Dedicated to innovation in aerospace

Applying innovation in MRO

Royal NLR - Netherlands Aerospace Centre

MRO solutions by NLR

Maintenance Management

NLR creates smarter organisations by providing managerial decision support tools and consultancy services for strategic challenges. We are capable of balancing business, economic and technological issues.

Maintenance Technology

NLR creates smarter technologies by developing innovative soft and hardware tools and solutions. We create new maintenance resources and capabilities. We employ cutting-edge knowledge and technologies to automate maintenance tasks and processes using robotics, prognostics and artificial intelligence.

Maintenance Training

NLR creates smart training curriculums and training devices with state-of-the-art training concepts and technologies. We create training value using state-of-the-art training design principles and modern technologies such as virtual and augmented reality.

Maintenance Engineering

NLR creates smarter solutions by combining existing knowledge, techniques and methods. We optimise your maintenance operation, maintenance planning, and resources, spares and personnel allocation. We drive process and product improvements, for example with quantitative data analysis.

Royal NLR

Applying innovation in MRO

If you are maintaining aircraft or if you are looking for innovative maintenance technologies to improve the availability of your aircraft or to reduce costs, NLR can support you. Or if you want to prepare for the future of aircraft MRO, we are your sparring partner.

Operators, maintenance organisations and OEMs aim for maximum aircraft availability at minimal costs. This objective drives, to a large extent, the value of aircraft maintenance. Achieving these goals requires expert knowledge and game-changing technologies. NLR offers practical solutions for excellence in maintenance operations and innovative maintenance technologies to improve availability and affordability for civil and military maintenance organizations, airlines and OEMs.

We have selected some of the projects, research and capabilities that we have developed ourselves and together with partners, for you to get to know more about NLR and our MRO activities.

We hope you enjoy reading and discovering more about NLR.

Michel Peters, CEO
Royal Netherlands Aerospace Centre

THE SOLUTION

Royal NLR works on maintenance technology to perform autonomous robotic aircraft inspection that can help improve productivity and make the working environment for aircraft technicians more interesting.

NLR's Autonomous Robot for Aircraft Inspections (ARAI) comprises:

- A robot to move the sensors to the right locations around the object
- One or more sensors to scan the object
- Advanced defect detection algorithms
- Automation technology to autonomously perform the prescribed inspections.

ARAI - Autonomous Robot for Aircraft Inspections

Robots to support aircraft technicians

Aircraft inspections are a large part of the aircraft maintenance activities but can be difficult and tedious. They require highly trained technicians with a sharp eye to detect defects. Some defects are very small or hidden and difficult to detect, with or without inspection tools like mirrors, looking glasses, multi-meters, non-destructive testing devices, etc. Royal NLR has performed elaborate research on technological solutions to improve the detection of multiple defect types using multi-sensor technology and automated defect recognition software.

THE CHALLENGE

- To develop novel methods to perform inspections more efficiently to cover the many defect types. From obvious defects (nicks an gauges) to the detection of leaks and missing nuts and bolts.
- To find very different defects in very different materials in very different parts of the aircraft. There are many areas, systems and components that require inspection, and each may fail in different ways.
- To develop the technology and systems that can perform these inspections autonomously. There is not a single sensor to scan all parts of the aircraft and detect all thinkable defects. And from a productivity point-of-view, it makes no sense to hand-carry these sensors through the aircraft or to manually analyze the scans or images.

WHAT DID WE DO?

The ARAI test rig is suitable to inspect fuselage panels, wing sections, and helicopter main rotor blades. It can be fitted with multiple sensors to inspect for example composite structures for delamination, skin-to-core unbonds, and so on.

In the background, our algorithms detect defects and also classify and measure the size the defects. The software compares the actual sizes against the allowable damage limitations.

Project partners
Research organisation : Royal NLR
University: Delft University of Technology Universiteit Groningen, Universiteit Twente, InHolland, Hogeschool van Amsterdam, Saxion

Leading Edge Scanner
Autonomous Robot for Visual Inspections

Aircraft inspections require time and highly professional technicians. This makes aircraft maintenance time-consuming and expensive. Royal NLR does research on the possibilities to make aircraft visual inspections faster and more affordable by automating and robotising these visual inspections..

THE CHALLENGE

Aircraft inspections are critical for the continued operations of aircraft. However, the downtime and costs are a burden for operators. Current developments in automation, robotics, photonics, sensor technology and image processing are rapidly advancing. NLR's research focuses on whether these technologies can be applied to visually inspect aircraft.

Benefits:

- Productivity: robots can minimise the routine work allowing the expert technicians to focus on more demanding inspections. This may become particularly relevant with an aging population of technicians
- Make the work more pleasant for technicians. Robots can take over dull, dangerous and dirty work.

LE SCANNER

Our leading edge scanner is our test bed to integrate different steps of the process to enable robots to autonomously inspect complex objects and parts such as aircraft.
It can inspect metallic leading edges for dents, scratches, gouges, missing rivets, and can also inspect composite structures for delamination, skin-to-core unbonds, and so on.

One of the challenges is the automation of an inspection robot. Not only does it require a robot arm (or a cartesian or delta robot), but it also requires different sensors to detect, classify and measure different defect types. And if we inspect larger objects, the images may require alignment and stitching too. In the background, machine vision technology and image processing algorithms are hard at work to process the images and draw meaningful conclusions. And it is not sufficient if you can perform one of the tasks, for an automated inspection, all these steps are necessary.

THE SOLUTION

Royal NLR developed a system to investigate the possibilities visually inspect aircraft and components.

Building blocks:

- One or more sensors to scan the object. The choice for the sensors depends on the type of defect you need to find
- A robot to maneuver the sensors to the right locations around the object
- Algorithms to detect, classify and measure defects
- Automation technology to autonomously perform the prescribed inspections

Project partners

Research organisation : Royal NLR

University: Delft University of Technology Universiteit Groningen, Universiteit Twente, InHolland, Hogeschool van Amsterdam, Saxion

Project partners
Industry NL: DCMC
Defence NL
Research organisation: Royal NLR

Fast Contactless Multidomain Non-Destructive Inspection

Currently, not a single NDI technique is able to find all defects considered inside of a part. By combining multiple NDI techniques into a single platform, defects are better found and classified. By using non-contact techniques with a large Field Of View (FOV) scanning can be done rapidly. The NDI techniques provide a data set that enables, a complete digital twin of the inspected part.

