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 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:

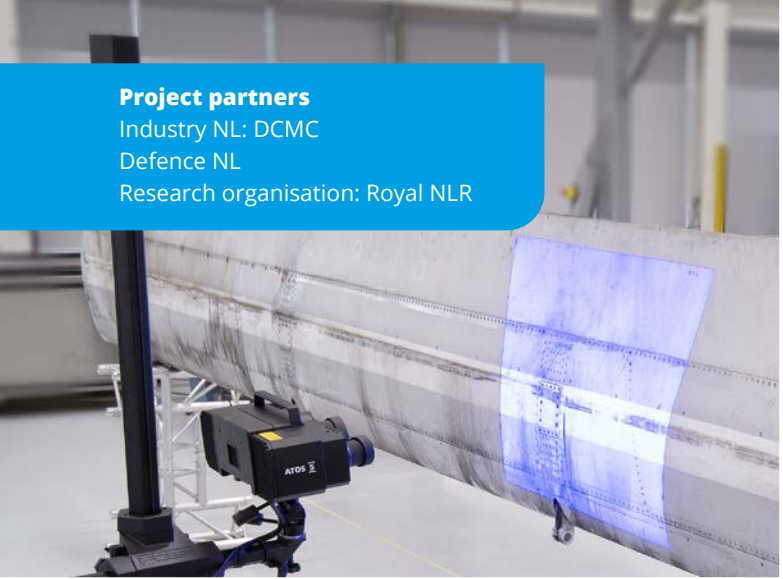
- One or more sensors to scan the object. The choice for the sensors depends on the type of defect you need to find
- A robot to maneuver the sensors to the right locations around the object
- Algorithms to detect, classify and measure defects
- Automation technology to autonomously perform the prescribed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

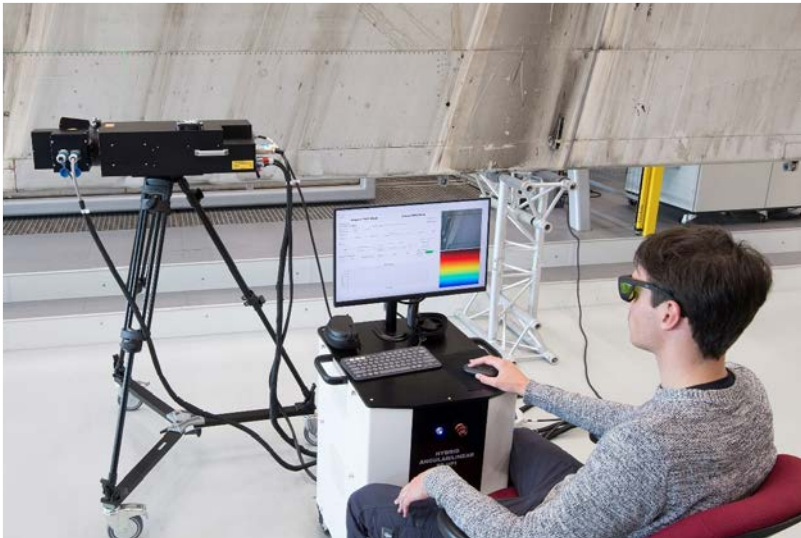
Project partners

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

Aircraft structural parts need to be inspected regularly to safeguard 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 solve this problem. In this respect the of state-of-the-art contactless techniques with a large Field Of View (FOV) is beneficial since it significantly reduces the inspection time and the digital data that are acquired can be fed into a digital twin of the inspected part.

THE CHALLENGE

The challenge for most hardware maintainers is that data from inspections are usually very fragmented and not easy to find. For example: digging up 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 consist of scanning helicopter 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. And recently NLR has acquired a Laser Ultrasonic inspection system. This system is a next step in moving towards complete contactless multidomain NDI.

NDI methods must be able to capture the geometry of the part, defects and be able to identify and locate 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, since the data is projected on top of the 3D surface mesh, a complete digital representation of the blade is achieved. This allows the user to go back to every single inspection event to look for the evolution of damages during its life cycle. Using augmented reality assists the maintainer in assessing these damages and comparing them to the historic data from the rotor blade at hand or from the fleet.

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?

