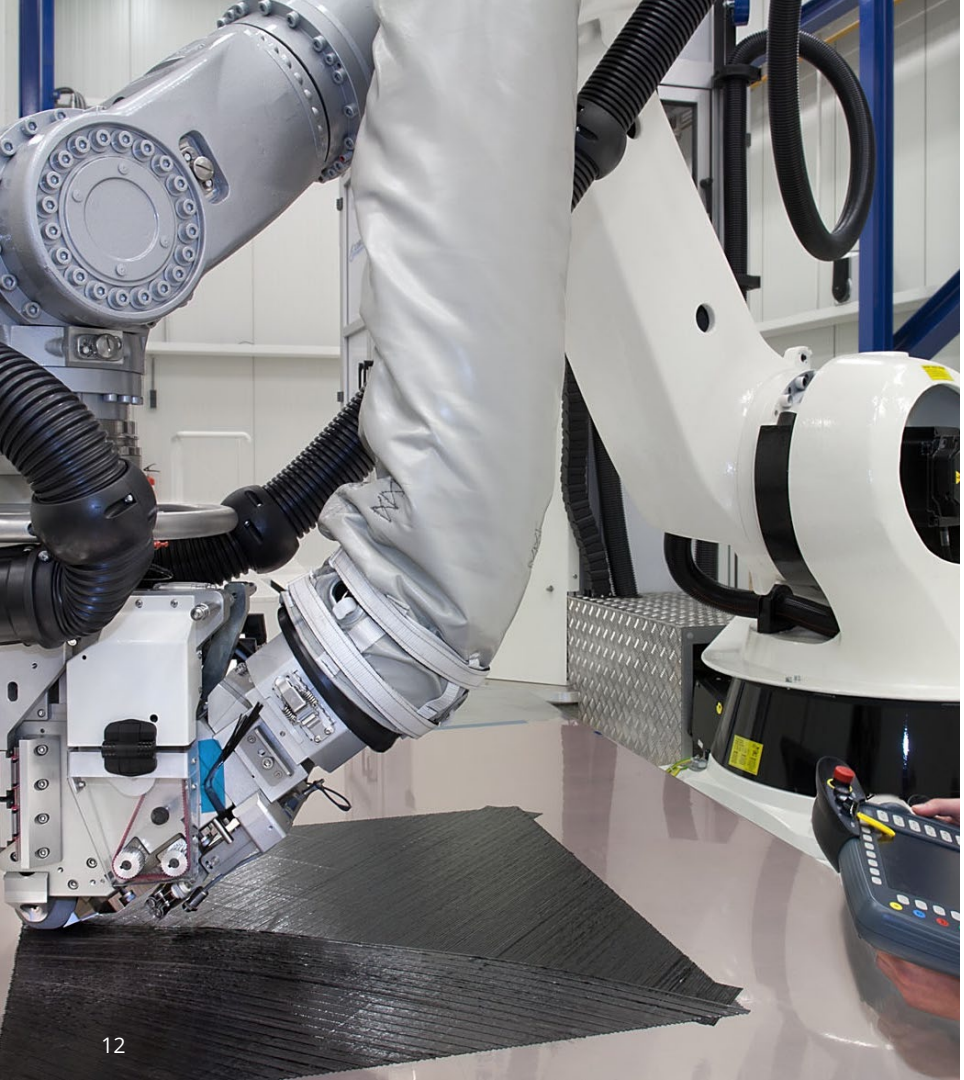
Thermoplastics composites provide a durable, automated and sustainable material with higher performance qualities compared to thermoset composites. The use of thermoplastics introduces flexibility and modularity in composite structure configurations. The challenge with thermoplastics is that they are difficult to produce. Together with its partners NLR has advanced fiber placement technology, welding, 3D printing of fiber reinforced high performance polymers, and autoclave and out-of-autoclave consolidation processes to optimally manufacture thermoplastic composite structures. Within project 'STUNNING' NLR and partners realized the biggest single piece thermoplastic composite structure ever made.

Application and Materials

- Large single piece complex structures
- Welding
- PEEK, PEKK and PEAK

Industry Partners

- Airbus
- GKN Fokker
- Toray (TenCate)



Smart Layup

Focus and Impact

With the introduction of smart layup technology, unique layups can be realized that were previously impossible. This is done using the design and manufacturing freedom of fiber placement and ¼" tape by applying active fiber steering and smart overlapping. This results in ultra-efficient and lightweight composite structures with increased performance over traditional manufactured layups.

Applications and Materials

- Stiffened panels for wings and movables
- Wide range of thermoset and thermoplastic ¼" UD tapes

Industry and Academic Partners

- Airbus
- GKN Fokker
- Diehl
- TU Delft
- TU Twente

Projects and Patents

- CANAL, MAAXIMUS
- AP-PLY patent

Structurally Integrated Antennas

Focus and Impact

Royal NLR develops composite panels with embedded multilayer antennas. Part of the skin panel is EM-transparent, enabling the embedded antennas to receive electromagnetic signals. The AFP-manufactured, orthogrid stiffened panel is capable of withstanding the extreme mechanical, temperature and aerodynamic pressure loads experienced during flight.

Applications and Capabilities

- EM Engineering Design tools,
- Antenna Test Range,
- Experimental Electronic laboratory,
- Electro Magnetic facility

Projects

- ACASIAS
- Smart antennas, phased array antennas
- Integration of antennas in structures
- EM interference research
- Software Defined Radio applications

Production

Factory of the Future

Machines are getting smarter. Nowadays there are sensors to record almost everything. Almost anything can be modeled and simulated. But what to do with all that information? How to translate data into solutions that really make a difference for manufacturing? Royal NLR can help answer those questions using Digital Twin technology. In the context of Industry 4.0 Royal NLR works on various aspects of the ‘Factory of the Future’.

We provide simulation of fabrication processes (virtual manufacturing), real-time monitoring of production unit performance (predictive maintenance, digital twins), and test-validated predictive simulation (virtual certification).