THE CHALLENGE

The challenge for most hardware maintainers is that data from inspection can be quite fragmented and not easy to find. For example: The technical status of rotor blades are not easy to be found inside current systems. By using non-contact NDI methods this data can be extracted from the part itself. The NDI methods must be able to capture the geometry of the part, defects and be able to identify and locate previous repairs.

THE SOLUTION

The solution consist of scanning rotor blades with multiple NDI techniques. First, the external geometry of the part is captured using photogrammetry and 3D structural light scanning. This enables the detection of geometrical defects like dents, holes and scratches. Additionally, the surface mesh is used as a template to map the NDI inspections on. Thermography and Shearography can locate defects and repairs in the subsurface of the part.

WHAT DID WE DO?

Royal NLR has developed a method to combine multiple NDI data streams on top of a single surface mesh. This allows for easy comparison of defects in different NDI data, leading to better defect classification. Additionally, since the data is stored on top of the 3d surface mesh, a complete digital representation of the part is achieved. This allows the user to go back to every scan interval looking for changes inside of the product during in-service. Additionally, this can also be used to view the results using augmented reality.

Engineering Failure Analysis

Do you need to know the root cause of why your component, structure or plant failed? What causes your decrease in production yield? Or to know whether your component or structure sustained damage during operations that exceeded the operational limits? Do you need a second opinion, an independent expert, a report on failure analysis or recommendations to prevent failure in the future?

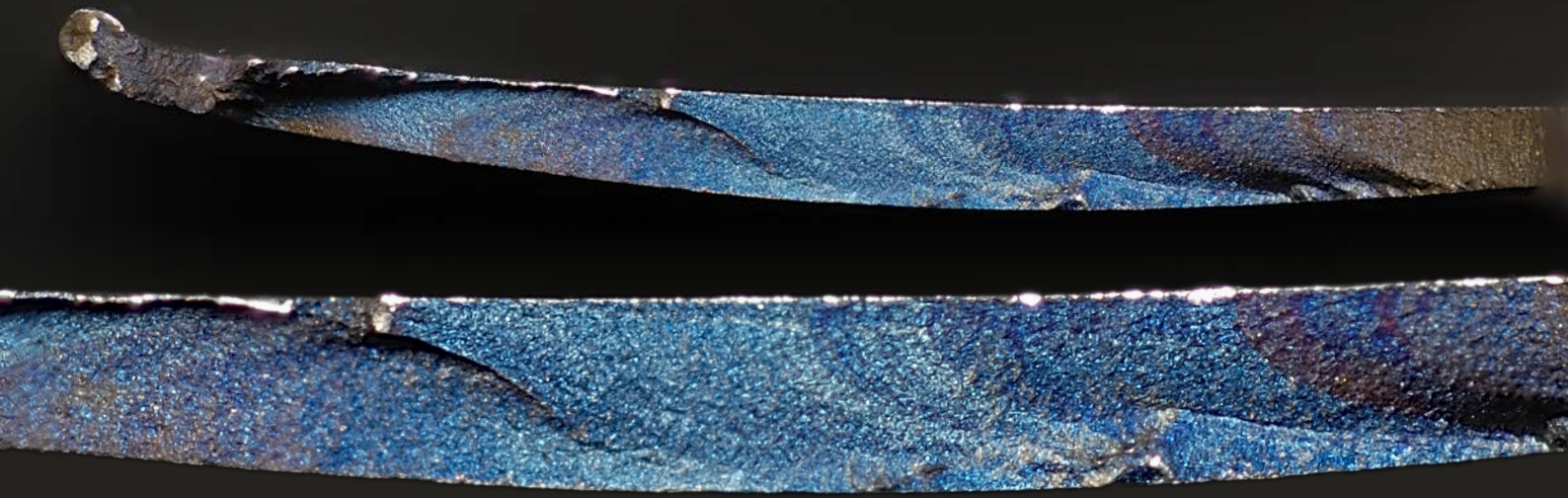
NLR's Test House is specialized in material research and engineering failure analysis on complex components. We have over 60 years of experience in aerospace, defense and high tech industry that strive for the highest safety standards with extensive knowledge on failure modes of materials with a specialization in:

