Accelerating the future of 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 to address strategic challenges. We are capable of balancing business, economic, and technological issues.

Maintenance Technology

NLR creates smart technologies by developing innovative software 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 develops smart training curriculums and devices by combining cutting-edge training concepts and technologies. We leverage advanced training design principles and modern technologies, including virtual and augmented reality, to deliver effective training experiences.

Maintenance Engineering

NLR offers smart maintenance solutions by integrating existing knowledge, techniques, and methods. We optimise your maintenance operation, including planning, resource allocation, and personnel deployment. We drive process and product improvements through data-driven approaches, such as quantitative data analysis.

Royal NLR

Applying innovation in MRO

Whether you're maintaining aircraft or seeking innovative maintenance technologies to enhance availability or reduce costs, NLR can provide support. Alternatively, if you're looking to future-proof your aircraft MRO operations, we are here to help you every step of the way.

Operators, maintenance organisations, and OEMs strive to maximise aircraft availability while minimising costs. This dual objective underpins the value of effective aircraft maintenance. Achieving these goals requires expert knowledge and state-of-the-art technologies. NLR offers practical solutions that enable excellence in maintenance operations, as well as innovative maintenance technologies that enhance availability and reduce costs for both civil and military maintenance organisations, airlines, and OEMs.

We have highlighted some of the projects, research and capabilities that we have developed in-house and in collaboration with our partners, to give you a deeper insight into NLR and our MRO expertise.

We hope you enjoy reading and discovering more about NLR.

NLR – Royal Netherlands Aerospace Centre

THE SOLUTION

Royal NLR develops maintenance technology that enables autonomous robotic inspection of aircraft, which can help boost productivity and make the working environment more engaging for aircraft technicians.

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

- A robot that positions sensors at the required locations around the object
- One or more sensors to scan the object
- Advanced defect detection algorithms
- Automation technology for autonomous inspection.

Robots to support aircraft technicians

ARAI - Autonomous Robot for Aircraft Inspections

Aircraft inspections are a large part of aircraft maintenance activities, but they can be difficult and tedious. They require highly trained technicians with a sharp eye to detect defects. Some defects are very small or hidden, making them challenging to detect, even with the aid of inspection tools such as mirrors, looking glasses, multimeters, and non-destructive testing equipment. Royal NLR has conducted extensive research into technological solutions that improve the detection of various defect types using multi-sensor technology and automated defect recognition software.

THE CHALLENGE

- To develop novel methods for more efficient inspections that can detect a wide range of defect types, from obvious damage such as nicks and gouges to more subtle defects like leaks and missing fasteners.
- To identify a wide range of defects in various materials and components across different parts of the aircraft. With numerous areas, systems, and components requiring inspection, each has its own unique potential failure modes.
- To develop the technology and systems that enable autonomous inspections. Since no single sensor can scan all areas of the aircraft and detect every conceivable defect, a more sophisticated approach is needed. Furthermore, from a productivity standpoint, it would be impractical to carry sensors throughout the aircraft or manually analyse scans and images.

WHAT DID WE DO?

Our ARAI test rig is designed to inspect fuselage panels, wing sections, and helicopter main rotor blades. It can be fitted with multiple sensors to inspect composite structures for defects such as delamination and skin-to-core unbonding.

In the background, our algorithms automatically detect defects, classify them, and measure their size. The software then compares the actual sizes against the allowable damage limits.

Project partners:
Royal NLR, Delft University of Technology, University of Groningen, University of Twente, Inholland University of Applied Sciences, Amsterdam University of Applied Sciences, Saxion University of Applied Sciences

Leading Edge Scanner Autonomous Robot for Visual Inspections

Aircraft inspections are labour-intensive and require highly skilled technicians, which makes maintenance time-consuming and expensive. Royal NLR is exploring ways to speed up and reduce the cost of aircraft visual inspections by automating and robotising these tasks.

THE CHALLENGE

Aircraft inspections are crucial for ensuring the continued airworthiness of aircraft. However, the resulting downtime and costs pose a significant burden for operators. Current advances in automation, robotics, photonics, sensor technology, and image processing are transforming the landscape. NLR's research focuses on whether these technologies can be applied to visually inspect aircraft.

Benefits:

- Robots can automate routine tasks, freeing up expert technicians to focus on more complex inspections. This is particularly important given the ageing workforce.
- Robots can take on tasks that are dull, dangerous, or dirty, making the work environment more pleasant and safe for technicians.

LE SCANNER

Our leading edge (LE) scanner serves as a test bed for integrating various stages of the inspection process, enabling robots to autonomously inspect complex objects and components, such as aircraft. It is capable of inspecting metallic leading edges for damage including dents, scratches, and gouges, as well as missing rivets. Additionally, it can inspect composite structures for defects such as delamination and skin-to-core unbonding.

One of the key challenges is automating an inspection robot. This requires not only a robotic arm (or a Cartesian or delta robot), but also a range of sensors capable of detecting, classifying, and measuring various types of defects. When inspecting larger objects, image alignment and stitching may also be necessary. Behind the scenes, machine vision technology and image processing algorithms work tirelessly to process images and extract meaningful insights. To achieve automated inspection, all these steps are essential.

THE SOLUTION

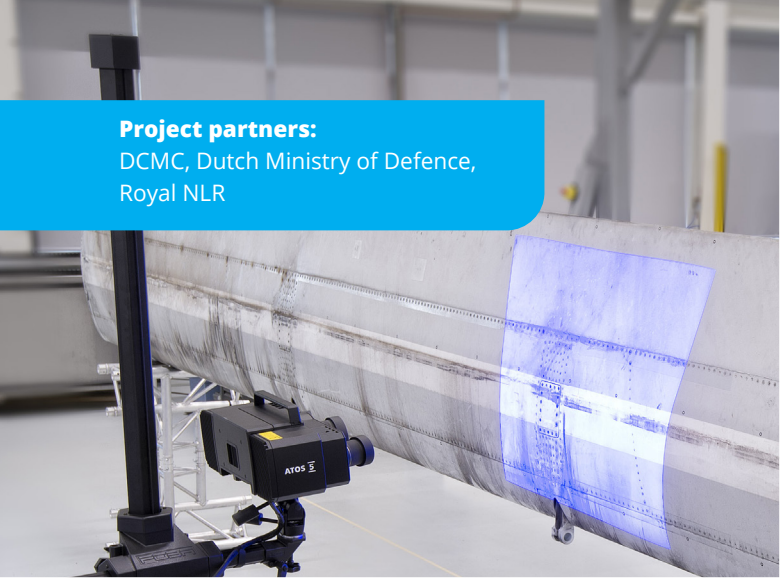
Royal NLR has developed a system for visually inspecting aircraft and components.