Royal NLR can help to decide what Industry 4.0 approach to use, leading to potential time and cost savings, both in the short-term and in the long-term. Our experience with application of smart technologies to foster improvement in process control and machine and component design, efficiency, and lifetime has been a distinguishing characteristic in the aerospace industry for over 100 years.

The following pages will provide more information on collaboration opportunities with NLR regarding Factory of the Future.

Digital Twin (Production)

Focus and Impact

Royal NLR conducts research on digital twins for production processes in the ACM Pilot Plant. In this unique facility, Digital Twin Technology controls the process by monitoring the health of the parts being produced, in real time.

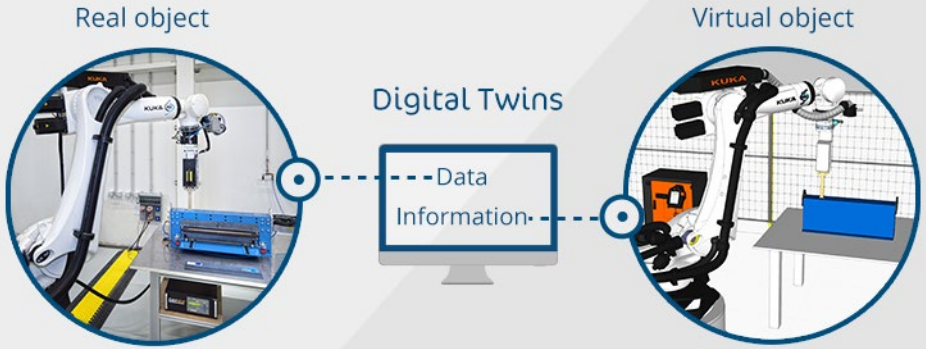
Using the Digital Twin, we can optimize and tailor production processes to consistently improve quality, tolerances and performance.

Application and Capabilities

- Detailed multi-domain modelling of complex components and systems
- Simulation of dynamic, thermal, structural, electrical, and mechanical systems
- Efficient integration of data science, artificial intelligence, robotics, and new technologies
- Coupling PLM/ERP systems with real-time production systems

Industry Partners

- GKN Fokker
- Boikon
- Perspective



Smart Sensors (IoT)

Focus and Impact

A driving force in the performance of Digital Twin lies with the judicious application of smart sensors and data science. Sensors coupled to the simulated digital twin of the production process measure and provide real-time information. The challenge is to efficiently apply data science, artificial intelligence, robotics and state-of-the-art IT technologies to measure the right parameters with the right tolerances. Royal NLR can help realize an efficient and tailor-made integration.

Application and Capabilities

- Continuous monitoring of production processes & equipment
- Expertise coupling information technology, real-time systems and assets with remote and embedded sensors
- Realizing efficient and tailor-made user interfaces

Industry Partners

- Boikon
- Photon First

Sustainment

Hangar of the Future
Contributing to Technology Innovation with State of the Art Facilities & Tools

Durable Sustainment & Repairs
Providing Durable and Affordable Sustainment Solutions

Sustainment

Hangar of the Future

In the Hangar of the Future concept flight maintenance inspections are using robots, cobots and state-of-the-art sensors. After each run the platform can return to the hanger, where, as it taxies in, an automatic inspection is initialized by sensors surrounding the platform. Sensor scans are automatically processed and analyzed to give the maintenance crew a real-time update of the status of the platform. Areas requiring detailed inspection are immediately highlighted and AR-assisted maintenance applications assist the crew further in their work.

The ambition of this concept is to be data-centric. Data from each step in the process are closely monitored and processed into a database, making it possible to use the data to optimize maintenance planning and provide lifetime predictions using digital twins. A tailor-made dashboard projects all the required information for a specific platform, as well as fleetwide statistics. This leads to higher availability, higher affordability, higher productivity, shorter inspection times, and fewer errors.

The following pages provide more information on collaboration opportunities with NLR regarding Hangar of the Future.

Autonomous Inspections

Focus and Impact

Aircraft maintenance requires multiple detailed visual inspections. Aircraft inspections are time-consuming, adding pressure to already scarce resources and time. Qualified technicians are hard to come by, while the world fleet continues to expand, making it difficult to compete on personnel costs. The solution is autonomous visual inspections using robots and cobots to improve productivity.

This leads to higher availability, higher affordability, higher productivity, shorter inspection time, and fewer errors.

Applications and Capabilities

NLR provides robot, sensor, machine vision and certification expertise to build and deploy autonomous robots for visual inspections. NLR has several test rigs in-house to develop inspection robots to improve maintenance productivity.

Projects

- Leading Edge Scanner
- ARBI
- Gerda

Maintenance Technology Infusion

Focus and Impact

Aircraft are maintained by humans, yet human resources are scarce. Automation and robotization improve productivity and increase availability and affordability.

This leads to higher availability, higher affordability, and higher productivity.

Applications and Capabilities

NLR can aid with the infusion of maintenance technology to improve the productivity of the workforce. NLR has experience with the use of robotic inspections, but has a much wider view on productivity improvements opportunities in aircraft maintenance than robotics alone.

Projects

- Leading Edge scanner
- Autonomous Robot for Blade Inspections (ARBI)
- FlexPlan
- ShopPlan

Multi-Domain NDO

Focus and Impact

Autonomous inspection using optical and laser based techniques allows inspection of the outer surface of an aircraft without human interaction. This can be combined with automatic interpretation of inspection results. A more comprehensive image of the condition of the structure can be attained by combining various NDO inspection techniques (Multi-domain NDO) . The purpose of this development is to shorten inspection time, reduce the workload, and eliminate potential human error.

Applications and Capabilities

- Automation and thermography, shearography and 3D visual scanning

Industry and Academic Partners

- Development centre for maintenance of composites
- USL
- Royal Netherlands Air Force

Digital Twin (Sustainment)

Focus and Impact

To optimize aircraft sustainment, models and usage, and maintenance data of individual aircraft are required. This allows maintenance engineers to quickly assess the state of the aircraft and develop repair plans and other maintenance activities. NLR has developed life prediction models and databases that contain vast amounts of loads and usage data. In addition NLR has developed KPIs, dashboards, and a comprehensive suite of visualisation tools.

