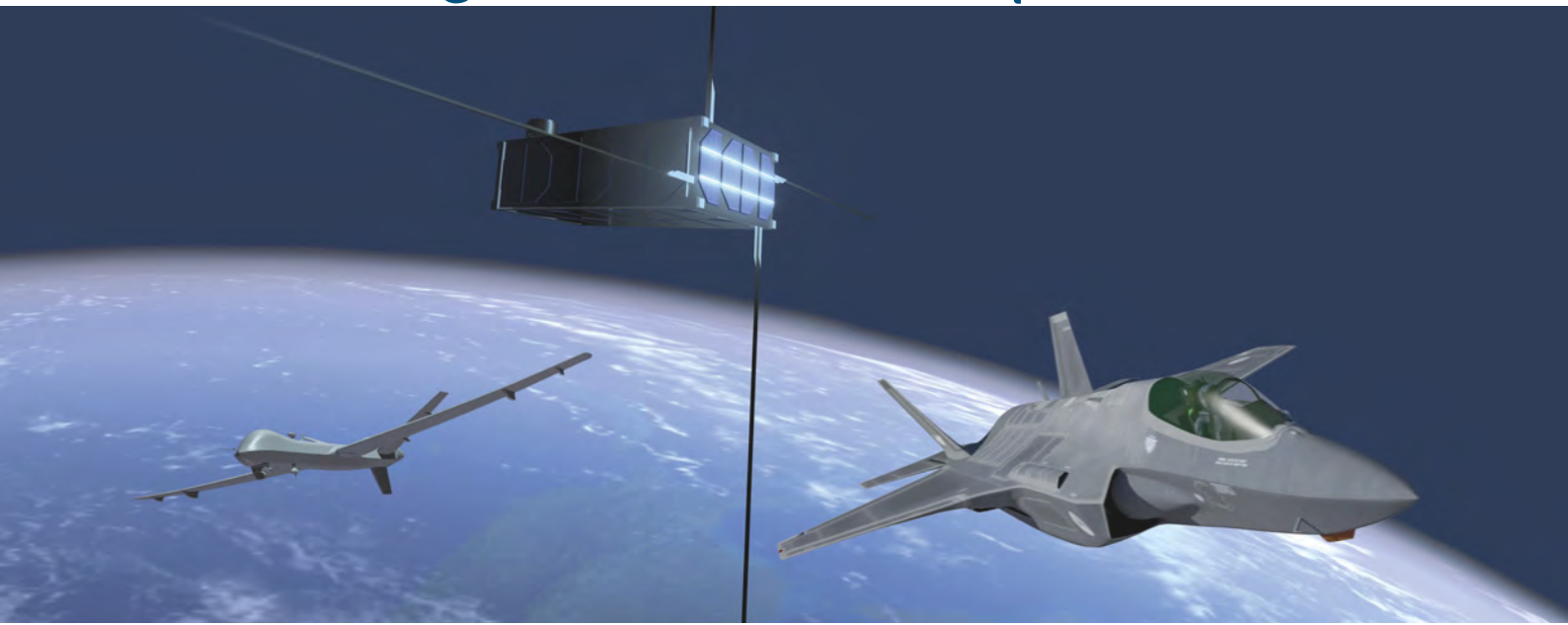
Dedicated to innovation in aerospace

Adding value to what protects us



Royal NLR - Netherlands Aerospace Centre

Royal NLR

The research and activities of Royal NLR comprise working in a challenging and fast-changing field of research every day, assisting a wide range of clients. NLR has available a wide range of test facilities with which we can test, verify and validate products. Royal NLR can support anyone in need of technical and operational support for the safe and effective deployment of air defence platforms such as

- technical support for the acquisition of new weapon systems and their subsequent modifications
- support for the life cycle management of aerospace-related weapon systems
- support in determining and implementing military aviation standards
- research into the environmental aspects pertaining to military aviation and advising the Defence department in the formation of its policy in this area
- the implementation or design of effective training programmes for pilots, onboard personnel, ground-station and maintenance personnel of aviation systems
- technical support for the interoperability of aviation weapon systems or support for the Ministry of Defence's general policy.

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 activities.

We hope you enjoy reading and discovering more about Royal NLR.