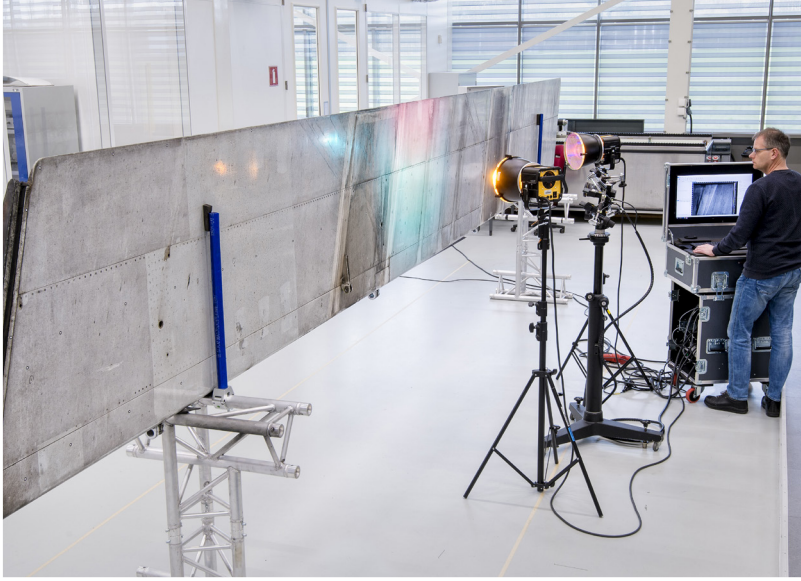
The key components are:

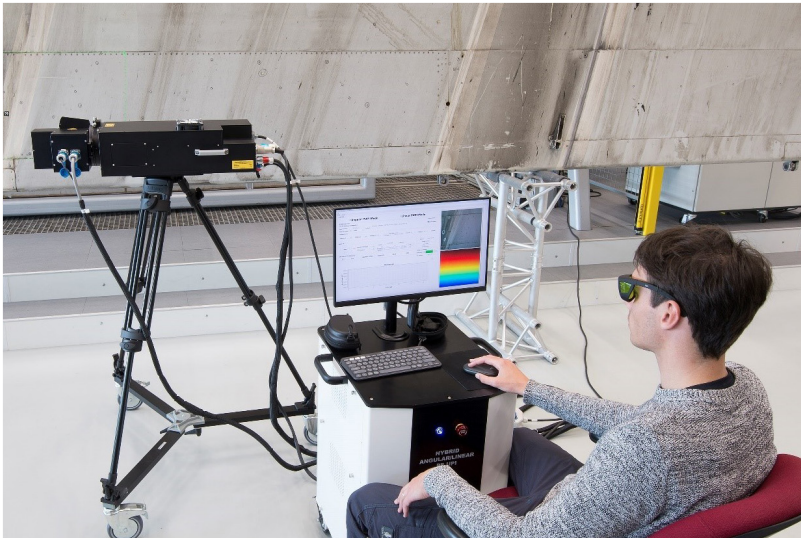
- One or more sensors to scan the object, tailored to the specific target defect
- A robot to maneuver the sensors to the right locations around the object
- Algorithms to detect, classify and measure defects
- Automation technology for autonomous inspection

Project partners:
Royal NLR, Delft University of Technology, University of Groningen, University of Twente, Inholland University of Applied Sciences, Amsterdam University of Applied Sciences, Saxion University of Applied Sciences

Project partners:
DCMC, Dutch Ministry of Defence,
Royal NLR







Fast Contactless Multidomain Non-Destructive Inspection

Aircraft structural parts require regular inspection to ensure their airworthiness. For this purpose, many Non-Destructive Inspection (NDI) techniques are available. However, none of these techniques is capable of finding all possible types of defects that may be present in a part. Combining multiple NDI techniques into a single inspection system is the key to solving this problem. In this regard, state-of-the-art contactless techniques with a large Field of View (FOV) are beneficial, as they significantly reduce inspection time. Moreover, the digital data acquired can be fed into a digital twin of the inspected part.

THE CHALLENGE

The challenge for most hardware maintainers is that inspection data is often fragmented and difficult to find. For example: retrieving the repair and maintenance status of helicopter rotor blades from the current maintenance information systems can be very challenging. By using non-contact NDI methods, this data can be extracted from the part itself.

THE SOLUTION

The solution involves scanning helicopter rotor blades using 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. The surface mesh is then used as a template to map NDI inspections onto. Thermography and Shearography can locate defects and repairs in the subsurface of the part. Furthermore, NLR has recently acquired a Laser Ultrasonic inspection system, which represents a significant step towards achieving complete contactless multidomain NDI.

To be effective, NDI methods must be capable of capturing the part's geometry, detecting defects, and identifying and locating any previous repairs.

WHAT DID WE DO?

Royal NLR has developed a method to combine multiple NDI data streams on top of a single surface mesh of inspected helicopter rotor blades. This allows for easy comparison of defects in different NDI data, leading to better defect classification. Additionally, by projecting the data onto a 3D surface mesh, a comprehensive digital representation of the blade is created. This allows users to review every inspection event and track the progression of damage throughout the blade's life cycle. Using augmented reality assists the maintainer in assessing these damages and comparing them to historical data from the specific rotor blade or the fleet.

Engineering Failure Analysis

Do you need to know the root cause of why your component, structure or plant failed? What causes the decrease in your production yield? Or maybe you need to determine if your component or structure has suffered damage during operation that has exceeded its design limits? If so, we can provide an independent expert opinion, a comprehensive failure analysis report, or recommendations to help prevent future failures.

NLR's Test House specialises in materials research and engineering failure analysis for complex components. With over 60 years of experience serving the aerospace, defence, and high-tech industries, where high safety standards are paramount, we have extensive knowledge of material failure modes. Our particular areas of expertise include:

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

NLR offers mechanical testing, materials analysis, and fractography, providing comprehensive analysis capabilities. Our equipment includes: 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.

Through its multidisciplinary approach, NLR can provide critical feedback for design, manufacturing, maintenance and repair, as well as safe operations.


59%
Create Damage Sheet
Select Equipment
Syncing
Tail number filter
all
Start date filter
22 Mar 2021
End date filter
19 Apr 2021
More filters
Off
Legend
Corrosion
Crack
Not identified
version: 1.1.2
Project partners:
Royal NLR,
Royal Netherlands Air Force
Undo
Moving
Selecting
Isolate
View Timeline
Damage Data Sheets
3D Digital Twin

Digital Crack & Corrosion Logbook

Reliability-Centred Maintenance (RCM) processes, such as MSG-3, are designed to reduce maintenance workload, minimise operational risks, and achieve sustainable equipment reliability and readiness. To achieve this, high-fidelity inspection and maintenance records are essential.

THE CHALLENGE

The current generation of maintenance data systems has a cumbersome and unintuitive data entry portal, which relies heavily on manual data entry. This increases the risk of entering inconsistent and/or incomplete data, resulting in poor-quality inspection and maintenance records. Consequently, this hinders 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).