Applications and Capabilities

- Requirements for digital twins for sustainment
- Crack and corrosion logbook
- Total life cycle management

Industry and Academic Partners

- Prespective
- NATO STO
- Royal Netherlands Air Force

Life Prediction Models

Focus and Impact

To maintain aircraft safety, the remaining viability and lifetime of components needs to be estimated. The latest version of MIL-STD-1530 calls for a stochastic approach. Another area of interest is the modelling of short cracks. NLR has developed a structural risk analysis tool that enables analysis and prediction of slow crack growth in failure-tolerant structures– a unique capability in the industry. It incorporates the latest short crack growth models that have been developed at NLR.

Applications and Capabilities

- A-10 round robin
- RAP++ and SLAP++
- F-35 equivalent initial discontinuity size determination
- ASSIST challenge

Industry and Academic Partners

- GKN/Fokker
- Embraer
- Korean Aerospace Industry
- Airbus
- Lockheed Martin
- USAF

Failure Diagnoses using Explainable AI

Focus and Impact

Aircraft parts occasionally fail irregularly and unexpectedly. A lack of spares results in unavailability. Advanced prediction and warning of imminent failures would allow for planned parts replacement before failure. And an effective failure diagnoses helps to troubleshoot the serviceable part once it arrives at the shop. This leads to higher availability, higher affordability, lower turn-around times, and the opportunity to implement optimized surgical repairs.

Applications and Capabilities

Royal NLR uses data-driven prognostic methods to predict component failures well in advance. These methods are capable of identifying likely failure modes before they become critical. Moreover, these tools help explain *why* a failure mode might occur, using advanced eXplainable Artificial Intelligence (XAI) to substantiate possible root causes for technicians troubleshooting components.

Projects

- WCM Maintenance Innovation Awards 2018
- MATLOG

Smart Maintenance Planning

Focus and Impact

Maintenance programs differ from operator to operator. OEMs therefore shift from predefined checks, and increasingly towards custom packages, to tailor their maintenance programs to their own specific needs.

The impact is higher availability, higher affordability, higher interval utilization, and smarter application of scarce resources.

Applications and Capabilities

NLR has a smart maintenance planning suite, which includes advanced solutions for packaging, long term-planning for resources, short-term planning for robustness, and shop planning for hangar TAT. This suite is very efficient and offers two distinct possibilities, namely to manage the day-to-day planning and to run different strategic planning scenarios to explore planning options and optimization opportunities.

Projects

- FlexPlan
- ShopPlan

AR-assisted Maintenance

Focus and Impact

New digital techniques like AR can increase the efficiency an quality of maintenance. AR can be widely applied for the maintenance activities and process, including:

- previous findings available at time of inspection
- projecting danger zones or no repair zones
- remote (AR enhanced) assistance
- more efficient handover/takeover
- reduced administrative burden

This leads to more effective maintenance. NLR is a frontrunner when it comes to MRO training, simulation, and the application of AR.

Applications and Capabilities

- X-Lab for virtual reality (VR) and augmented reality (AR) experimentation.
- Frameworks for web-based and tablet-based applications.

Projects and Partners

- Digital crack and corrosion logbook
- KLM
- Royal Netherlands Air Force

Aircraft Availability and Affordability Estimator

Focus and Impact

Aircraft are prone to failure and expensive to operate. This decreases the availability and affordability which are generally considered highly unpredictable. Thorough understanding of the effects of budgets and resources on the on-time-performance (and vice versa) improves sustainment strategies and decision-making.

This leads to higher availability, higher affordability, better sustainment strategies, and lifecycle decision support.

Applications and Capabilities

NLR offers an analysis tool to evaluate the influence of labor costs, reliability and spares inventories, and facilities and tooling for the On-Time Performance of an aircraft operation. The tool is specifically built to address uncertainty.

Projects

RNLAF C-130H replacement

Sustainment

Durable Sustainment & Repairs

A key objective for more efficient and sustainable aircraft is to make lightweight, durable and affordable parts that are designed for ease of maintenance. To be allowed to use parts made of new materials like composite and metal additive printed components in an industry like aviation, all of the materials must be accompanied by the right certification.

NLR takes care of the entire process, from calculation and design all the way through to manufacturing, repair and certification. NLR assesses material properties, develops structural concepts and manufacturing technologies, designs components and builds parts all the way up to the level of full-scale prototypes. Spanning the entire spectrum of product development is what makes NLR unique.

The following pages provide more information on the collaboration opportunities with NLR regarding Durable Sustainment & Repairs.

Structural Health Monitoring

Focus and Impact

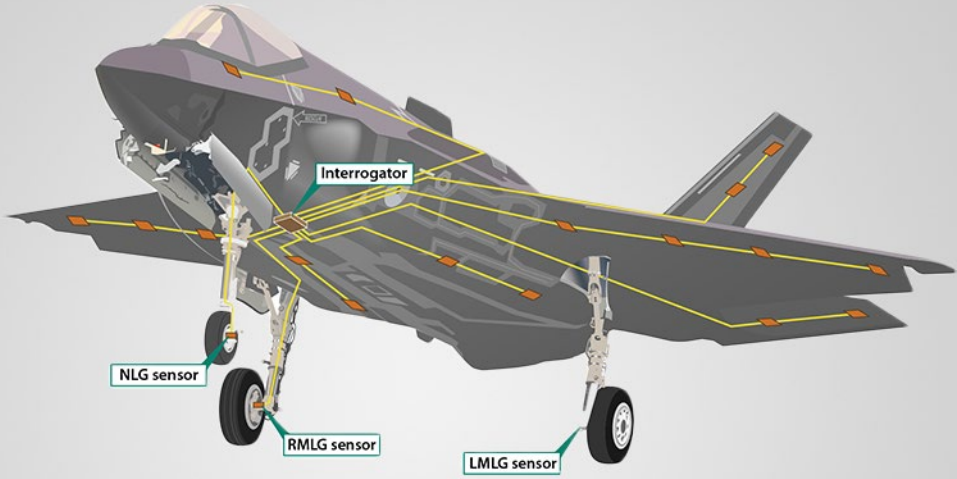
To maintain the safety of aircraft, non-destructive inspections are conducted regularly. This is a time-consuming and costly effort. To reduce costs and also increase aircraft safety, structures can be equipped with sensors which monitor the health of the aircraft. Royal NLR uses fiber optic sensors to perform load and usage monitoring, detect mechanical impact damage, and locate where those impacts took place.