Requirements
Life cycle support
Improvements
LC SUPPORT
SYSTEM
OPERATIONS
OT&E
Flight safety
Operations

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

Start: February 2000
Duration: ongoing

F-35 Acquisition & Operational Readiness Preparation

WHY?

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

HOW?

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

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

WHAT?

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

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

Royal NLR contribution to the F-35 Lighting II of the Royal Netherlands Air Force

- ET Simulator/ET Demo
- SJE Wind Tunnel Testing
- Low Speed Inlet Test
- IOT&E Participation
- Gun Pod
- Embedded Training

ISR: Lead by Information with Innovation

Superior information position calls for the right information in the right place at the right time. Increasing complexity and hybrid nature of current conflicts call upon a proper intel position within the military context. Data is gathered from a variety of sources and contains varying types of information. These different types of data are fused in order to increase the situational awareness.

WHAT YOU NEED

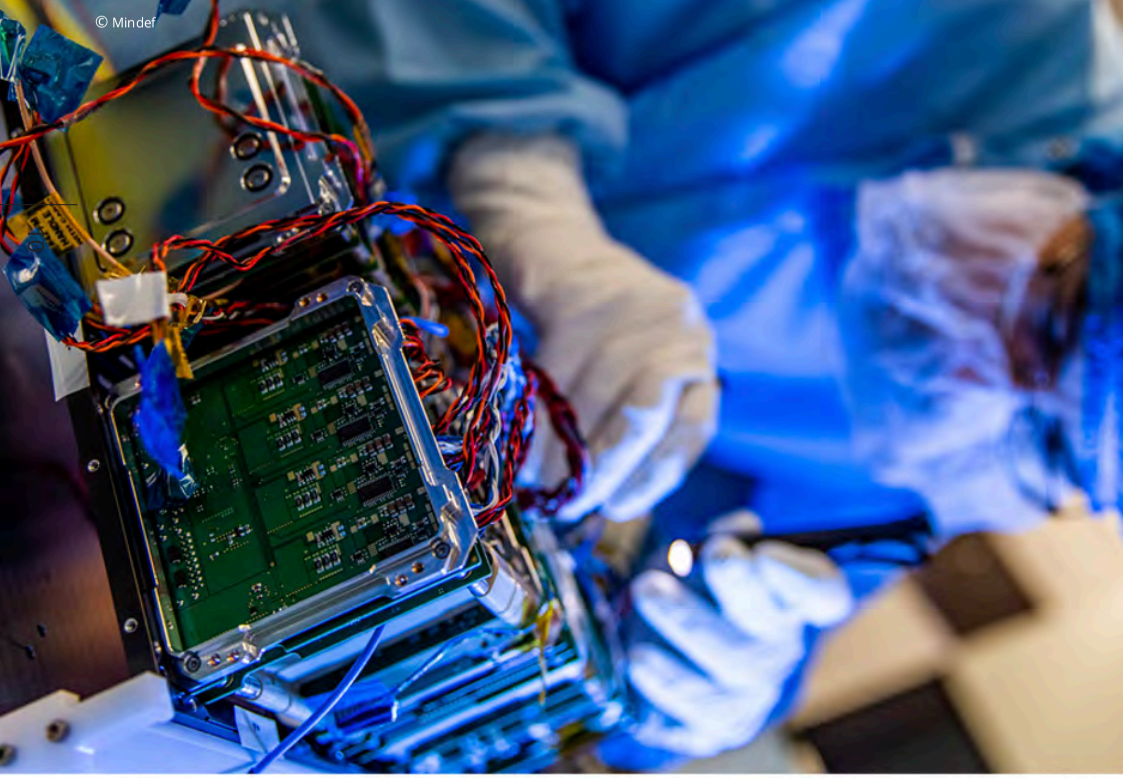
- Right information in the right place at the right time to support the right decision making of commanders and operational units in the field in order to generate the right military effects
- Looping through the Observe-Oriënt-Decide-Act OODA cycle faster than the adversary in order to achieve and maintain a lead with respect to the adversary