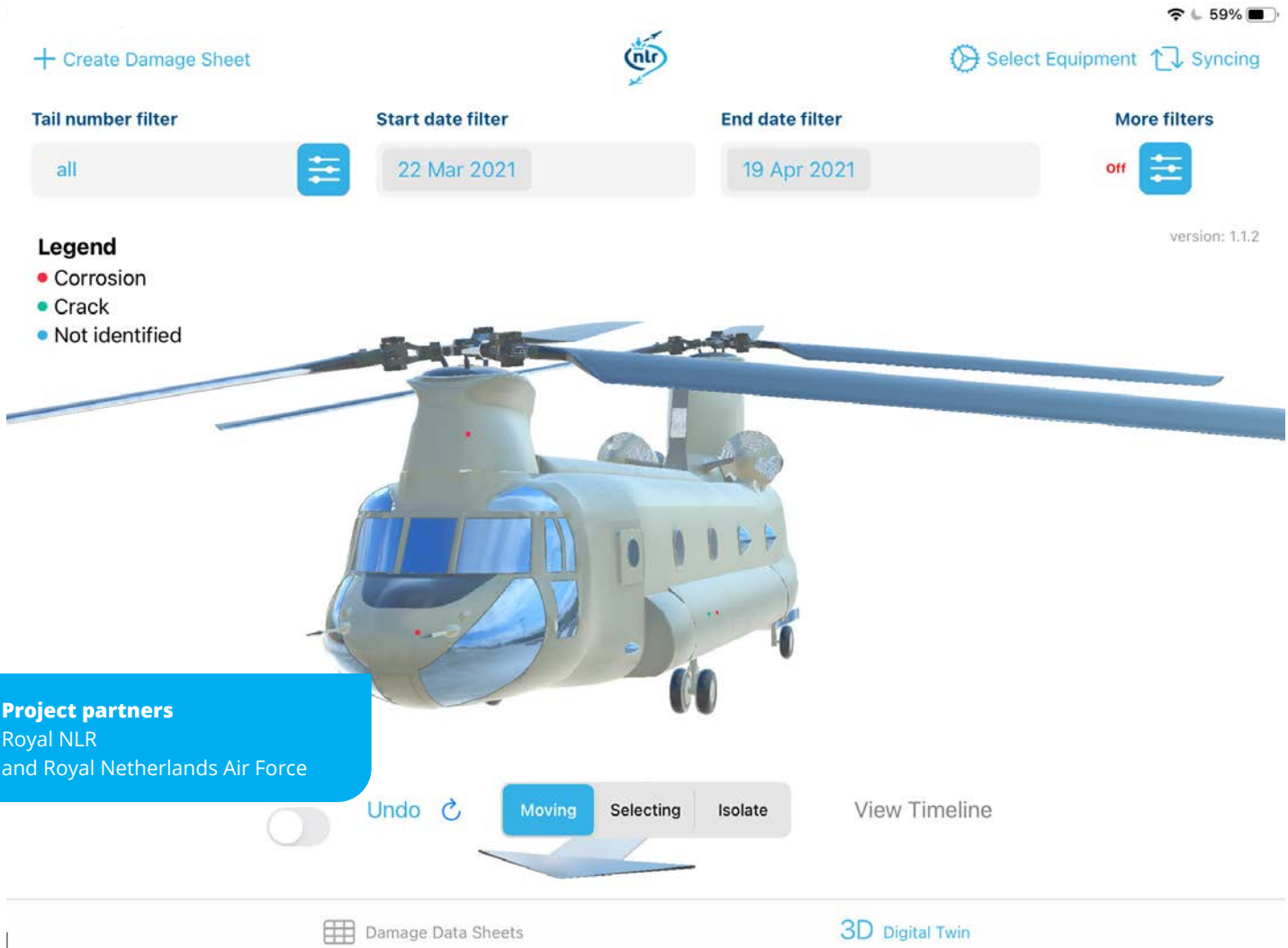
- structural materials
- high temperature materials (Ni-, Co- and Ti-alloys)
- composites

Equipment for mechanical testing, materials analysis and fractography, which enable full analysis capabilities, including: dynamic and static test machines, optical- and scanning electron microscopes (SEM), energy dispersive analysis of X-rays in the SEM (EDX, for analysis of the chemical composition) and non-destructive testing.

From a multi-disciplinary approach NLR delivers the essential feedback to design, manufacturing, maintenance/repair and safe operation.

NLR offers material and failure analysis for the aerospace and high tech industry.
From a multi-disciplinary approach NLR delivers the essential feedback to design, manufacturing, maintenance/repair and safe operation. The modern material facilities and extensive experience provide NLR the capabilities to ensure proper material solutions for our national and international customers.





Project partners
Royal NLR
and Royal Netherlands Air Force

Digital Crack & Corrosion Logbook

Reliability Centred Maintenance processes such as MSG-3 aim to decrease the maintenance burden, mitigate operating risks and deliver sustainable equipment reliability and readiness. For this, high fidelity inspection and maintenance records need to be available.

THE CHALLENGE

The data entry portal of the current generation of maintenance data systems is cumbersome and non-intuitive. Most of the data has to be entered manually and the likelihood of entering inconsistent and/or incomplete data is high. The quality of the recorded inspection and maintenance records therefore is often less than satisfactory. This negatively affects the ability to conduct useful reliability analyses.

THE SOLUTION

To improve the consistency and completeness of structural inspection findings, and to reduce the administrative burden on maintenance personnel, Royal NLR developed an intuitive and easy-to-use interface, the digital Crack & Corrosion Logbook (d-CCL) that takes away the data entry burden for the maintenance engineers.

WHAT DID WE DO?

The d-CCL is an app that runs on a tablet computer and features an intuitive 3D web interface. The inspection findings can be entered either graphically, through a 3D model of the aircraft at hand, or by means of pull-down menus. The app connects to a server as soon as an internet connection is available, upon which data synchronization is performed with the ERP system of the aircraft operator.

Historical data and data from other aircraft in the fleet are thus readily available to the maintainers. This enhances their situational awareness and increases the probability of detecting structural anomalies.The app is complemented with centralised software for performing fleetwide reliability analyses.

FD XAI

Failure diagnostics with eXplainable Artificial Intelligence (XAI)

THE CHALLENGE

Would you like to know how your component or when system is going to fail, before it fails? This would help you with your troubleshooting, repair planning or to scope repairs to preventively remove a working component.

HOW CAN WE SUPPORT YOU

NLR developed a new tool to diagnose failures using Artificial Intelligence. It is a clever piece of software that looks at the failure modes of previous repairs and the aircraft usage. We use Artificial Intelligence to determine the relation between aircraft and system usage and the actual failure modes of repaired parts. We can use these relationships to diagnose components or systems and identify the failure modes.

The trust in the results of computerized diagnoses is highly dependent on the transparency of the analyses. To make the outcomes of failure diagnoses acceptable for maintenance personnel, the algorithms use eXplainable Artificial Intelligence.

FD XAI not only identifies the failure modes, it also explains why a specific failure mode occurs (and not another failure mode). The explanation helps maintenance personnel understand the diagnosis, and troubleshoot failures on the line and in the shop.

Failure diagnoses using eXplainable Artificial Intelligence can be performed before a part actually fails. This means that it is a useful tool to determine the failure mode of parts removed in serviceable condition based on predictive indicators. It helps the shops to repair these parts and it reduces no-fault-founds.

AARE
Aircraft availability and resource estimator

THE CHALLENGE

Maintaining aircraft means balancing budgets and resources to achieve the best aircraft availability. This balancing act is complicated by uncertainty; maintenance is inherently unpredictable.