WHAT DID WE DO?

The d-CCL is an app that runs on a tablet computer and features an intuitive 3D web interface. Inspection findings can either be entered graphically, through a 3D model of the aircraft at hand, or by means of drop-down menus. Once connected to the internet, the app seamlessly synchronises data with the aircraft operator's ERP system, ensuring that all records are up-to-date. This gives maintainers access to historical data and data from other aircraft in the fleet, enhancing their situational awareness and increasing the probability of detecting structural anomalies. The app is complemented with centralised software for performing fleet-wide reliability analyses.

FD XAI

Failure diagnostics with eXplainable Artificial Intelligence (XAI)

Components that are removed preventively before they fail are difficult to troubleshoot, as they may still function on a test bench. To enable MROs to repair these components with surgical precision, it's essential to understand the likely failure mode. FD XAI helps you determine the probable failure mode of a functional component and provides an explanation for why it occurs.

THE CHALLENGE

Imagine being able to predict when a component or system is likely to fail, before it actually does. This kind of foresight would be invaluable for troubleshooting, planning repairs or scoping repairs to preventively remove a still working component.

HOW CAN WE SUPPORT YOU

NLR has developed a cutting-edge tool that leverages Artificial Intelligence (AI) to diagnose failures. By analysing the failure modes of previous repairs and aircraft usage, the tool can pinpoint relationships between aircraft and system usage and the actual failure modes of repaired parts. We can then use this data to diagnose components or systems and identify the underlying failure modes.

The fidelity of computerised diagnoses relies heavily on the transparency of the analyses. To make the outcomes of failure diagnoses acceptable for maintenance personnel, the algorithms use eXplainable AI.

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

Failure diagnoses using eXplainable AI 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 reduces no-fault-founds.

AARE
Aircraft availability and resource estimator

Aircraft maintenance costs and aircraft availability are uncertain and difficult to estimate in advance. To effectively manage this uncertainty, a risk-based approach is necessary. Our estimates can help you make more accurate availability and resource estimations for inherently unpredictable maintenance operations.

THE CHALLENGE

Maintaining aircraft requires balancing budgets and resources to achieve optimal aircraft availability. This balancing act is complicated by uncertainty, as maintenance is inherently unpredictable.

HOW CAN WE SUPPORT YOU

AARE, or Aircraft Availability and Resource Estimator, is a management decision-support tool that helps determine the impact of changes to budgets and resources on fleet availability (and vice versa), using realistic reliability data. Specifically designed to cope with uncertainty, it provides users with valuable insights into the relationship between fleet availability, resources, and budget. This enables informed financial planning and allows you to set realistic availability targets, such as On-Time Performance.

In addition to its purpose for existing operations, AARE can also be used to support strategic planning and decision-making in times of change. For example, it can help you assess the impact of introducing a new aircraft type or adjusting your operations on your fleet's availability and resource requirements. 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

NLR'S FLEXPLAN

- Reads a Maintenance Planning Document, interprets the applicability of individual tasks and creates an operator specific Aircraft Maintenance Programme 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 these processes.

The result is a comprehensive maintenance programme, 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.

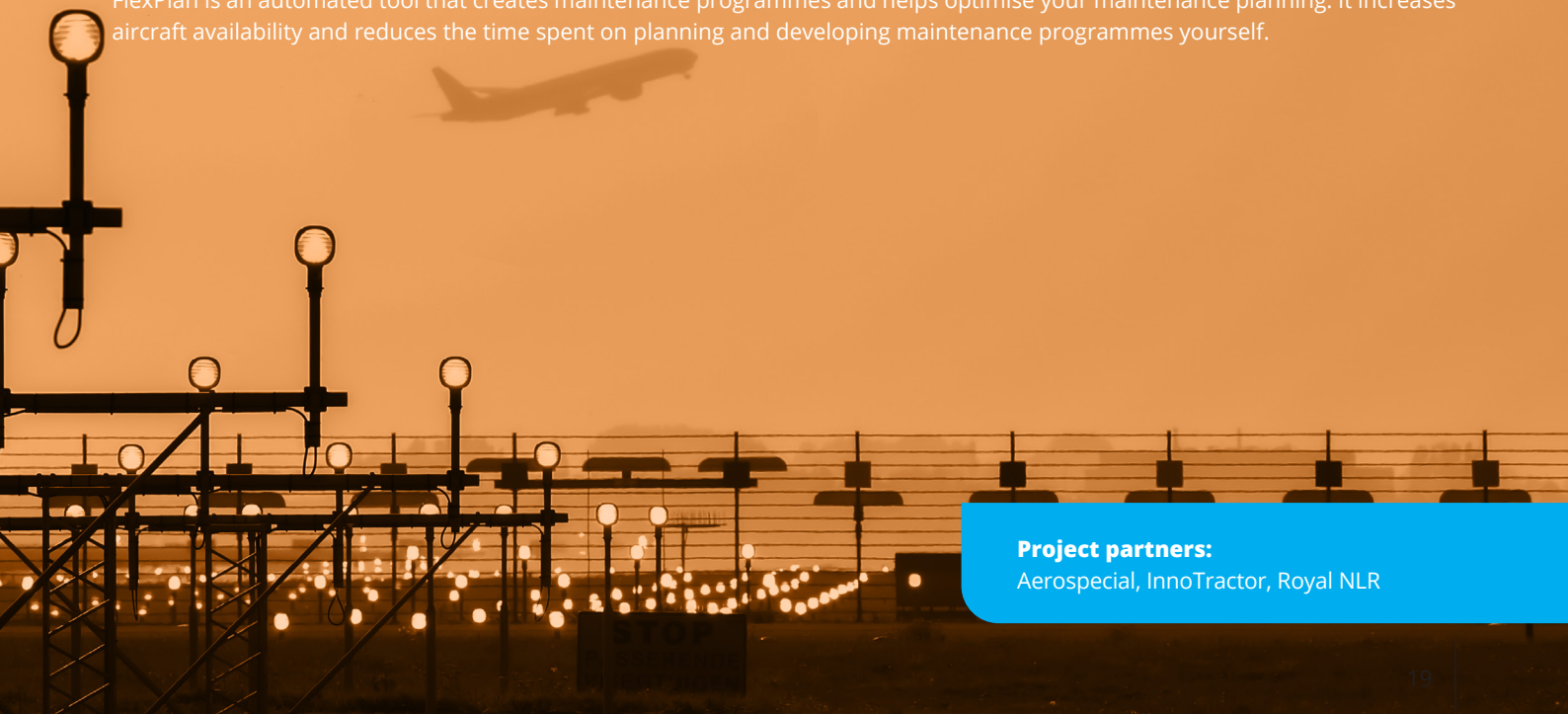
And the best thing is, it is all done automatically; you do not need to spend time on an operator specific Aircraft Maintenance Programme or maintenance scheduling. It is all done for you. And since FlexPlan adheres to the task intervals specified by the original equipment manufacturer, you do not face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