WHAT WE DELIVER

- NLR is a one-stop-shop for end-to-end complete chain-based ISR solutions by means of innovative sensor, processing, analytics and presentation techniques
- NLR supports, analyses and advises for ISR procurement, exercises and operations for the continuous improvement of Information Governed Operations (IGO)

OUR CAPABILITIES

- NLRs capabilities comprise of
- Innovative sensors for Air- & Spaceborne platforms for i.e. geolocation & identification
- Federated Processing Exploitation and Dissemination (FPED) processes
- ISR information analytics by Artificial Intelligence and Big Data techniques
- Effective decision support for operators
- Presentation of ISR information for operators using Virtual and Augmented Reality
- Protection against cyberattacks
- Support Information Governed Operations by Concept Development & Experimentation
- Provide tactical and operational support for Information Governed Operations
- Provide products and services to enhance Situational Awareness and Understanding
- Enhance Processing Exploitation & Dissemination cycle
- Expertise in reconnaissance pods
- Real-time Access to Airborne ISR (RAAISR)
- Apache Data Video Intelligence SystEm (ADVISE)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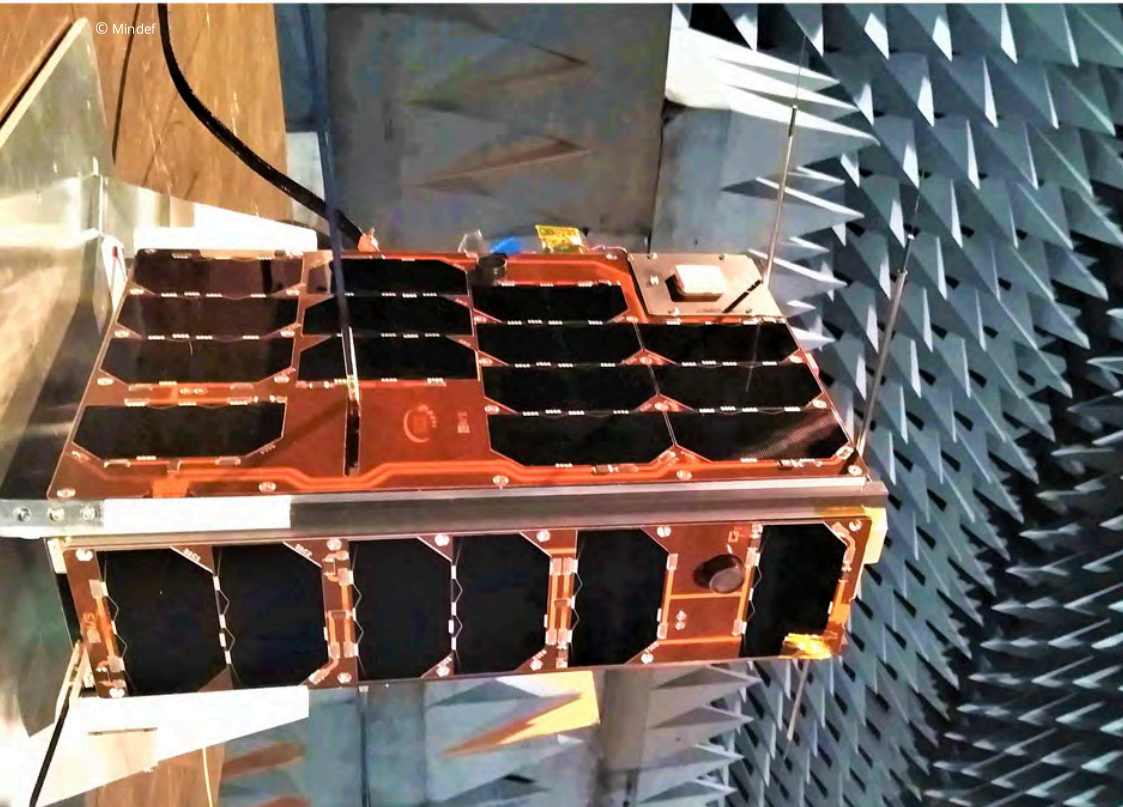
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BRIK II, the first Dutch military satellite

The first Dutch military satellite was successfully launched in June 2021. The BRIK II nanosatellite is an experimental project of the Royal Netherlands Air Force. On 30 June, the Virgin Orbit company launched the "LauncherOne" rocket, with BRIK II as one of its payloads from Mojave in the United States.