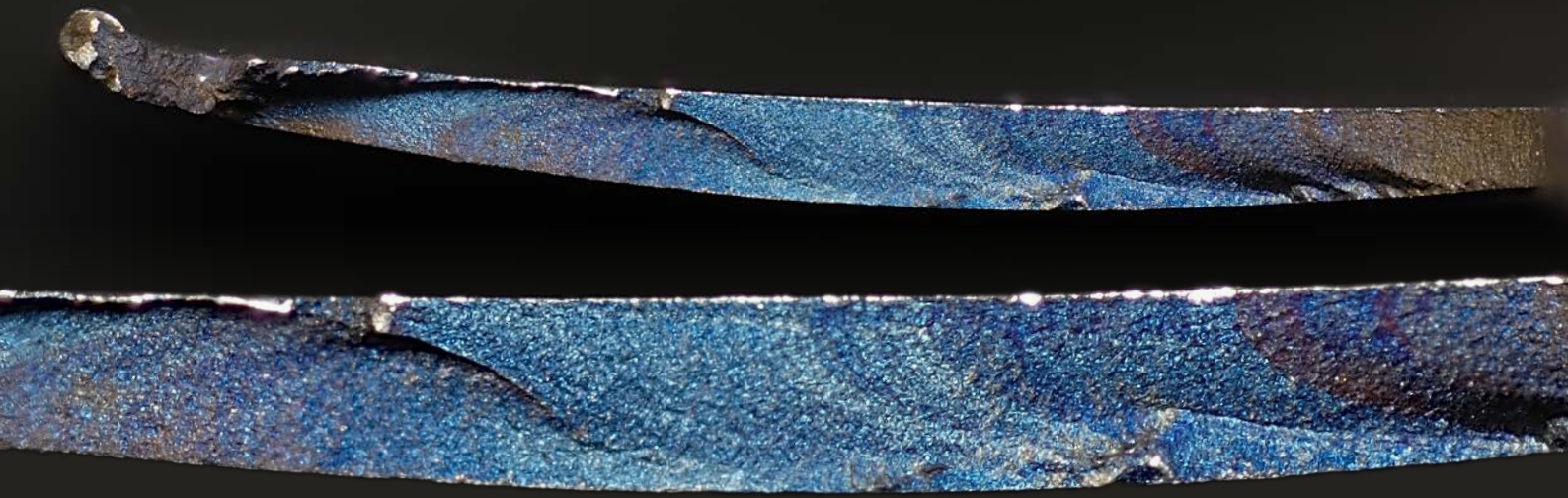
NLR's Test House is specialized in material research and engineering failure analysis on complex components. We have over 60 years of experience in aerospace, defense and high tech industry that strive for the highest safety standards with extensive knowledge on failure modes of materials with a specialization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

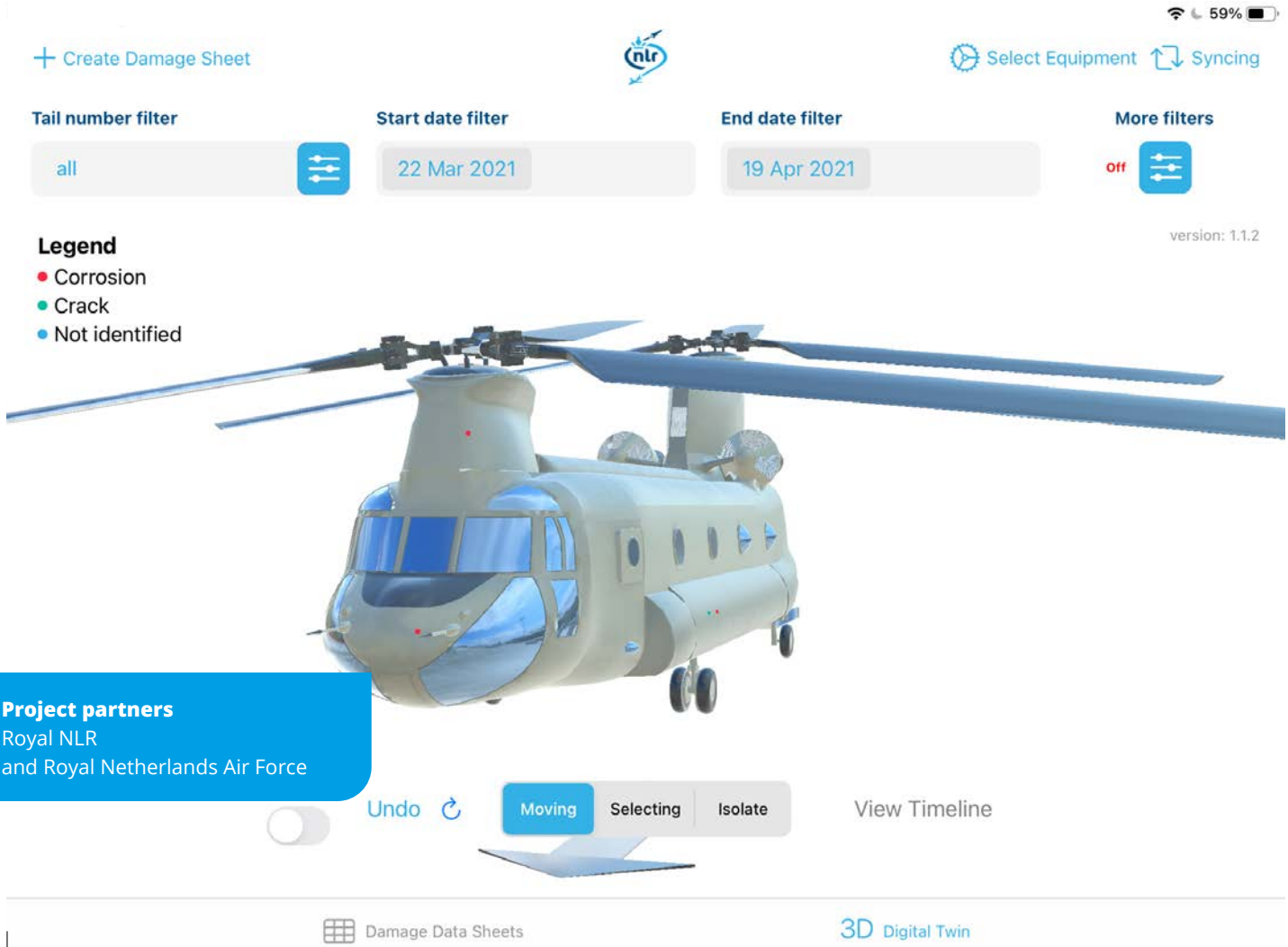
- structural materials
- high temperature materials (Ni-, Co- and Ti-alloys)
- composites