THE CHALLENGE

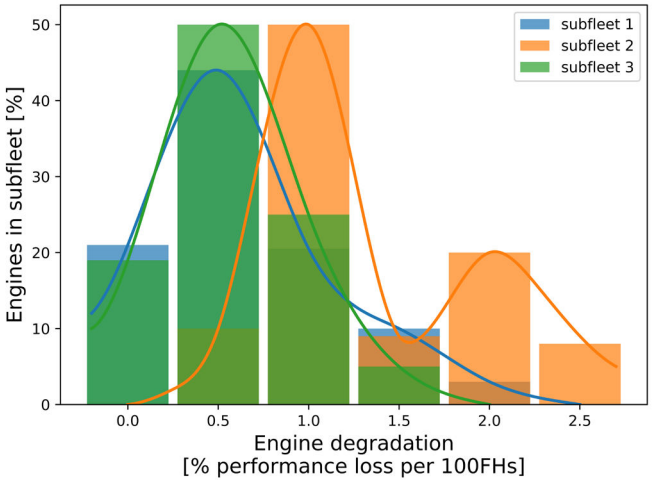
Operators use various maintenance planning concepts, but none fully account for the flight programme. Conventional concepts, such as block programmes, are easy to schedule, but take an aircraft out of service for some time. Equalised programmes break down large inspections into smaller tasks, but they can introduce excessive access and preparation times. NLR has developed a maintenance planning concept that solves these issues.

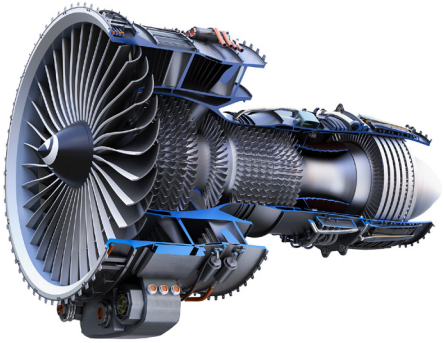
HOW CAN WE SUPPORT YOU

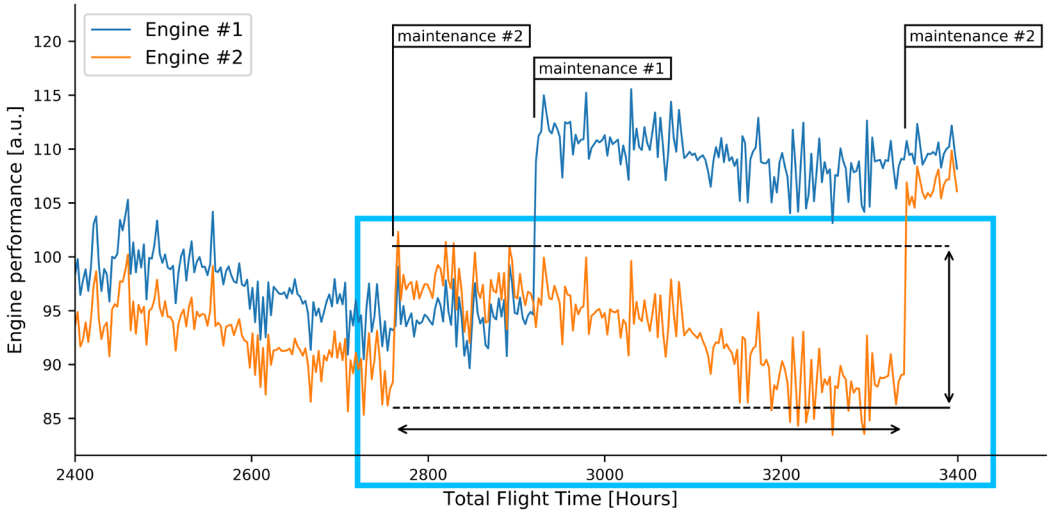
FlexPlan is an automated tool that creates maintenance programmes and helps optimise your maintenance planning. It increases aircraft availability and reduces the time spent on planning and developing maintenance programmes yourself.



Project partners:
Aerospecial, InnoTractor, Royal NLR







Project partners:
Royal NLR,
Royal Netherlands Air Force

Engine Condition Trend Monitoring for predictive maintenance

An important trend in aircraft engine sustainment is the transition from preventive to predictive maintenance. This approach aims to minimise engine downtime and maintenance costs while maintaining its required performance level and airworthiness. To achieve this, it's essential to be able to determine the current engine condition and reliably predict its future state, enabling effective planning.

THE CHALLENGE

Legacy aircraft engines only have basic health monitoring capabilities, making it difficult to determine and predict their condition without resorting to intrusive and time-consuming post-flight inspections.

THE SOLUTION

NLR has developed an alternative and simple approach, Engine Conditioned Trend Monitoring, to determine the current and future engine condition using limited data from the digital engine control unit (DECU) found on many legacy aircraft engines.

WHAT DID WE DO?

For a particular turboshaft engine used in a military helicopter, we have developed a data-driven approach to empirically establish a measure for the overall engine condition from a limited set of sensor data, including the engine torque, power turbine inlet temperature, airspeed, outside air temperature, and pressure altitude. This allowed us to identify engine degradation over time and correlate it with specific usage patterns and maintenance actions. As a result, the helicopter operator was able to perform predictive maintenance based on the operational theatre and helicopter usage. The model was validated against historical data of known engine failures.

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 standardisation and the poor integration of new technologies with existing data acquisition systems.

THE SOLUTION

The developed SHM system enables more efficient loads and usage monitoring compared to conventional technology. Moreover, it combines functionalities that could not be integrated before, namely simultaneous loads monitoring, mechanical impact event detection and damage detection/localisation, for both stationary and rotating aircraft components. The following examples illustrate the relevance and potential use of the developed SHM technology:

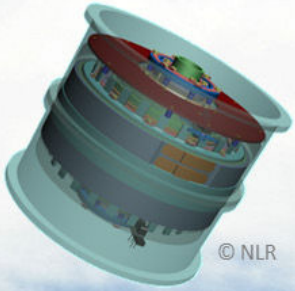
- Loads monitoring of landing gears (hard landings, remaining service life)
- SHM of medium-sized and large UAVs
- Enhanced rotor balancing of helicopters

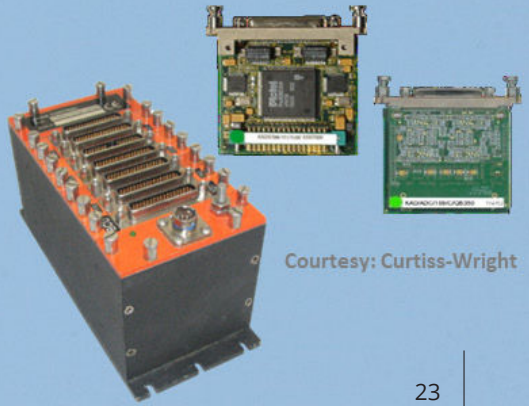
WHAT DID WE DO?