HOW CAN WE SUPPORT YOU

AARE or aircraft availability and resource estimator offers a management decision support tool to determine the impact of changes to budgets and resources on the fleet availability (and vice versa) based on realistic reliability data, and it is specifically tailored to cope with uncertainty. It provides the user with valuable insights into the relation between fleet availability, resources and budget. It supports you with your financial planning, and set realistic availability targets, such as your On Time Performance.

AARE serves different purposes. It can help you with your financial and operational planning in an existing operation. However, you can also use it if your operations change or of you prepare for fleet changes, such as the introduction of a new aircraft type. It also offers an interesting learning experience for managers and management trainees. AARE can be tailored to your needs.

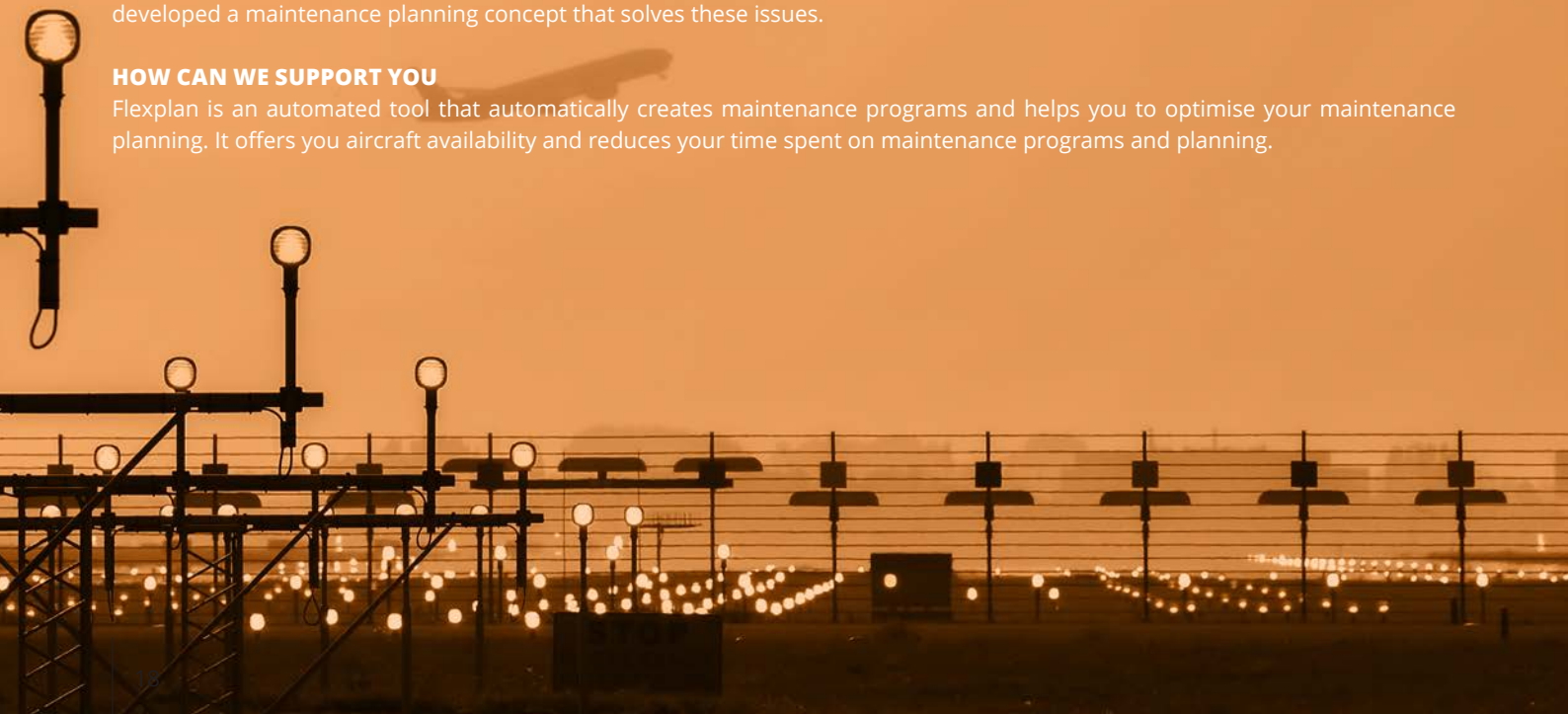
FlexPlan
Flight schedule driven maintenance planning

THE CHALLENGE

Operators use various maintenance planning concepts, however, none of these concepts really takes the flight program into account. Common maintenance concepts such as block programs are easy to schedule, but take an aircraft out of service for some time. Equalized programs break up large inspections but they can introduce excessive access and preparation times. NLR has developed a maintenance planning concept that solves these issues.

HOW CAN WE SUPPORT YOU

Flexplan is an automated tool that automatically creates maintenance programs and helps you to optimise your maintenance planning. It offers you aircraft availability and reduces your time spent on maintenance programs and planning.



NLR'S FLEXPLAN

- Reads a Maintenance Planning Document, interprets the applicability of individual tasks and creates an operator specific Aircraft Maintenance Program automatically
- Creates small packages of tasks, optimally clustered to minimise access and preparation times
- Assigns the packages to maintenance slots based on the flight schedule
- Updates the maintenance slots if last-minute changes in the flight schedule occur.

FlexPlan only uses readily available information, namely a Maintenance Planning Document, the aircraft maintenance status, the aircraft configuration, a flight schedule, and a list of maintenance facilities. We then use an automated workflow to dissect the Maintenance Planning Document, create packages, schedule these packages and update the schedule if required.

FlexPlan makes extensive use of Artificial Intelligence to optimise the packages, schedule these packages and update the schedule.

The result is a comprehensive maintenance program, with packages that minimise access and preparation times, that schedules maintenance around your flight schedule, and is sufficiently robust to facilitate last-minute changes to the maintenance schedule if your flight schedule is disrupted.