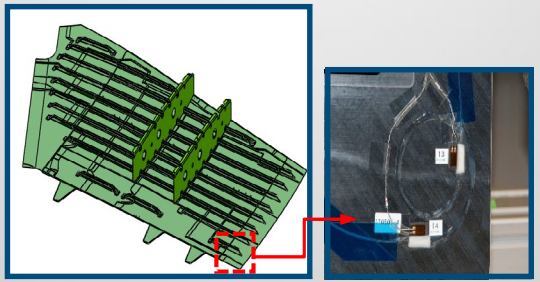
Applications and Capabilities

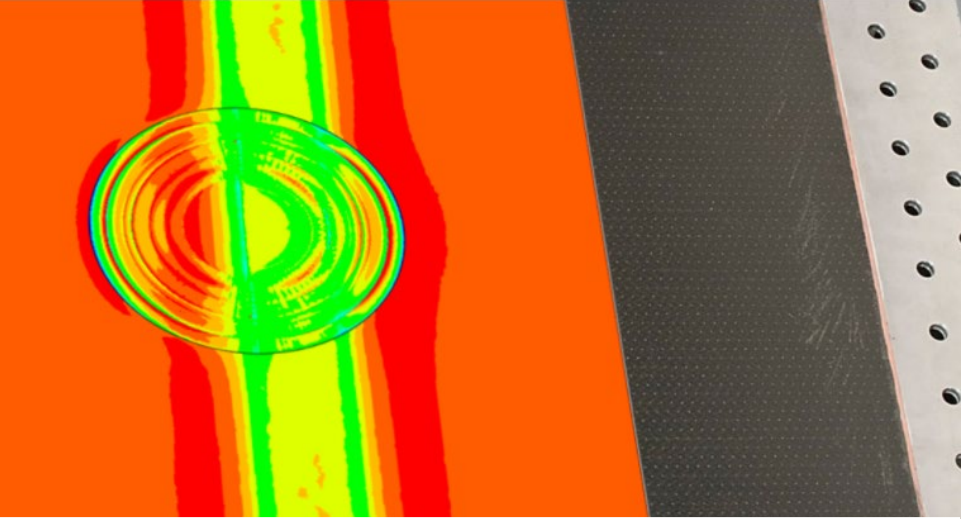
- Load monitoring of landing gear
- Impact detection on stiffened fuselage and wing panels
- Damage detection in multiple load path structures

Industry and Academic Partners

- Airbus
- PhotonFirst
- Somni Solutions
- Redondo Optics
- Boeing







Composite Repair

Focus and Impact

Modern aircraft consist of lightweight composite structures often combined with metallic parts. To maintain low observable properties of such structures flush repairs are required. NLR has developed technology to design and apply structural bond repairs with no rivets or bolts, including the required certification methodology.

Applications and Materials

- Thermoset materials
- Pre-preg and vacuum infusion

Industry and Academic Partners

- Development Centre for Maintenance of Composites
- Fokker Services
- Royal Netherlands Air Force

Corrosion

Focus and Impact

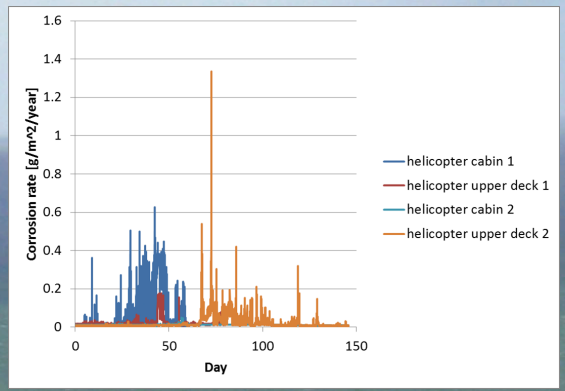
Aircraft and helicopters operated in a saline environment are prone to severe corrosion. This is more serious for hybrid composite / metal structures than for all-metal structures. Understanding of corrosion in hybrid metal-composite structures and translation of sensor data to corrosion risk for aircraft is researched at NLR and applied to reduce the corrosion on the NH90 helicopter.

Applications and Materials

- Root cause analysis of corrosion occurrences
- Definition of mitigating measures
- Characterization and modelling of environmental corrosivity using sensors

Industry and Academic Partners

- Airbus
- Leonardo
- GKN Fokker
- NH90 operators (Nahema)



Cold Spray

Focus and Impact

Aircraft usage results in heavy wear and tear. Several technologies exist to repair components. Royal NLR develops repair technology for repair of composites, direct energy deposition (DED) and cold spray. The focus is on the development of process parameters and certification.

Applications and Materials

- Metals - metals
- Composite - metals

Industry and Academic Partners

- Dycomet
- Royal Netherlands Air Force and Navy

Heat Management & Cooling

Focus and Impact

Modern aircraft made of composite materials retain more internal heat than conventional metallic aircraft. This implies additional load cases on new materials which influence the aircraft component lives and/or operational mission capabilities. NLR assesses power and thermal margins to determine the effect on airframe life cycle management and operational mission capabilities.