The project partners aimed 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 miniaturised fibre-optic interrogator based on ASPIC technology (application specific photonic integrated circuits).

The loads and damage data collected with the SHM system were 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 were incorporated in the SHM system offer many significant advantages over conventional strain gauges.

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



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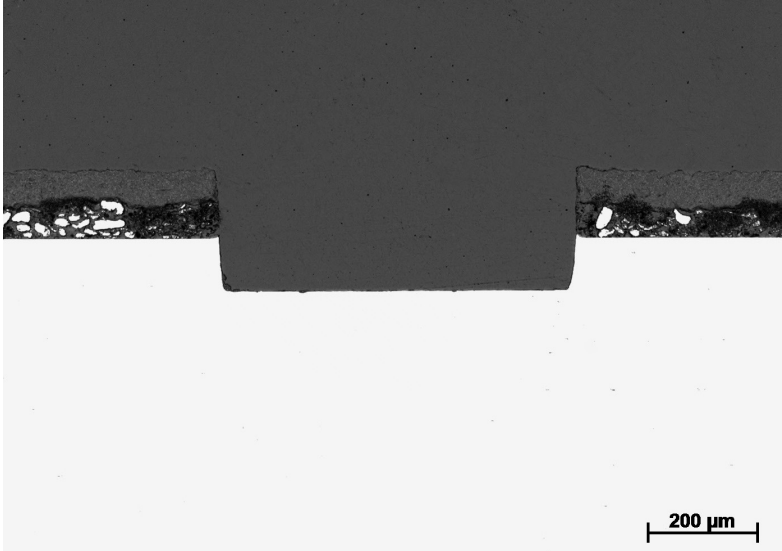
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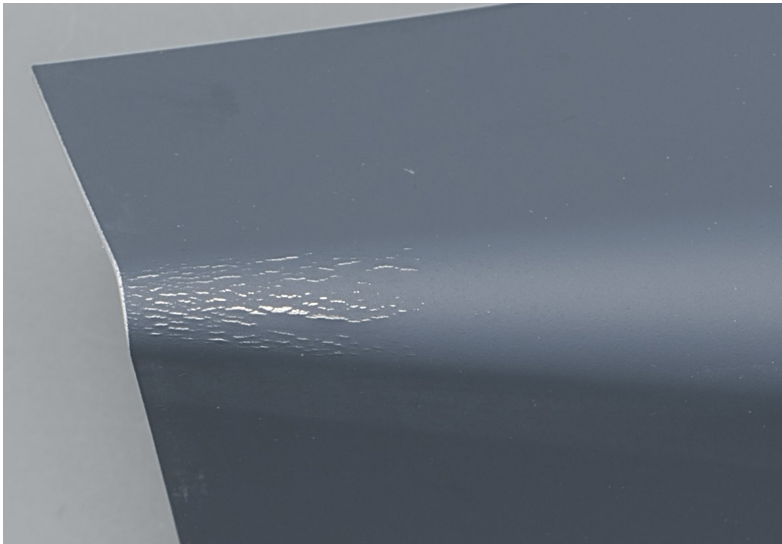


Development of chromate free primer technology

THE CHALLENGE

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

THE SOLUTION

- Development of magnesium-rich primer: magnesium particles act as a sacrificial anode to the underlying substrate, which is more noble than magnesium.
- Development of lithium inhibitor technology: similarly to chromates, lithium salts leach out of the primer when the coating is damaged. The lithium salts then form a protective layer on the (aluminium) substrate.

WHAT DID WE DO?

The project was divided into two phases. During the first phase, chromate-free inhibition technologies in their current development stage were benchmarked against existing chromate-containing and chromate-free primers. The screening involved testing for properties such as adhesion (dry and wet), corrosion resistance (in various forms), and flexibility. The latter property is particularly important for fighter aircraft, which undergo significant deflections under certain loading conditions. Benchmark testing was done to assess performance in comparison with existing products and identify areas where improvement of the lithium and magnesium technology was needed.

Additionally, paint systems known to have good properties were selected as positive references for comparison. In the second phase, the improved primers were re-tested to determine the extent of improvement.

Project partners:
Akzo Nobel Aerospace Coatings, Royal 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 often need to be replaced with new ones. However, recent developments in cold spray repair techniques have made it possible to repair parts that would previously have been rejected and replaced. NLR aims to reduce the impact of damaged components and structures, as well as dependence on parts supply, on fleet availability through the use of cold spray repairs.

THE CHALLENGE

The operability of a fleet depends, among other things, on maintenance efficiency and the quality of any accompanying 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. Additionally, we explore how cold spray can be integrated into an automated inspection and repair process. Our activities also include qualification and certification procedures.

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 make repair a more viable option than component replacement in many cases.


Cold spray: Aluminium alloy 6061
Substrate: Aluminium alloy 6061

Project partners:
Royal NLR, Dutch Ministry of Defence

Metal part repair by Additive Manufacturing

The NLR MAMTeC (Metal Additive Manufacturing Tech Centre) is the Netherlands' leading 3D metal printing centre, established in 2013. An enthusiastic and multidisciplinary team of experts works in a state-of-the-art environment with expertise and facilities that are essential for developing advanced Metal Additive Manufacturing knowledge and skills. With over 50 years of experience in metals, NLR makes a valuable contribution to additive manufacturing research. MAMTeC is equipped with a BeAM Modulo 400 machine, dedicated to manufacturing and repairing parts using the Directed Energy Deposition (DED) process.

THE CHALLENGE

Metal parts can become damaged or worn, causing them to fall outside specifications. These parts can either be replaced or repaired. However, if a replacement part is not available, platforms can be out of service for an extended period. Additive Manufacturing has the potential to enable fast, efficient, and high-quality repair, allowing equipment to be made available for deployment again sooner.

THE SOLUTION

The availability of a method that enables high quality repair of metal parts can contribute to more effective platform deployment.

WHAT DID WE DO?

Royal NLR is developing a procedure for preparing damaged parts for repair. Pre-treatment may, for example, involve machining, heat treatment, and surface treatment.

- Process parameters are selected that enable material application with a minimum heat input to minimise distortions.
- 3D measurement of the part is used to apply material precisely at 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.
- Post-processing of the repaired part is also evaluated, including potential requirements such as post-machining and heat treatment.

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. Furthermore, the training did not fully meet the needs of (novice) maintenance mechanics, nor did it always accurately reflect real-world mechanical work. The training focused primarily on theory, without any integrated practical elements.