And the best thing is, it is all done automatically; you do not need to spend time on an operator specific Aircraft Maintenance Program or maintenance scheduling. It is all done for you. And since FlexPlan adheres to the task intervals specified by the original equipment manufacturer, you do not face regulatory issues.

Engine Condition Trend Monitoring for predictive maintenance

An important trend in the sustainment of aircraft engines is the transition from preventive maintenance to predictive maintenance. This concept aims to minimise the engine down-time and maintenance costs while preserving its required performance level and airworthiness. For this it is necessary that the momentary engine condition can be established and that this condition can be reliably extrapolated to a convenient moment in the future in order to facilitate the planning process.

THE CHALLENGE

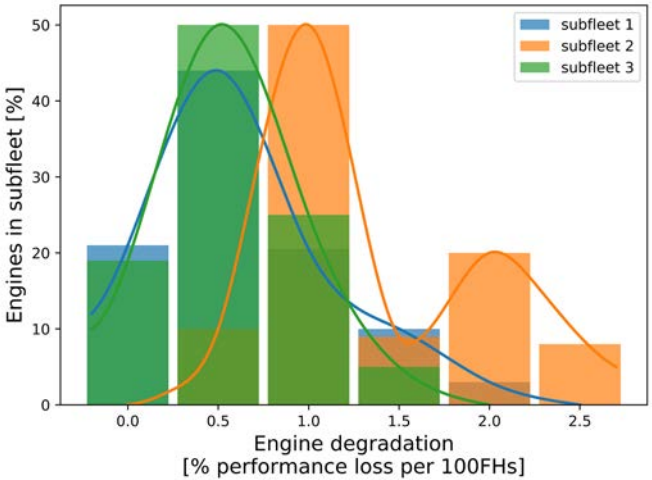
Legacy aircraft engines only feature a rudimentary form of health monitoring, which makes it hard to establish and extrapolate their condition without intrusive and time consuming post-flight inspections.

THE SOLUTION

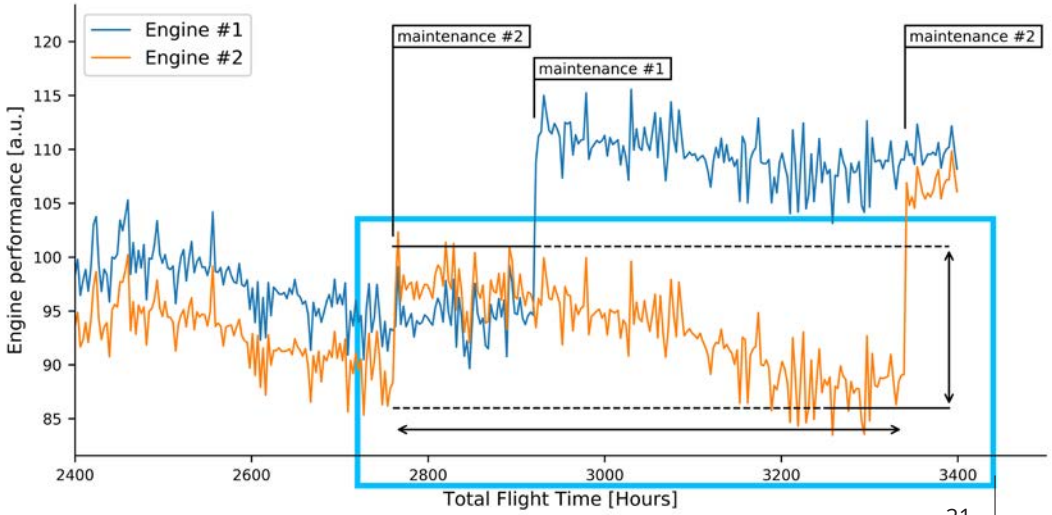
NLR developed an alternative and simple approach, Engine Conditioned Trend Monitoring, to establish the current and future engine condition from the limited data that is available from the digital engine control unit (DECU) which is present on many legacy aircraft engines.

WHAT DID WE DO?

For a particular turboshaft engine that is used on a military helicopter we have developed a data-driven approach to empirically derive a measure for the overall engine condition from a handful of sensor data, viz. the engine torque, the power turbine inlet temperature, the air speed, the outside air temperature and the pressure altitude. We were able to identify engine degradation over time and correlate it to specific usage patterns and maintenance actions. This enabled the operator of the helicopter to perform predictive maintenance based on the operational theatre and usage of the helicopter. The model has been verified against historical data (known engine failures).



© SHUTTERSTOCK



Project partners
Royal NLR and
Royal Netherlands Air Force


PH-NLX

Starling – On-ground research platform

Air transport regulations can often be a hurdle, hindering innovations through costly and time-consuming certification. NLR aims to reduce this hinderance by building an on-ground test platform that can be used to mature data acquisition technologies before being implemented in an aircraft.

THE CHALLENGE

The stringent regulations and certification processes of the aviation industry have made it the safest form of transportations. However, the same processes suffocate innovation because any new equipment installed on an aircraft must be certified. This process can be prohibitively costly especially if the technology needs multiple iterations of design and testing to become mature. As a result, small scale innovations that could be of significant impact at industrial scale will likely not be pursued because of the high development cost and time.

WHAT DID WE DO?

Starling is an electric vehicle that has been modified to be a research platform of new technologies that will go on to be implemented on future aircraft. The modularity of the platform offers many possibilities for low-TRL (Technology Readiness Level) research. Perhaps you want to test a new array of sensors, or you want to build new algorithms based on the data you acquired from the on-board sensors, or even change the powertrain to work on hydrogen. Many innovative ideas are possible in a modular research platform such as Starling.

THE SOLUTION

Starling offers an on-ground alternative to aircraft, to test and develop innovative technologies to a mature state. By using this platform we can delay or even avoid the heavy cost of certification, thereby enabling short-cycle innovations with quick iterations, for the betterment of future aviation.