Applications and Capabilities

- Digital Twin
- Cross-platform ground test facility
- Next-gen flight test equipment

Projects and Partnerships

- Fighter AiRcraft Power Management
- Royal Netherlands Air Force
- Air Force Research Laboratory (AFRL) – US Air Force

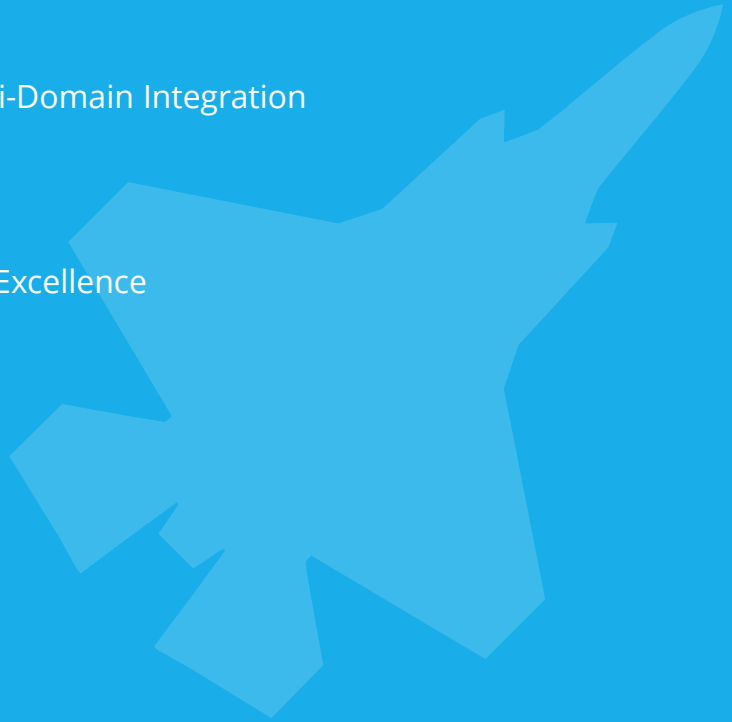
Operations

Multi-Domain Operations

Continuous Operational Improvement through Multi-Domain Integration

Operation Support & Training

Evaluating Concepts of Operations and Training for Excellence



Operations

Multi-Domain Operations

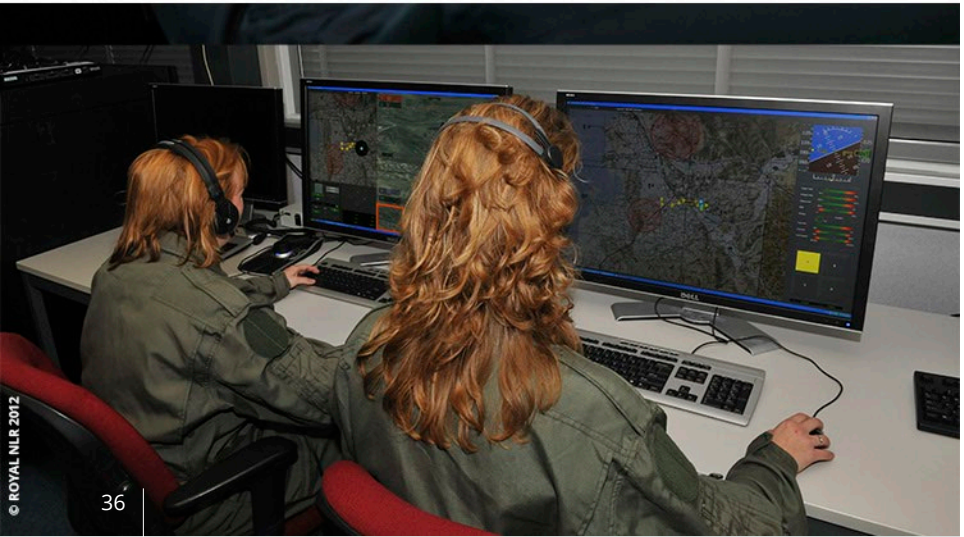
Over the years NLR has provided NLD-MoD with innovative and effective solutions for Air and Space Power related challenges by enabling them a unique smart specifier, buyer and integrator position within the full spectrum of the Technology Readiness Levels (TRLs). NLR supports the NLD-MoD in achieving information superiority by providing space-based intel technology as an enabler for Multi-Domain Operations.

MDO mainly concerns the improvement and acceleration of friendly OODA-loops, to achieve desired effect faster and more efficient. It is a comprehensive methodology that underscores means and methods in support of the people throughout the military organization. It deals with resources and capabilities to match intent from both friendly and hostile entities (armed forces but also “unarmed” organizations that can influence the world). MDO is thus all about collecting data, converting it to information and awareness to understanding, and transforming insight and knowledge into foresight, decisions and actions.

Research and development scope of MDO at Royal NLR focusses on the following themes:

- C5-ISR (Command, Control, Communications, Computers, Cyber – Intelligence, Surveillance, Reconnaissance)
- Platforms & Weapons
- Maintenance/Repair organization & Logistics
- Organization (expertise-, career, training & education- & change- management)
- Advanced training

The following pages provide more information on the collaboration opportunities with NLR regarding Multi-Domain Operations.



Battlelab

Focus and Impact

For decades, NLR has developed, operated and modified simulators thereby realistically simulating future operations.

NLR operates its own Battlelab, Cerebro, where it submerges participants in a realistic simulated environment. NLR has broad experience in assessing human performance during these experiments. This environment is suitable for investigating new platform capabilities, new weapons, the performance of our own weapon systems against new emerging threats, new tactics and new concepts of operation.