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)

Components that are removed preventively before they fail, are difficult to troubleshoot. They will still work on a test bench. To give MROs the chance to repair these components with surgical precision requires insight in the likely failure mode. FD XAI helps you to determine the probable failure mode of a functional component, and explain why.

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

Aircraft maintenance costs and aircraft availability are uncertain and difficult to estimate in advance. It requires a risk-based approach to cope with uncertainty. Our estimations help you with your availability and resource estimations for inherently unpredictable maintenance operations.

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

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.

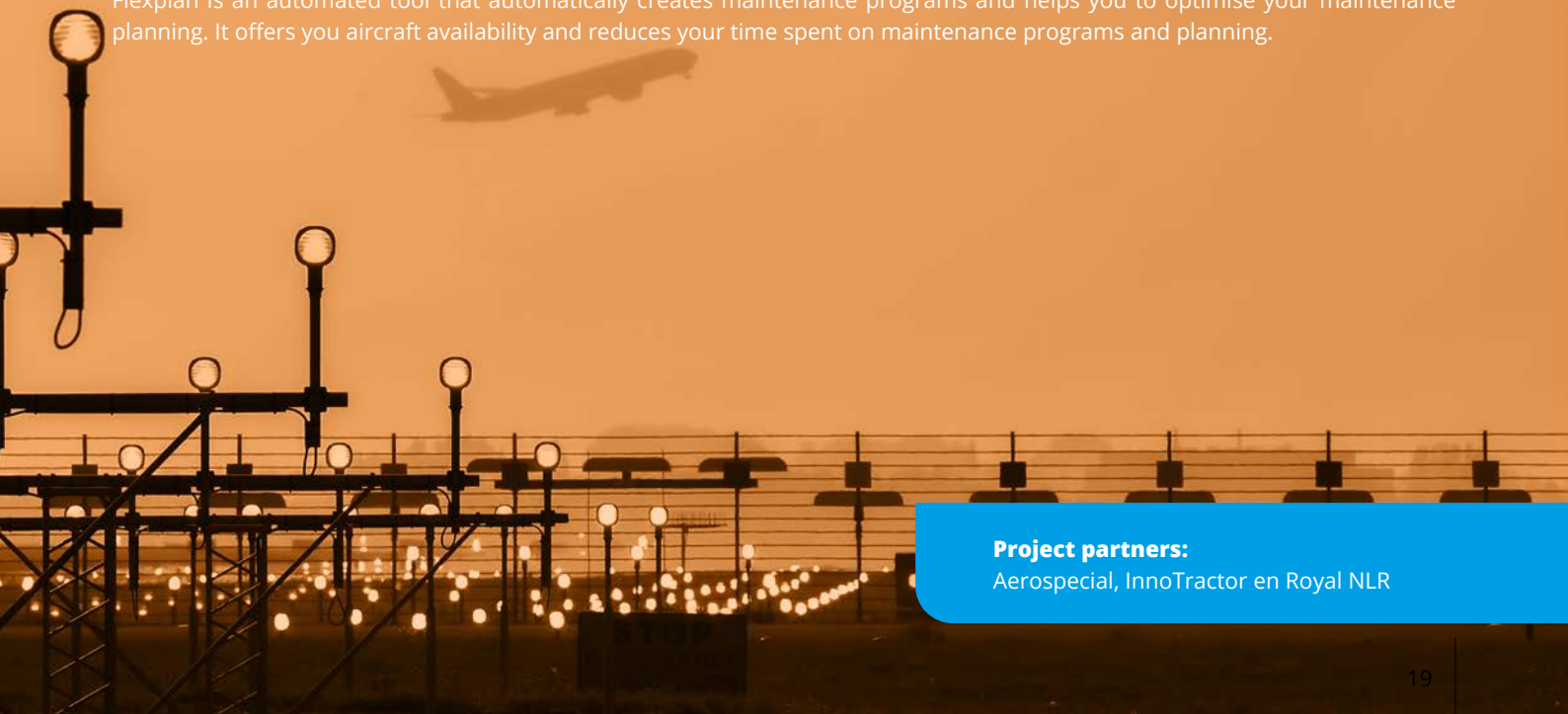
And the best thing is, it is all done automatically; you do not need to spend time on an operator specific Aircraft Maintenance Program or maintenance scheduling. It is all done for you. And since FlexPlan adheres to the task intervals specified by the original equipment manufacturer, you do not face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