1NTEGRATE: an integrated Structural Health Monitoring system for stationary and rotating aircraft components, based on fibre optic sensing

THE CHALLENGE

The sustainment costs of military aircraft make up a substantial part of the total life cycle costs. An important world-wide trend in this respect is the transition from corrective and preventative maintenance to predictive maintenance, which is expected to lead to large cost savings and availability improvements. For predictive maintenance it is essential that the actual system condition can be measured. Much research effort is currently being put in the development of technologies that enable predictive maintenance, among which Structural Health Monitoring (SHM). However, the transition of these technologies into service is very slow. One reason for this is the lack of standardization and the poor integration of the new technologies with existing data acquisition systems.

THE SOLUTION

The SHM system will enable loads & usage monitoring to be performed much more efficiently in comparison with currently available technology. Moreover, it will combine functionalities that could not be combined before, viz. simultaneous loads monitoring, mechanical impact event detection and damage detection/localization, both in stationary and in rotating aircraft components. The following examples serve to show the relevance and potential use of the developed SHM technology

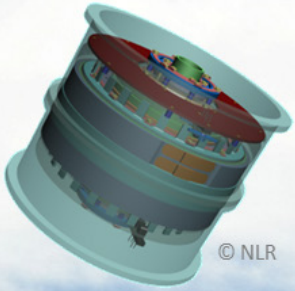
- Loads monitoring of landing gears (hard landings, remaining useful life)
- SHM of medium-sized and large UAVs
- Enhanced rotor balancing of helicopters

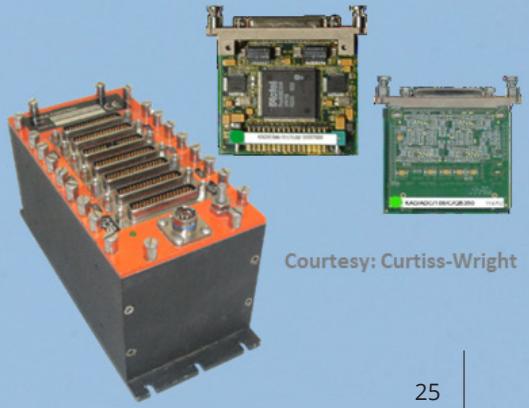
WHAT DID WE DO?

The project partners aim to integrate three key data acquisition technologies into one comprehensive Structural Health Monitoring system for stationary and rotating aircraft components, based on fibre optic sensing: an existing modular data acquisition unit, a patented contactless power and data transfer module and a miniaturized fibre optic interrogator based on ASPIC technology (application specific photonic integrated circuits).

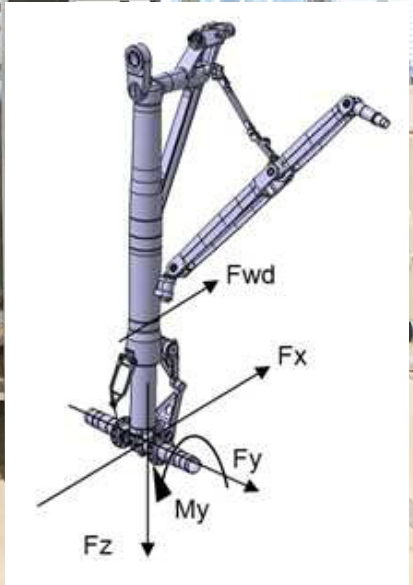
The loads and damage data collected with the SHM system will be fully synchronized with data from other sources, such as flight and usage parameters. The fibre optic sensors in the form of Fibre Bragg Gratings (FBG) that are incorporated in the SHM system will offer many significant advantages over conventional strain gauges.

Project partners:
Industry: Technobis Fibre Technologies, ACQ International, Curtiss-Wright Avionics & Electronics
Research organisation: NLR





Project partners
Industry (NL): Technobis Fibre Technologies BV
Industry (EU): Airbus (UK), MEGGITT (UK and CH)
Research organisation: NLR



ALGesMo: Advanced Landing Gear Sensing and Monitoring

THE CHALLENGE

Landing gears are designed according to the Safe-Life philosophy yielding a fixed number of load cycles. The true loads on landing gears during operation are not measured and the gear is replaced when it reaches the design life, irrespective of the remaining life. By measuring the loads on the landing gears the usage life can be improved. Apart from this, various other important quantities can be measured such as: accurate detection of hard landings, aircraft weight and balance measurements, sensitive air-ground transition detection, braking torque control and others.

THE SOLUTION

Several systems have been tried in the past to measure the loads on a landing gear. These all failed for one reason or another. A new very promising approach is to measure the loads with the use of optical fibre Bragg grating (FBG) sensors, which offer several advantages over traditional sensors, such as low weight, no EMI, no recalibration and robust for harsh environments.

WHAT DID WE DO?

In the project a complete monitoring system has been developed and tested on ground. The monitoring system consists of a (retrofit) sensor system for the landing gears, an optical fibre processing unit that can be mounted in the electronics bay of civil aircraft to measure the response of the optical fibre sensors based on state-of-the-art photonic integrated chips, the routing and harness of the optical connection between the sensor system and optical fibre processing unit. The whole system was thoroughly tested in a dedicated test rig to determine its performance under limit load conditions and endurance testing at elevated temperatures.

Chromate Containing Dust Analysis

Chromate containing dust can be found in aircraft and aircraft components and engines. It may or may not be recognisable by its yellow colour. The presence of chromate containing dust poses a health risk for mechanics and other people coming into contact with it. Therefore the questions where it originates from and how to mitigate the risk for personnel need to be answered for safe operation and maintenance of the aircraft.

THE CHALLENGE

The health risk posed by chromate containing dust must be solved. To assess the present and future risk a number of questions needs to be answered:

1. Where is chromates containing dust found?
2. What is the origin of the dust?
3. Can the dust be cleaned sufficiently to solve the health risk?
4. What conditions result in the formation of chromate containing dust?

WHAT DID WE DO?

The presence or absence of chromates in the dust is shown with wipe tests that contain reagents that exhibit a fast colour change in the presence of chromates. The exact amount of chromates is determined for a selection of locations with laboratory analysis. The locations where chromates were found provided information about the origin of the dust.The locations on the aircraft where chromates were found were first cleaned and then checked with the wipe tests to determine the effectiveness of cleaning.