THE SOLUTION

In cooperation with maintenance mechanics and instructors, the different steps in an instructional design process have been carried out. Several workshops were organised with both experienced and inexperienced maintenance mechanics to analyse the training needs. 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 programme 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, where 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 programme including supporting materials, was developed. An assessment method was also developed, in addition to training materials, enabling student coaching and evaluation. This method comprises competencies, including their observable behaviours, and can be used for continuous coaching and assessment.

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

Project partners:
KLM, Royal NLR

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 involves less traditional instruction and more trainee activity via paper-based assignments and problem-based AR scenarios.

The experiments showed that trainees perform better when using AR that is fully integrated into the training design; they retained more information, gained a deeper understanding, and had longer retention times compared to traditional classroom training. Key lessons learned include the importance of shared AR and a 20-minute limit for wearing AR goggles.

WHAT DID WE DO?

To ensure seamless integration of training media, the project started with a review of the existing training design and an analysis of current training content. This was followed by an investigation into the added value of Augmented Reality (AR) for aircraft systems that are challenging to train through traditional classroom methods. Requirements for the AR application and training design were defined before starting actual development. Finally, the prototype was evaluated through an experiment.

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

The impact (and solutions) of new technologies on maintenance personnel

The rapidly evolving technologies for conducting (predictive) maintenance are transforming the roles of maintenance personnel. This shift calls for research into how these technological developments impact maintenance personnel, their work and the daily operation of the organisation.

THE CHALLENGE

Advances in maintenance technologies, such as predictive maintenance, are affecting the way maintenance personnel work. For example, maintenance technologies are increasingly reliant on Artificial Intelligence for decision-making, and tasks previously performed by personnel are now more often automated.

Research suggests that there are multiple factors affecting 1) the acceptance and implementation of the technology into daily operations, 2) the correct and effective use of new technologies, and 3) the sustainment of the change that the technology brings about, such that the application of the new technology remains valuable.

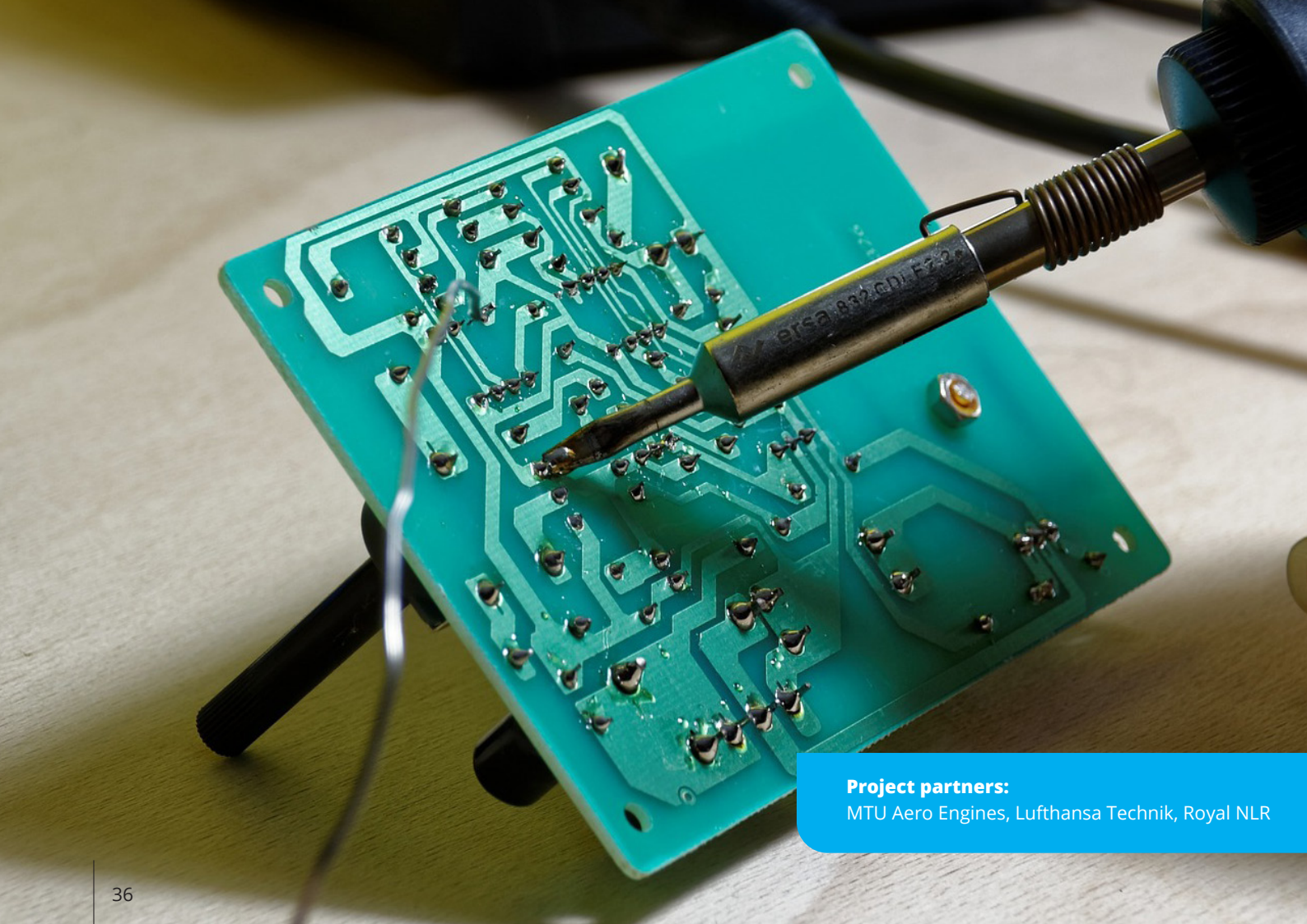
WHAT DID WE DO?

At NLR, we have combined multiple studies to build knowledge about the acceptance and implementation of new technology, and how change management can facilitate effective and efficient use of new technologies. We are currently researching the factors that influence acceptance of new technology in maintenance (e.g. trust, management support, training) to provide guidelines for different target groups. Furthermore, we have developed a manual and a set of templates to support change management in projects where a new technology requires, for example, a change in procedures.

THE SOLUTION

By researching the current situation and drawing on previous knowledge from research, we can provide personalised support during projects that involve organisational change and require the adoption of new technologies.

Project partners:
Royal Netherlands Air Force, Royal NLR



Project partners:
MTU Aero Engines, Lufthansa Technik, Royal NLR

Built-In Prognostic Health Management

If we are faced with an illness, we can describe the symptoms to the doctor. Imagine a component that can tell you how it is doing; a component that can describe the early symptoms of an imminent failure. How would that help you cure the problem?