THE CHALLENGE

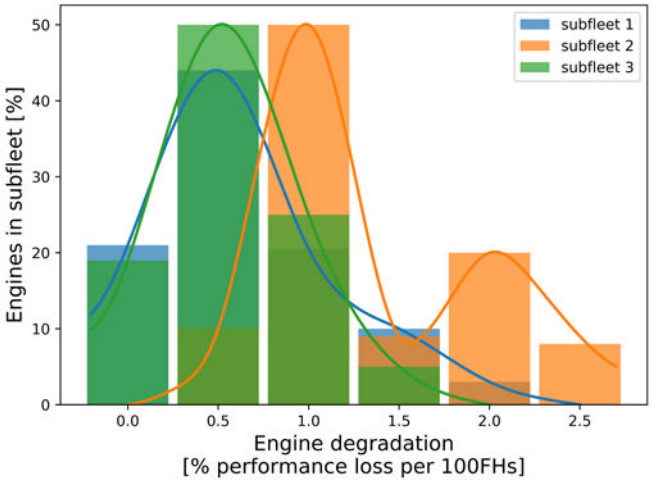
Operators use various maintenance planning concepts, however, none of these concepts really takes the flight program into account. Common maintenance concepts such as block programs are easy to schedule, but take an aircraft out of service for some time. Equalized programs break up large inspections 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.



Project partners:
Aerospecial, InnoTractor en Royal NLR



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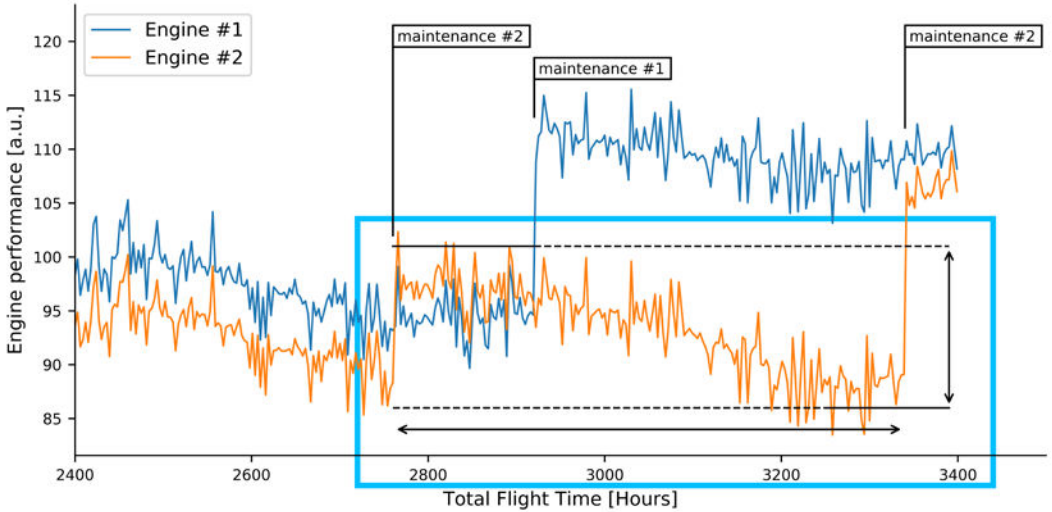


Project partners
Royal NLR and
Royal Netherlands Air Force

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).