Applications and Capabilities

- Part of a BattleLab network including the RNLAF battlelab, the RNLN battlelab and potential the NATO battlelab
- Testing systems in realistic operational scenarios in our Battlelab, Cerebro
- Development of system-of-systems multi-domain architectures
- Experimenting with low TRL-technologies
- Human performance evaluations

Partners

- RNLAF / RNN / NATO

Space ISR

Focus and Impact

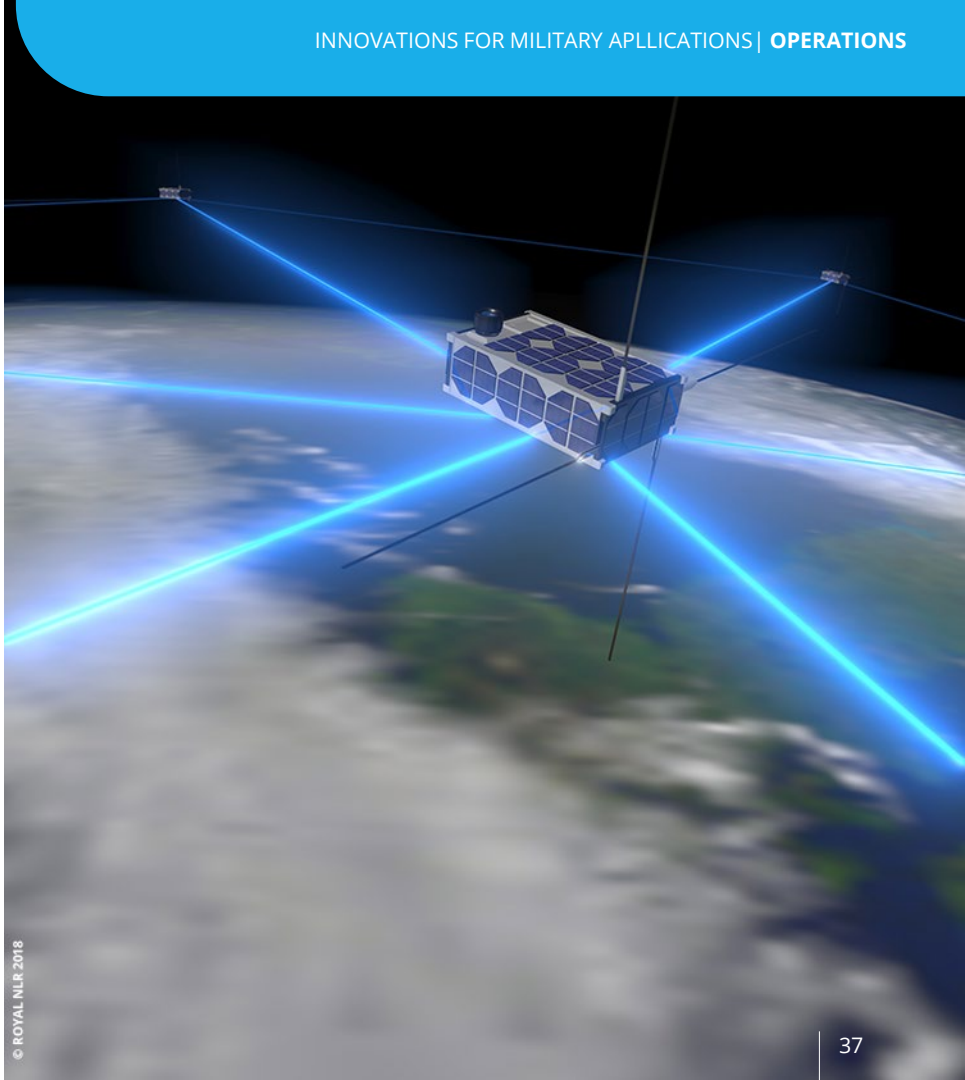
NATO already underlined the importance of the usage of Space at the end of 2019 in declaring Space as an operational domain. The Dutch Ministry of Defense recognizes the usage of space as an indispensable link within an information-driven Armed Forces. NLR has supported the RNLAF in the design and development of the nanosatellite 'BRIK-II'. This nanosatellite will provide the RNLAF with intelligence regarding navigation, communication and earth observation.

Applications and Capabilities

- Supporting military exercises using small, easy-to-launch space infrastructure
- Autonomous translation of operational satellite data to triggers for intel operations
- Thermal control systems
- Low to zero gravity flight testing
- Payload miniaturization

Projects and Partnerships

- BRIK-II (MoD, ISIS Space, TU Delft)
- Responsive Space Capabilities (MoU Netherlands & Norway)



MUM-T

Focus and Impact

Increase human performance by integrating, aligning, developing and CD&E-ing concepts for manned and unmanned co-operation.

Examples are: F-35 MQ-9 joined operation, fast loop simulation, shared information in research program in 2022.

Applications and Capabilities

- Human performance knowledge
- CD&E of new CONOPS
- Simulation environments (platform and C2)

Projects

- Manned-Unmanned Teaming
- Sensing in a networked environment

Operations

Operation Support and Training

NLR provides direct operational support to our Ministry of Defence – MoD in both training environments and during actual deployments. NLR has been embedded with detachments during large scale multi-disciplinary international and joint exercises such as Red Flag and Frisian Flag. In addition, direct operational support is provided by making threat analysis and bringing them into relation with the characteristics of our own platforms, such as their signatures and countermeasures. NLR has profound knowledge of the Netherlands' fixed-wing and rotary-wing aircraft, their subsystems, the weapons they use and their employment tactics. Mission planning and debrief is also amongst the cornerstones of the support NLR provides to our MoD. At the operational level, NLR addresses interoperability opportunities, command and control, decision support and performs operations research.

While providing operation support, NLR has also been the Royal Netherlands Air Force primary training innovation partner for decades, setting up competency based training curricula for both ab initio and continuation training. The ultimate goal of training innovation is optimized training in which units maintain high readiness levels throughout the year while personal training needs are addressed such that the best fitting training time, training event, and use of training media (ranging from apps to LVC setups) are known. Such minimalization of training gaps is being guided by Performance Based Training (PBT) approach and tooling.

Striving towards overall high readiness for a unit while trying to fulfil personal training needs for each individual pilot as well is a challenge that requires advanced optimization algorithms for scheduling, taking needs into account as well as constraints with respect to availability of personnel, assets and air space.