THE CHALLENGE

Operators and maintenance organisations dislike being surprised by unscheduled system and component failures that, for example, may ground an aircraft. This can have serious financial and operational consequences. Some aircraft manufacturers, operators and maintenance organisations are therefore implementing systems to predict these unscheduled failures. Unfortunately, the data and system or component knowledge is not always available to predict these unscheduled failures. So, what are the options to improve the predictability of unscheduled failures?

THE SOLUTION

We can help you with the research and development of innovative prognostic health management functions embedded on components. As a component manufacturer you can build and sell components with a truly predictive maintenance function (or even a prescriptive maintenance requirements concept) while retaining your intellectual property. As an operator or maintenance organisation, you can limit the number of unscheduled failures and grounded aircraft by using components with BI PHM.

WHAT DID WE DO?

NLR recognises that component manufacturers have all the knowledge about their systems in-house and that they already measure and collect data for built-in test equipment (BITE) functionalities. For them, it is a relatively small step to collect additional data to predict unscheduled failures. In fact, component manufacturers can embed a prognostic health management function within the component. This allows components with a built-in prognostic health management (BI PHM) function to report their own state of health to an operator or maintenance organisation. If a component manufacturer collects historic data from all their components, they can even improve the BI PHM function by using machine learning. As a result, operators and maintenance organisations will experience fewer unscheduled failures, reducing the number of grounded aircraft and increasing the component's value.

RAM tooling

By applying RAM (Reliability, Availability and Maintainability) analysis, maintenance organisations can identify the most critical components and systems, optimise maintenance schedules, and reduce aircraft downtime.

THE CHALLENGE

The periodic application of RAM analyses can yield significant cost savings and improved overall efficiency. Additionally, RAM analysis can help organisations prioritise maintenance activities and improve the overall reliability and availability of their systems and equipment. Periodically obtaining related data, performing RAM analyses, and interpreting the results is, however, an ongoing, time-consuming process.

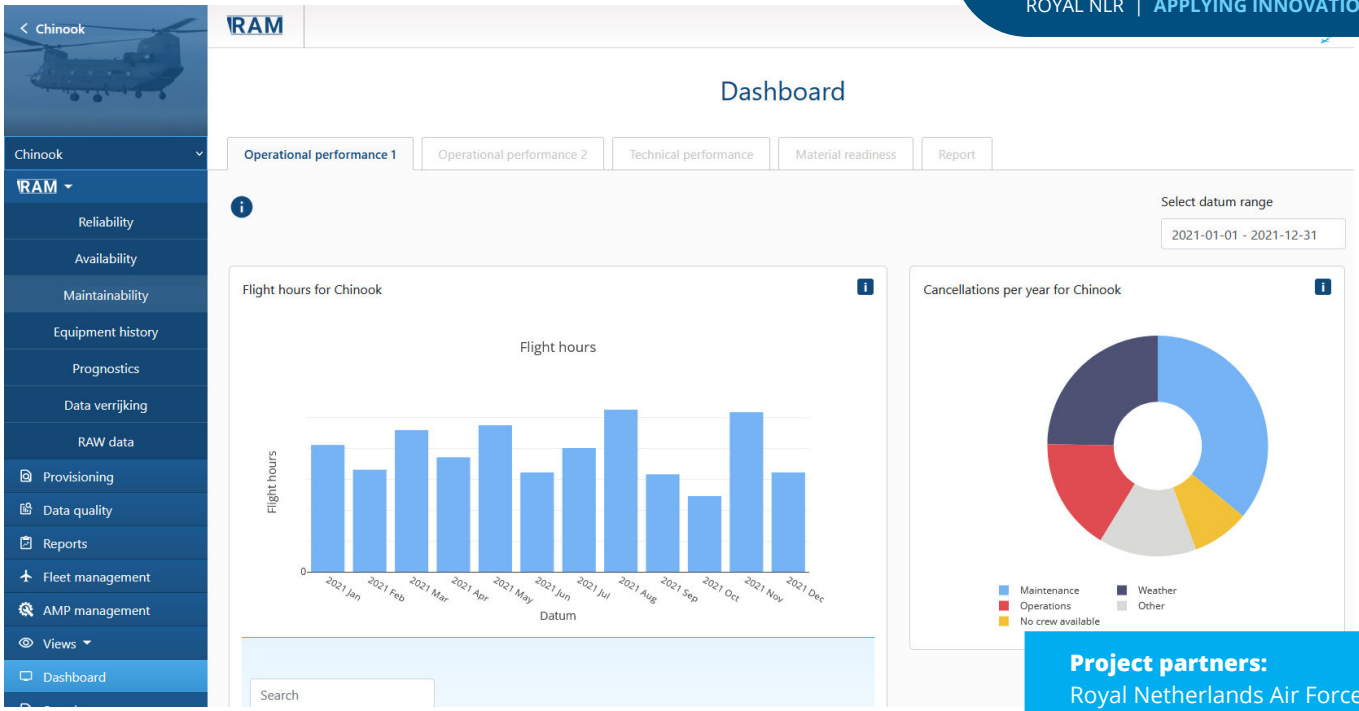
THE SOLUTION

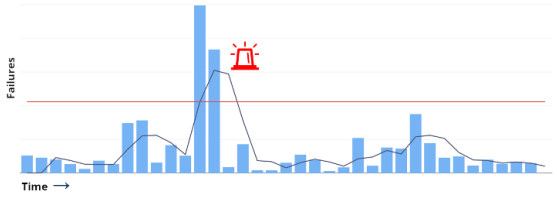
To optimise the availability of your fleet by reducing maintenance-related downtime, Royal NLR has developed a web-based application that offers insights into reliability, availability, and maintainability parameters.

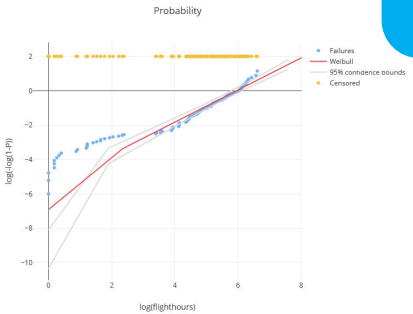
WHAT DID WE DO?