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

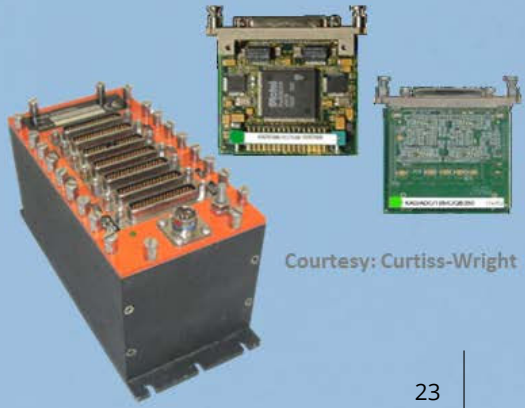
- Loads monitoring of landing gears (hard landings, remaining useful life)
- SHM of medium-sized and large UAVs
- Enhanced rotor balancing of helicopters

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

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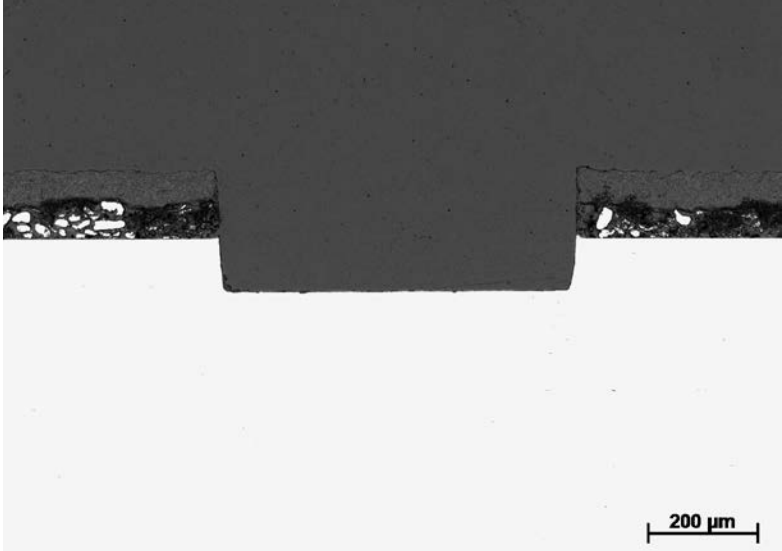
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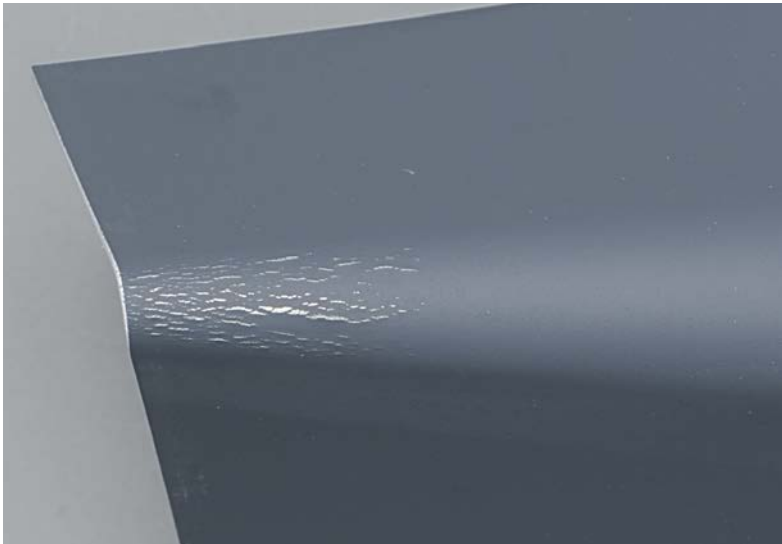


Development of chromate free primer technology

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.

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.

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

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

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 have impact on maintenance personnel, their work and the daily operation of the organisation.

THE CHALLENGE

As a result of rapidly evolving technologies for conducting (predictive) maintenance, jobs of maintenance personnel are changing. Maintenance technologies are, for example, more relying on Artificial Intelligence when it comes to decision making and tasks that were performed by personnel before, are more often performed by machines.

Research suggests that there are multiple factors affecting 1) the acceptation and implementation of the technology into their daily operations, 2) the correct and effective use of new technologies and 3) the sustainment of the change that the technology provokes, in such a manner that the application of the new technology will remain valuable.