We anticipate that such optimized PBT scheduling can only be achieved with an integrated LVC (Live Virtual Constructive) based data-driven ecosystem, including Embedded Training, MTDS, Virtual Cockpits, AR/VR applications, Smart Bandits, and an EBS CD&E environment.

Performance Based Training

Focus and Impact

Advanced data science enables data-driven qualification and refresher training such that training can be optimized to personal needs and capabilities. Performance Based Training (PBT) is a holistic training approach in which training concepts, training technologies, and data science are well-aligned. PBT optimizes proficiencies in a personalized way. PBT provides a justification for personalized and optimized training schemes such that time- and concurrency-based training regimes are no longer necessary.

Applications and Capabilities

- Learning Ecosystem infrastructure
- Dashboards for learning, performance, and readiness
- Apps for performance/proficiency (self-)assessments
- Recommendations for personalized training
- PBT schedulers

Partnerships

- Royal Netherland Air Force – RNLAF

Live, Virtual, and Constructive Simulation

Focus and Impact

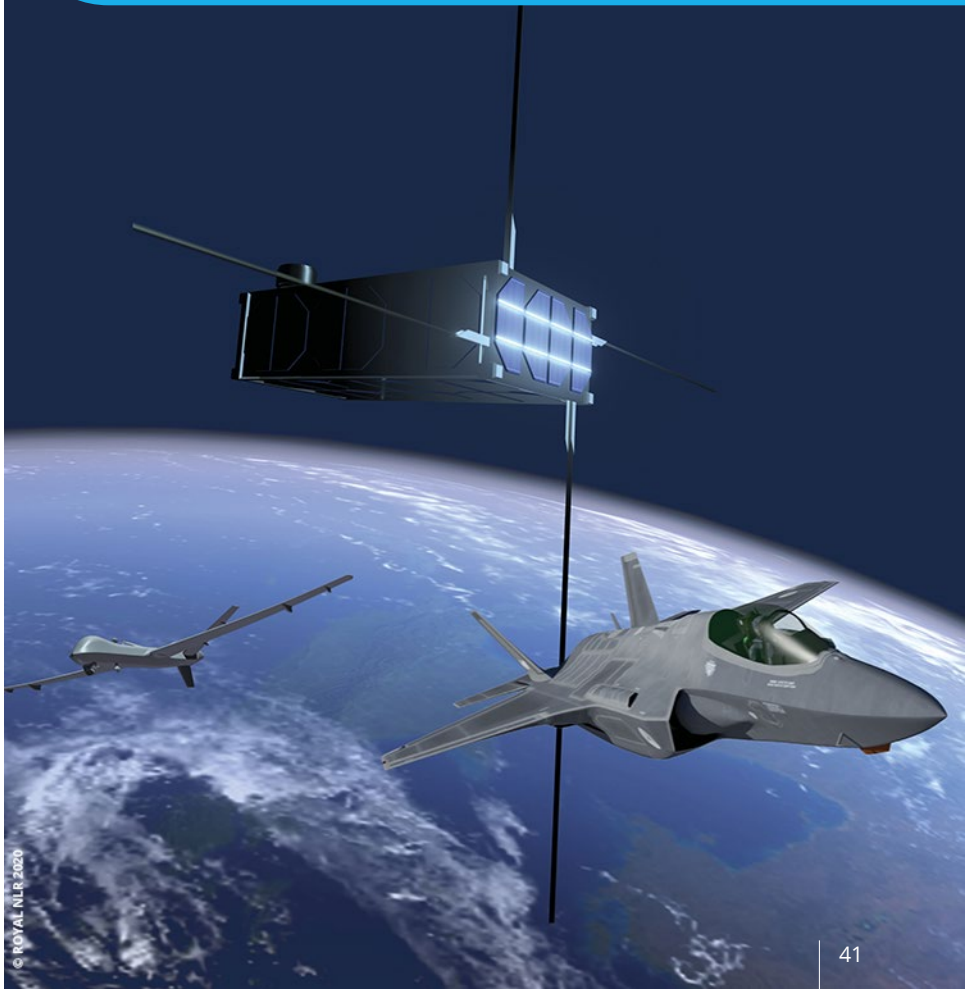
Training, exercises and experimentation are increasingly taking place in an environment where live systems operate together with man-in-the-loop simulators, or in a live environment enriched and stimulated by computer-generated players and events. Such Live Virtual Constructive environments open up new opportunities, but at the same time call for other demands than traditional live or simulation environments.

Applications and Capabilties

- Embedded Training (ACMI Pod)
- Scaled training exercises
- Mission Rehearsals
- CONOPS and Tactics, Techniques, and Procedures (TTP)

Partnerships

- NATO Working Group
- Royal Netherland Air Force – RNLAF



AR and VR Development

Focus and Impact

In our AR and VR development center (X-LAB) we (co-)create various applications to support operations. Training obviously benefits operations and within X-LAB we apply today's AR/VR technology directly to benefit from this. By leveraging homogeneous technologies we're able to maximize impact and ease of interoperability, allowing us to more effectively provide operational support when implementing new workflows such as virtual inspections, walk-throughs, and (de)briefings.

Applications and Capabilities

- Development and validation of virtual and augmented reality resulting in enhanced training, e.g. Virtual Cockpit
- Defense Technology Program exploring benefits of adding AR and related technology counter IED threats and the coherent networks

Partnerships

- Royal KLM Maintenance Engineering
- Royal Netherlands Air Force – RNLAF
- Royal Netherlands Army - RNLA

Virtual Cockpit

Focus and Impact

Virtual Cockpit bridges the gap between low-cost and high-fidelity training technology. By combining NLR's state-of-the-art modelling & simulation and customer operational knowledge we created a radical new low-cost mixed-reality cockpit solution with natural human machine interaction capabilities. Our concept involves the smart integration of Commercial Off-The-Shelf (COTS) products, 3D printing, Virtual Reality, and finger/hand tracking into a type-customizable simulated working environment with a natural feel.