Royal NLR has designed a web-based application that provides tools to monitor and analyse reliability, availability, and maintainability parameters to facilitate RAM analyses. By periodically obtaining and analysing operational and maintenance data, the tool offers:

- MTBF / MTBR / MTBUR analysis of individual components
- alerts when failures of components reach a certain threshold over time
- insight into the aircraft's operational status over time
- prognostic tools to predict additional failures in the future
- a visual timeline of which component is installed on which tail, including corresponding failure reports over time



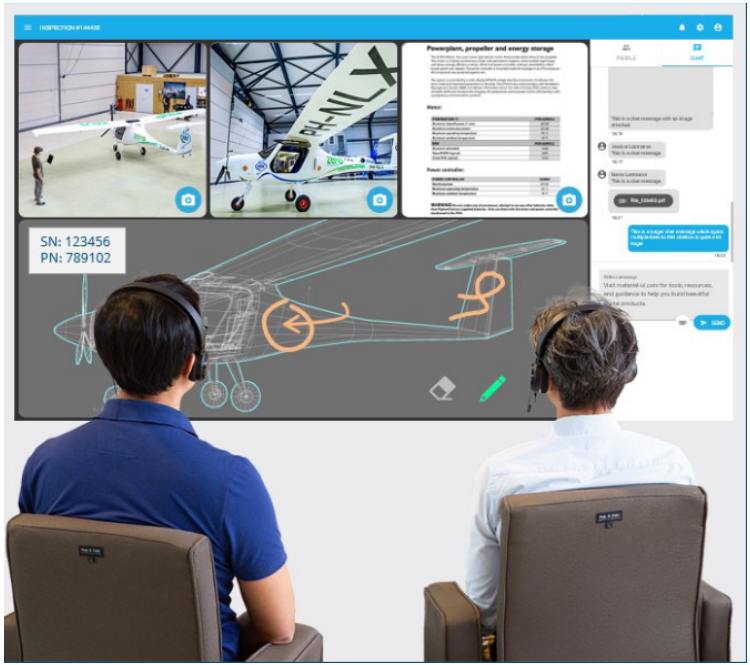




Project partners:
Royal Netherlands Air Force,
Royal NLR

On-site

Head-Quarter



Project partners:
KLM, Royal NLR

Remote Support for Maintenance Personnel

Global aviation is increasing, but the current lack of qualified maintenance personnel is becoming very problematic. It may eventually lead to a reduced availability of the fleets and, thus, reduced revenues for their operators. Part of the solution is to increase the efficiency of the existing maintenance processes by introducing innovative tooling. Royal NLR has developed a remote support tool in collaboration with KLM as part of the BrightSky R&D programme.

THE CHALLENGE

Currently, many airline operators have difficulties finding qualified and experienced maintenance personnel. This problem is expected to worsen in the near future and will lead to increased downtimes and reduced revenues. Increasing the productivity of maintenance personnel is necessary to address this issue.

THE SOLUTION

NLR demonstrated that the maintenance process can be successfully monitored and guided by qualified personnel using multiple vision angles (first-person and overview camera). Furthermore, the tool offers different means to exchange information (voice communication, chat functionality, maintenance manual, etc.), while the 3D situational representation can be assessed by remote support personnel, who can inspect and manipulate NeRF 3D models. This demonstration showcased an effective and innovative tool allowing maintainers to perform their tasks more efficiently.

WHAT DID WE DO?

Within the national research programme BrightSky, NLR designed a digital platform together with KLM that enables remote support for maintainers. The platform can be used to connect a concentrated pool of highly qualified experts at the home base to general maintenance personnel at other locations. This facilitates easier planning and reduced travel. To provide home-based experts a live overview of the situation, various viewing tools are integrated into the platform, including NeRF (Neural Radiance Field) technology; this enhances interaction between on-site personnel and remote experts.

Smart maintenance inspections and smart training devices

Effective maintenance is crucial to the success of aircraft operations. Unfortunately, the MRO industry is currently facing a shortage of skilled labour and environmental challenges. How can we use innovations to help the industry?

THE CHALLENGE

Aircraft maintenance organisations perform high-tech maintenance on aircraft. However, these maintenance activities are labour-intensive and require considerable resources. This research aims to investigate whether it is possible to make maintenance activities less labour-intensive and reduce the use of polluting resources, such as fossil fuels.

Some inspections are laborious and detrimental to the working environment; especially dull, dirty and dangerous tasks. Some training events such as engine ground runs and remote support activities are rather expensive and produce unwanted emissions.

THE SOLUTION

We can help make your maintenance organisation more efficient and sustainable with smart maintenance inspection robots and smart training devices that minimise maintenance resources, such as labour and fossil fuels.

WHAT DID WE DO?

NLR is part of the BrightSky consortium, which includes JetSupport, Air France KLM, and other partners. The consortium is developing innovative solutions to improve the economic viability and sustainability of aircraft maintenance and operations. NLR is involved in three BrightSky research projects: (i) developing and qualifying a robot to inspect high-pressure turbine blades, which reduces labour intensity; (ii) creating an engine ground run simulator using augmented reality to train technicians without burning fossil fuels; and (iii) designing an augmented reality application to supervise maintenance at remote locations, thereby reducing time and fuel-consuming trips to outstations. These solutions are designed to make aircraft maintenance more efficient, less labour-intensive, and more sustainable.

Project partners:
KLM, TU Delft, TNO, HvA, S[&]T, JetSupport, Royal NLR

Project partners:
KLM, InnoTractor, Dutch Ministry of Defence, OneLogistics, ILIAS, Royal NLR

Supply chain optimisation

It is difficult to control aircraft components in the supply chain. One important reason is the lack of information about the condition and the status of these components. It results in higher costs and emissions. This project shows how stakeholders in the supply chain can share data safely and benefit from shared data.

THE CHALLENGE

Aircraft operators use many resources to keep their aircraft in a safe and serviceable condition. Aircraft parts parts are repaired and overhauled by various maintenance organisations. By extending the lifespan of these parts, we can reduce waste in the supply chain. Furthermore, all these parts require transportation, which can sometimes lead to parts being sent to the wrong location, resulting in additional costs and environmental burdens. If we can minimise transportation needs, we can also decrease the emission of harmful substances. Moreover, if we can provide more accurate information about defective parts, we can extend their lifespan and reduce waste. Similarly, if we have better insights into which parts are likely to fail, we can direct replacement parts to the correct location, thereby reducing transportation-related waste. This approach benefits both the economy and the environment.

THE SOLUTION

We can help make your airline and maintenance organisation more sustainable, effective, and efficient. By doing so, you will require fewer parts, reducing your reliance on rare raw materials and minimising waste streams. Additionally, you will need less transportation, decreasing waste even more.

WHAT DID WE DO?

NLR is part of the HYPERION consortium, together with Air France KLM, InnoTractor, ILIAS and the Dutch Ministry of Defence. The consortium is developing a framework to (i) install additional sensors to aircraft systems and parts to enrich the parts information, (ii) use a Digital Product Passport to store all relevant information about aircraft parts, and (iii) use parts information and apply algorithms to direct replacement parts to the locations where they are most needed. As a result, fewer technicians and resources are needed for the same result. The goal is to develop an industry standard that will help us expand this solution to other interested operators and maintainers. The consortium collaborates with strategic partners such as Embraer, Airbus and Boeing.

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
€ 127 M turnover	78% Dutch, 19% EU and 3% worldwide	Active in 24 countries	Very 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 value 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 also find its way into successful aerospace programmes of OEMs like Airbus, Boeing and Embraer.

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