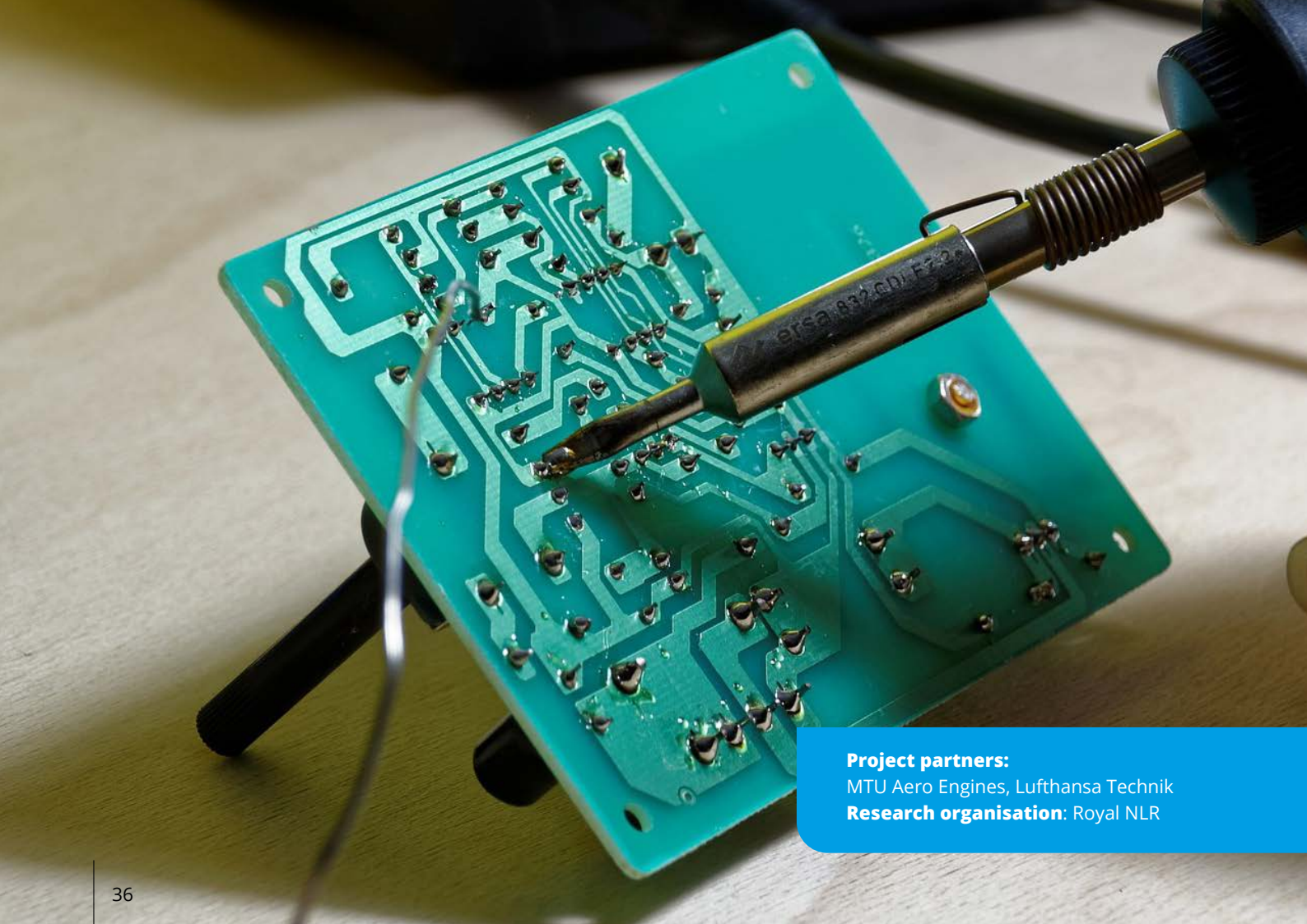
WHAT DID WE DO?

At NLR we combined multiple researches to build knowledge about acceptation and implementation of new technology and how change management can foster effective and efficient use of new technologies. Currently, we are researching the factors affecting acceptation of new technology in maintenance (e.g. trust, support of management, training) to provide guidelines for different target groups. Furthermore, we developed a manual and a set of templates to support change management in projects when a new technology requests, for example, a change in procedures.

THE SOLUTION

By researching the current situation and applying previous knowledge from research to provide personalised support during projects that require organisational change when new technologies need to be accepted and implemented.

Project partners:
Royal Netherlands Air Force
Research organisation: Royal NLR



Project partners:
MTU Aero Engines, Lufthansa Technik
Research organisation: 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 do not like to be surprised by unscheduled system and component failures that may for example keep an aircraft on ground. 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) whist retaining your intellectual property. As an operator or maintenance organisation, you can reduce the number of unscheduled failures and aircraft on ground by using components with BI PHM.

WHAT DID WE DO?

NLR recognises that the component manufacturers have all the knowledge about their systems in house. And component manufacturers already measure and collect data for built-in test equipment (BITE) functionalities. For them, it is a small step to measure and collect additional data to predict unscheduled failures. In fact, component manufacturers can embed a prognostic health management function on the component.
And 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. And if the component manufacturer collects the historic data of all their components, they can improve the BI PHM function using machine learning techniques. As a result, operators and maintenance organisations will experience less unscheduled failures, thus reducing the number of aircraft on ground and increasing the value of the component.

RAM tooling

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

THE CHALLENGE

The periodic application of RAM analyses can entail significant cost savings and improved overall efficiency. Additionally, RAM analysis can help organizations to prioritize maintenance activities and improve the overall reliability and availability of their systems and equipment. However, periodically obtaining related data, performing RAM analyses and interpreting the results is an ongoing time consuming process.