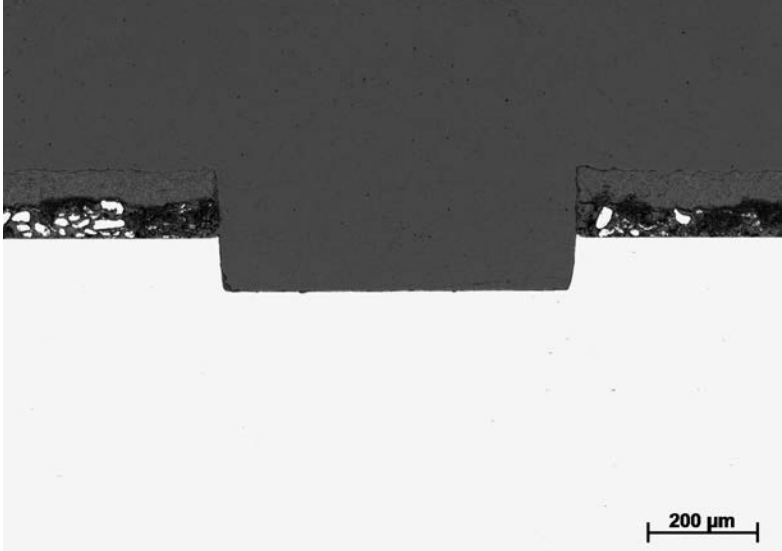
The results of the elevated temperature testing of materials to find the conditions for chromate formation in engines, enabled identification of locations of high risk for chromate formation.

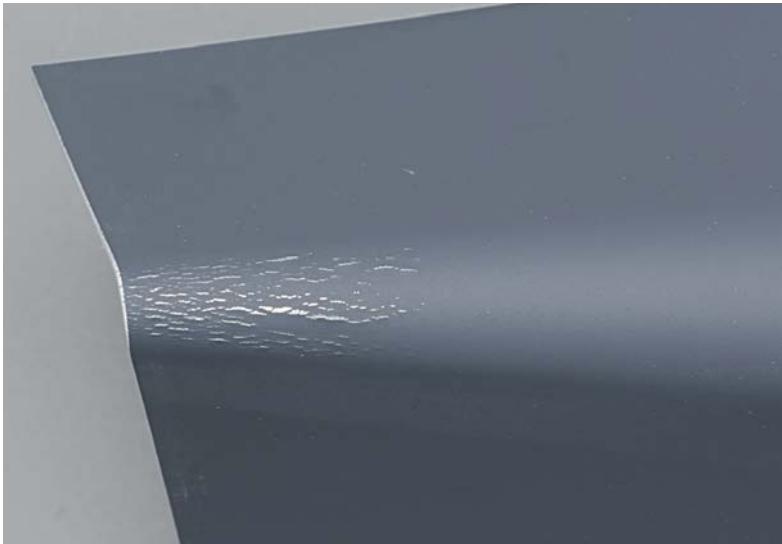
THE SOLUTION

Analysis of the locations where chromate containing dust is found can provide information on the origin of the dust. Additionally the amount of chromates in the dust is relevant for the risk analysis. Cleaning procedures can be applied to remove the chromate containing dust, independent of whether the dust is found on the aircraft of on the engine. Additional laboratory experiments are performed to determine the conditions that allow the formation of chromates on several materials at elevated temperatures.

Project partners
Industry NL: RPS, SEEF
Research organisation: Royal NLR
Ministry of Defence


MM-A2-6-2
MM-A2-7-2
MM-A2-9-2
MM-A2-10-2
MM-A2-3-3
MM-A2-4-3
MM-A2-6-3
MM-A2-7-3
MM-A2-10-3
MM-A7-1-1
MM-A7-4-1
MM-A7-7-1
MM-A7-8-1
MM-A7-1-2


200 µm



Development of chromate free primer technology

THE CHALLENGE

For decades, RNLAF has relied on the robust corrosion inhibition by use of pre-treatments and primers containing hexavalent chromium. However, the downside to the use of Cr6+ is its toxicity to humans and the environment. As a result, the use of Cr6+ is restricted increasingly by legislation such as REACh (Registration, Evaluation, Authorisation and restriction of Chemicals). The research into chromate free products is ongoing for years and this research contributes to developing alternative products for corrosion prevention.

THE SOLUTION

- Development of magnesium rich primermagnesium particles serve as sacrificial anode to the underlying substrate, which is more noble than magnesium)
- Development of lithium inhibitor technology Similarly to chromates, the lithium salts leaches out of the primer upon damaging of the coating. The lithium salts form a protective layer on the (aluminium) substrate

WHAT DID WE DO?

The project is divided into two phases. During the first phase, the chromate free inhibition technologies in their current development stage are benchmarked with existing chromate containing and chromate free primers. The screening consists of testing for the properties adhesion (dry and wet), corrosion resistance (in various forms), and flexibility. The latter property is of importance especially for fighter aircraft, which undergo significant deflections under certain loading conditions. The goal of the benchmark testing is to determine performance in comparison with existing products and determine areas in which improvement of the lithium and magnesium technology is desired.

Thereto, paint systems known to have good properties were selected as positive references for comparison. In the second phase, the improved primers will be tested again to determine the degree of improvement.

Project partners
Industry: Akzo Nobel Aerospace Coatings
Research organisations (NL): NLR
Defence Material Organisation

Cold spray as repair process for metal parts

Metal parts that are damaged as a result of wear, corrosion or fatigue, for example, must in many cases be replaced by new ones. With recent developments in the field of cold spray repair techniques, parts can be repaired that previously had to be rejected and replaced. NLR aims at reducing the impact of damaged components and structures and the dependence on parts supply on fleet availability by means of cold spray repairs.

THE CHALLENGE

The operability of a fleet depends, among other things, on the efficiency of the maintenance and the quality of the accompanied repairs.