Applications and Capabilities

- Rapid Cockpit Design & Development
- Rapid 'Work Shop' Design & Development
- Procedure Pilot Training Devices
- Procedure Operator (e.g. Maintainer/ Logistics) Training Devices

Partnerships

- European Customers
- Royal Netherlands Air Force – RNLAF

Blended Vision Systems

Focus and Impact

The ability to effectively operate a fighter aircraft depends to a certain degree on the visibility conditions. In reduced visibility conditions, the pilot is aided by tactical and flight symbology as well sensor imagery. Traditionally, these are added as one or two layers over the outside world. Novel augmented reality technologies allow to more subtly integrate symbology, sensor imagery (from on-board sensors or from other sources) and synthetic imagery. This allows for a seamlessly blended and intuitive outside world view, and emphasizes important elements in far more intuitive manner than was previously possible. This next-gen vision system forms a great SA enhancer for the pilot.

Applications and Capabilities

- Combines two track records: developing and evaluating helmet mounted display symbology and augmented reality

Partnerships

- Open for business

Society

F-35 Noise

Perceiving the Sound of Freedom

Safety & Regulations

Society

Aircraft Noise, Safety & Regulations

In a densely populated country as the Netherlands aircraft noise is a notorious issue. Royal NLR provides in-depth knowledge about airport operations, its resulting noise and the impact that this noise has on people living close to and further away from airports. Over the years Royal NLR has worked closely together with partners such as Schiphol Airport and the Royal Netherlands Air Force to work on noise impact and annoyance levels experienced. Alternative operational procedures and flight profiles have been adopted to reduce the impact of aircraft noise on society.

The following pages provide more information on the opportunities at NLR regarding Noise Reduction, Safety & Regulations.

Noise and emissions (1/2)

Focus and Impact

Military aircraft produce noise and emissions affecting the environment and population in the vicinity of an airbase. NLR assists the RNLAF and MoD with legal compliance, community engagement support, and practical and accurate studies on noise, safety and environmental impacts.

Technologies and Applications

- NLR supports F-35 sound perception flights of both the RNLAF and RDAF allowing local residents to experience the noise signature of the new F-35 in direct comparison to the F-16
- Assessment of the effectiveness of sound isolation for F-35 noise reduction (compared to F-16 noise)
- Assessment of measures to improve safety of airbase personnel due to exposure to noise and emissions of the F-35 within shelters
- Support setting up a noise monitoring network around airbases, to inform residents and to validate noise computations
- Noise contours and noise predictions assessments and baselining for regulatory compliance and operational planning

Noise and emissions (2/2)

Focus and Impact

Military aircraft produce noise and emissions affecting the environment and population in the vicinity of an airbase. NLR assists the RNLAF and MoD with legal compliance, community engagement support, and practical and accurate studies on noise, safety and environmental impact.

Technologies and Applications

- Development of noise abatement procedures for military aircraft, optimizing the noise exposure based on local conditions.
- Assessment of rattle noise (mainly Chinook) and selection of local residencies that qualify for constructive counter-measures
- Mobile and scalable VR simulation environment to inform policy makers and local residents on noise impact of future aircraft or flight procedures
- Detailed noise measurements to obtain insight in the noise production of military aircraft
- Investigation of alternative methods to reduce the environmental impact of engine testing, such as water injection to reduce emissions and noise

Regulatory processes

Focus and Impact

Aircraft are maintained by people. People work using ad-hoc processes and procedures, which may be inefficient and ineffective. Sound processes and procedures improve efficiency and effectiveness of the workforce. This leads to higher availability, higher affordability, leaner processes, fewer errors, and higher productivity.

Applications and Capabilities

NLR brings regulatory process management experience, as well as business process re-engineering expertise. NLR further can assist with the automation and robotization of processes and procedures.

Projects

RNLAF Continuing Airworthiness Management Organization (CAMO), various aircraft operators and maintenance organisations

A century of knowledge and innovation in aerospace

Wanting to progress is human nature. We dream about the unknown. We're curious about what we may find beyond the horizon and want to get to the bottom of things we don't understand. NLR has been an ambitious, knowledge-based organization for a hundred years now, with a deep-seated desire to keep innovating. We are very proud that we have received the royal predicate and that we are now the **Royal Netherlands Aerospace Centre**. Our knowledge and expertise have made us one of the driving forces in the aerospace sector, both in our own country and abroad. Our staff search tirelessly for new technology and have the courage to think outside the box, translating trends and developments into actual solutions for the market.

That drive is helping us make the world of transport safer, greener, more efficient and more effective.
Above all, we keep looking ahead – because we have to keep setting ourselves tougher challenges if aerospace is to become more sustainable in the long term. How can we make sure that the environmental impact is minimized? How can we guarantee aviation safety despite its exponential growth? In short, how can we use airspace more efficiently? How can we make the best possible use of satellites and satellite data? The future looks highly demanding yet fascinating and it will require even faster innovation and closer cooperation, with the right driving forces behind it. We are devoting our knowledge and expertise to that future, with an eye on the interests of the commercial sector, the general public and the environment at all times.

Together with our partners, we can help shape the fascinating world of tomorrow. We are on the threshold of innovations that will really break the mould. But plans and ideas only really get moving if they are nourished with the right kind of energy – and the amazing thing is that the source of that energy is still exactly the same as it was when we started a hundred years ago. That driving force is NLR's knowledge.

Knowledge powers the future

For more information:

Egbert Smit, Contact NLR Defence
p) +31 88 511 37 78
e) Egbert.Smit@nlr.nl
l) www.nlr.org/defence

Arno Rook, Contact NLR Defence Industry
p) +31 88 511 32 77
e) Arno.Rook@nlr.nl
l) www.nlr.org/industry

NLR Amsterdam
Anthony Fokkerweg 2
1059 CM Amsterdam
p) +31 88 511 3113
e) info@nlr.nl i) www.nlr.org

NLR Marknesse
Voorsterweg 31
8316 PR Marknesse
p) +31 88 511 4444
e) info@nlr.nl i) www.nlr.org

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