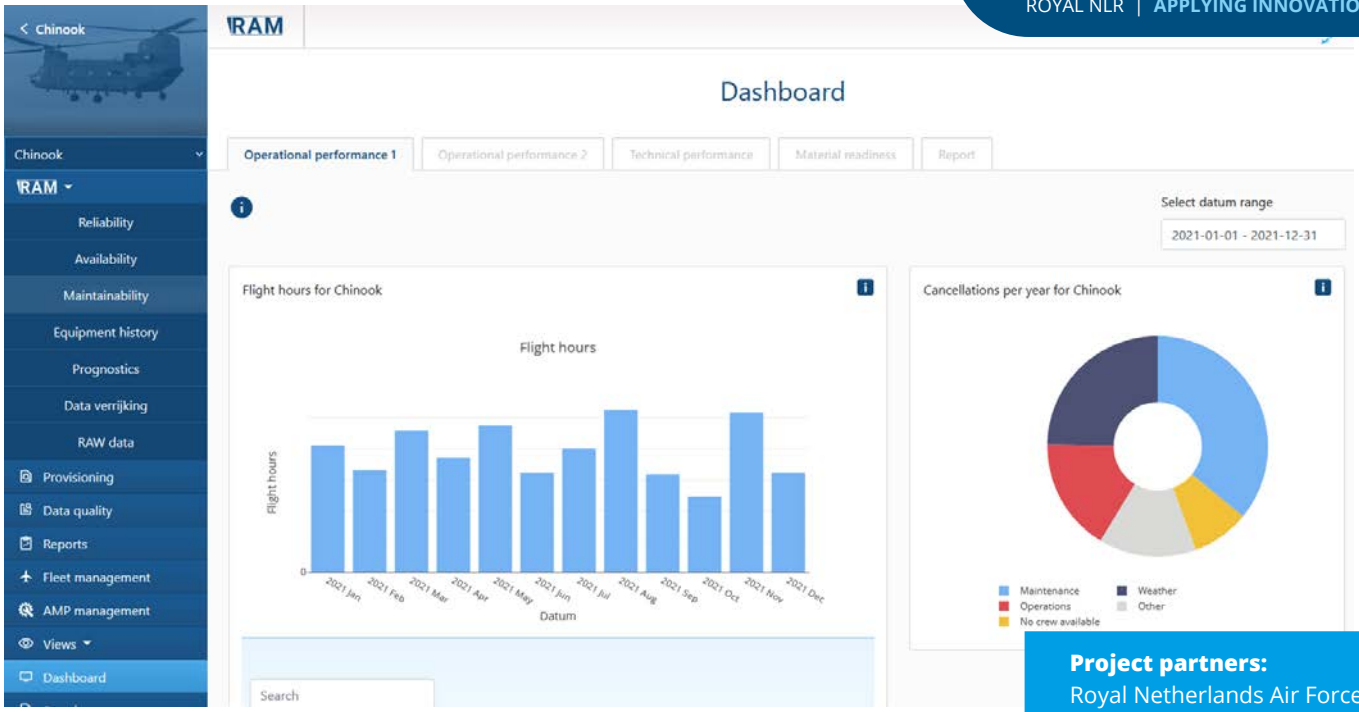
WHAT DID WE DO?

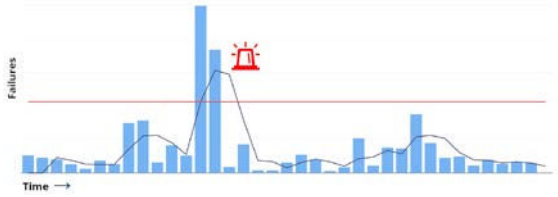
To assist in the process of performing RAM analyses, Royal NLR developed a web-based application that provides tools to gain insight in reliability, availability and maintainability parameters. By periodically obtaining and analyzing operational and maintenance data the tool provides:

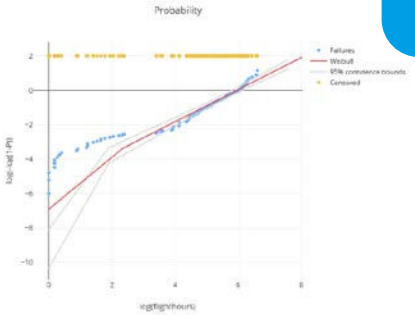
- MTBF / MTBR / MTBUR analysis of individual components
- Alerts when failures of components reach a certain threshold over time
- Insight in the aircraft's operational status over time
- Prognostic tools to projected additional failures in the future
- A visual timeline of which component is installed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

THE SOLUTION

To optimize the availability of your fleet by identifying the maintenance-related downtime, Royal NLR developed a web-based application that provides tools to give insight in reliability, availability and maintainability parameters.