A successful repair depends on many things:

- the stability and repeatability of the spraying process
- using the right material combinations and process parameters
- a thorough qualification and certification methodology
- lead time and costs

WHAT DID WE DO?

in collaboration with our partners, we investigate topics related to the process and material aspects of cold spray. In addition, it is investigated how cold spray can be incorporated into an automated process of inspection and repair. The associated activities in the context of qualification and certification are also part of the activities.

THE SOLUTION

NLR is working on various repair processes, including cold spray, to reduce reliance on spare parts supply and make maintenance processes more sustainable. Ultimately, cold spray can enable that repairing becomes preferable over component replacement in many cases.


Cold spray: Aluminium alloy 6061
Substrate: Aluminium alloy 6061

Project partners
Royal NLR
Ministry of Defence

Metal part repair by Additive Manufacturing

The NLR MAMTeC (Metal Additive Manufacturing Tech Centre) is the 3D metal printing centre in the Netherlands that was established in 2013. An enthusiastic multidisciplinary team works in an environment with expertise and facilities that are essential for building up advanced Metal Additive Manufacturing knowledge and skills. The more than 50 years of experience of metals is a valuable contribution to the additive manufacturing research. MAMTeC is equipped with a BeAM Modulo 400 machine dedicated to manufacture and repair parts using the Directed Energy Deposition (DED) process.

THE CHALLENGE

Metal parts can get damaged or wear can cause the part to become outside specifications. These parts can either be replaced or repaired. Platforms are out of service for a longer time when a replacement part is not available. Additive Manufacturing can potentially enable fast, efficient high quality repair so that the equipment is made available for deployment again.

THE SOLUTION

The availability of a method that enables high quality repair of metal parts contributes to a more effective employment of platforms.

WHAT DID WE DO?

Royal NLR is developing a procedure for the preparation of a damaged part for repair. A pre-treatment can for example involve machining, heat treatment and surface treatment.

- Process parameters are selected that enable material application with a minimum heat input to minimize distortions.
- 3D measurement of the part is used to apply material exactly on the right location.
- The influence of process parameters on residual stresses and on the quality of the interface between substrate and added material are investigated.
- Also the post processing of the repaired part is evaluated. Post machining and a heat treatment are examples of possibly required postprocessing.

F-35 Acquisition & Operational Readiness Preparation

THE CHALLENGE

NLR helped the Royal Netherlands Airforce (RNLAF) with the F-35 acquisition and operational readiness by focussing on transforming the Defence Equipment Organisation (DMO) into a smart buyer and by assisting the Air Force with a smooth transition from F-16 to F-35. Within this programme, multiple training & education projects have been carried out to design and improve training for pilots, maintenance staff, and mission support crew.

HOW CAN WE SUPPORT YOU

Several training methods, tools and activities conducted by NLR throughout the F-35 programme include:

- Training Needs Analysis for pilot maintenance staff, and mission-support roles
- Design of a F-35 Pilot Competency Profile, initial and recurrent training course content
- Training Media Selection Analysis
- Business case for a Maintainer Training Centre (MTC)

The activities mentioned helped develop a variety of products and services, including:

- Initial and recurrent training course content for pilots and maintenance staff
- Design and execution of an Operational Test & Evaluation plan for Continuation Training
- Design and construction of a WLT (Weapons Loader Trainer) including Augmented Reality applications.

Project customers:
Royal Netherlands Air Force (RNLAF)
Defence Equipment Organisation (DMO)
Research organisations: NLR
Netherlands Organisation for Applied Scientific Research (TNO)

Project partners:
Royal Netherlands Air Force:
Royal Military Air Force School (KMSL)
Research organisation: NLR

Competency based maintenance training

THE CHALLENGE

The development of the European Military Aviation Regulations (EMAR) resulted in changes in the Dutch military aviation regulations. The content and levels of the maintenance type training for the F-16, AH-64D, CH-47D/F and the NH-90NFH therefore needed to be updated. Besides, the training did not fully meet the needs of the (novice) maintenance mechanic and the training did not always represent the actual work of mechanic accurately. The focus of the training was merely on theory. Practice was not offered in an integrated manner.

THE SOLUTION

In cooperation with maintenance mechanics and instructors, the different steps in an instructional design process have been carried out. To analyse the training needs, several workshops where held with both experienced and inexperienced maintenance mechanics. Throughout the process, different presentations and discussions were held to explain and define the desired training concept.

Working sessions with the instructors and developers were subsequently held, in order to develop a training in accordance with this concept.

WHAT DID WE DO?

First, a competency based training concept was defined in line with the 4 components instructional design principles (4C/ID). This concept focuses on whole task training. Theory and part task practice are integrated to support the whole task scenario. Based on the outcome of the training needs analysis, qualification profiles were defined. Finally the training, including supporting materials, was developed. Besides training materials, an assessment method also was developed, allowing student coaching and evaluation. This method comprises competencies including their observable behaviours and can be used for continuous coaching and assessment.

Augmented reality for maintenance training

THE CHALLENGE

KLM expressed the need for more innovative training media to modernise and improve maintenance training.

THE SOLUTION

The result of the project is a modernised, problem-based training design for maintenance training that enhances understanding of the systems and system interaction. This design comprises less traditional instruction and more trainee activity via paper-based assignments and problem-based AR scenarios.

The experiments proved that trainees score better using AR when it is fully integrated in the training design; trainees retained more of what they learned, had deeper understanding and retention time was longer compared to the traditional classroom training. Important lessons learned are the importance of shared AR and a maximum of 20 minutes wearing the AR goggles.

WHAT DID WE DO?

To ensure well integrated use of training media, the project started with a review of the current training design and analysis of current training content. Subsequently, there was a study of whether Augmented Reality (AR) could add value for the aircraft systems that are difficult to train through traditional classroom training. Requirements for the AR application and training design were defined before starting actual development. Finally the prototype was evaluated through an experiment.

The project is performed in a highly interactive and agile way. Bi-weekly sprints were held with experts from relevant areas such as maintenance experts, application developers, human machine interface experts and educational experts, which ensured accuracy and acceptance of intermediate and final results.

Project partners:
Royal Dutch Airlines (KLM)
Research organisation: Royal NLR

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

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 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

February 2024