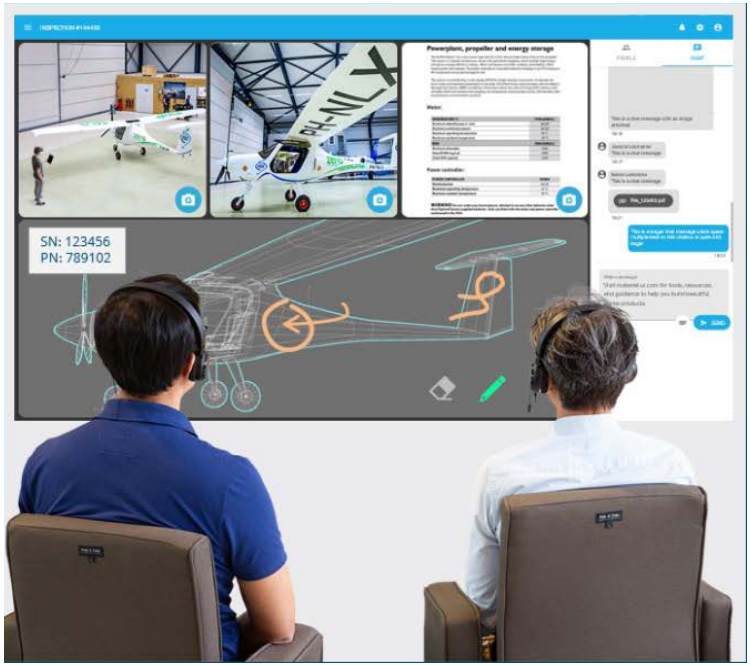




Project partners:
Royal Netherlands Air Force
Research organisation: Royal NLR

On-site

Head-Quarter



Project partners:
Industry NL: KLM
Research organisation: 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 together with KLM within the R&D program BrightSky.

THE CHALLENGE

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

THE SOLUTION

NLR demonstrated that the maintenance process can be successfully monitored and guided by qualified personnel by 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 the remote support personnel by inspecting and manipulating NeRF 3D models. This demonstration showed an effective and innovative tool allowing the maintainers to perform its tasks more efficiently.

WHAT DID WE DO?

Within the national research program BrightSky, NLR developed together with KLM a digital platform which enables the remote support of 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 less travel. To provide the home based experts a live overview of the situation, various viewing tools are integrated into the platform, including NeRF (Neural Radiance Field) technology; this offers improved interaction between the on-site personnel and the remote expert.

Smart maintenance inspections and smart training devices

Maintenance is important to make aircraft operations a success. Unfortunately, the MRO industry is faced with a shortage of labour and pollution. How can we use innovations to help the industry?

THE CHALLENGE

Aircraft maintenance organisations perform high-tech maintenance on aircraft. The maintenance activities are labour intensive and require considerable resources. In this research, we investigate if it is possible to make maintenance activities labour extensive and if it is possible to reduce polluting resources, such as fossil fuels.

Some inspections are labour intensive and are 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 you make your maintenance organisation more efficient and sustainable with smart maintenance inspection robots and smart training devices that minimise the maintenance resources, such as labour and fossil fuels.

WHAT DID WE DO?

NLR is part of the BrightSky consortium, together with JetSupport, Air France KLM, and others. The consortium develops solutions to improve the economics and sustainability of aircraft maintenance and operations. NLR is involved in three BrightSky research projects where we (i) develop and qualify a robot to inspect high pressure turbine blades which is a labour extensive way of working, (ii) develop an engine ground run simulator using augmented reality to train technicians without burning fossil fuels, and (iii) develop an augmented reality application to supervise maintenance at remote locations, avoiding time and fuel consuming trips to outstations. These solutions make aircraft maintenance more labour extensive and more sustainable.

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

Project partners:
KLM, InnoTractor, Minstry of Defence, OneLogistics, ILIAS
Research organisation: 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 good condition. Aircraft parts parts are repaired and overhauled by many different maintenance organisations. By extending the lifespan of parts, the less waste we create in the supply chain. And all these parts must be transported. And sometimes these parts are sent to the wrong place, leading to extra costs and an extra burden for the environment. If we can reduce transportation, we can reduce the emission of harmful substances.

If we can provide better information about the defective parts, we can extend the life of parts reducing waste. And if we have better information about which parts are going to fail, we can direct the replacement parts directly to the right location, reducing the transportation waste. This is good for the economics and the environment.

THE SOLUTION

We can help you make your airline and maintenance organisation more sustainable, more effective and more efficient. You will need fewer parts, which reduces the use of rare raw materials and waste flows. And you will need less transport, reducing waste too.

WHAT DID WE DO?

NLR is part of the HYPERION consortium, together with Air France KLM, InnoTractor, ILIAS and the Netherlands Ministry of Defence. The consortium develops 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 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.

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