The launch is a first test for Defence to demonstrate the potential of nanosatellites for military and civil use. The Dutch Defence Vision 2035 states that space has become a necessary link for information-driven action by the armed forces. Defence is highly dependent on satellites. For example, consider the use of navigation and communication systems. In order to keep the development scalable and affordable, Defence works together with Dutch industry and knowledge institutes. BRIK II emerged from this.

COOPERATION

The Delft company Innovative Solutions in Space is the designer and integrator of BRIK II. NLR has developed new technologies that are put into practice via the BRIK II. In addition, there is cooperation with Delft University of Technology and internationally with the University of Oslo.

The name of the satellite is a reference to the first aircraft for the Aviation Department in Soesterberg. This aircraft from 1913 was called 'De Brik' and was used by the Dutch armed forces to discover the aviation domain.

CONTROL/OBSERVE:

- SCENARIO CONTROL
- OBSERVERS
- RECORDING
- ANALYSIS
- DEBRIEF

BACKBONE:

- CORE SERVICES: GEODATABASE, SIMULATION SUPPORT, ...
- CONNECTIVITY: DIS/HLA, EXTERNAL BATTLELABS
- LIVE ASSETS CONNECTIONS (LVC)

TACTICAL LEVEL:

- FIGHTERS: F-16 &-F-35
- HELICOPTERS: AH-64, CH-47, NH90
- TRANSPORT & TANKERS:C-130, KDC-10
- UAV'S: MQ-9, SCAN EAGLE
- SPACE ASSETS: SPACE SA, BRIK-II
- WEST
- TACTICAL REFERENCE MANUAL
- SMART BANDITS
- F35 CDEF

OPERATIONAL LEVEL:

- AOC: MASE, SCOTT
- ISRD: INFORMATION FUSION & SHARED SU DASHBOARD
- AIR C2: RESOURCE MANAGEMENT, PLANNING & MONITORING/CONTROL
- SMART MISSION PLANNING & DEBRIEF

CEREBRO:

The NLR Air & Space Operations Battlelab

WHY?

The increasing complexity of modern warfare, with its various forms ranging from very asymmetric counterterrorism operations to full scale peer conflicts, requires research on new tactical and operational systems and concepts. These, usually joined and combined, operation concepts need to be tested in a secure environment which can be safely connected to similar secure battelabs located at national and international partners. New generation platforms, new command and control concepts and the increased adoption of "information governed operations" in combination with the quick rise of big data analysis and artificial intelligence capabilities pose new operational challenges for the RNLAF.

HOW?

NLR provides a battlelab capability by integrating high fidelity platform simulators with additional proof of concept demonstrators and extension to other battlelabs. The platforms include Fighters (F-16 and F-35), Helicopters (AH-64, CH47, NH-90), UAV's (MQ-9, ScanEagle) while the concept demonstrators include e.g. (Air-) C2 and ISR related systems. Cerebro can ultimately also be coupled with live systems when connected to e.g. a Link-16 or a DIS gateway.
The extensive use of platform simulators and computer generated forces will reduce the costs while enabling testing of new functionalities concepts in a safe environment and freeing operational flying hours for other purposes.

NLR has a long history in Military Operations research which has produced a number of operational tools that will be integrated in Cerebro. These include a threat reference manual, mission planning tools with AI support and very advanced and accurate weapon system models. The dedicated NLR developments are combined with products developed by industry and other research institutes to create a state of the art battlelab environment allowing CD&E sessions of different scales without the need to (re)build the test environment first. New systems will be added to Cerebro over time when developed in separate programs and these will then be maintained for use in new programs that will run on the Cerebro environment.

High Energy Laser Lab (HEL LAB)

WHY?

Governments are facing a upcoming threat of small and cheap air vehicles (drones) intruding restricted air-space. The use of High Energy Laser as an effector against these threats is an potential upcoming technology. Research of effective ways to detect and neutralize these vehicles with a minimum of collateral damage is essential and urgent.

Project partners
Netherlands MOD (NL)
Research organisations: The Royal Netherlands Aerospace Centre (NL)

Start: June 2018
Duration: Ongoing

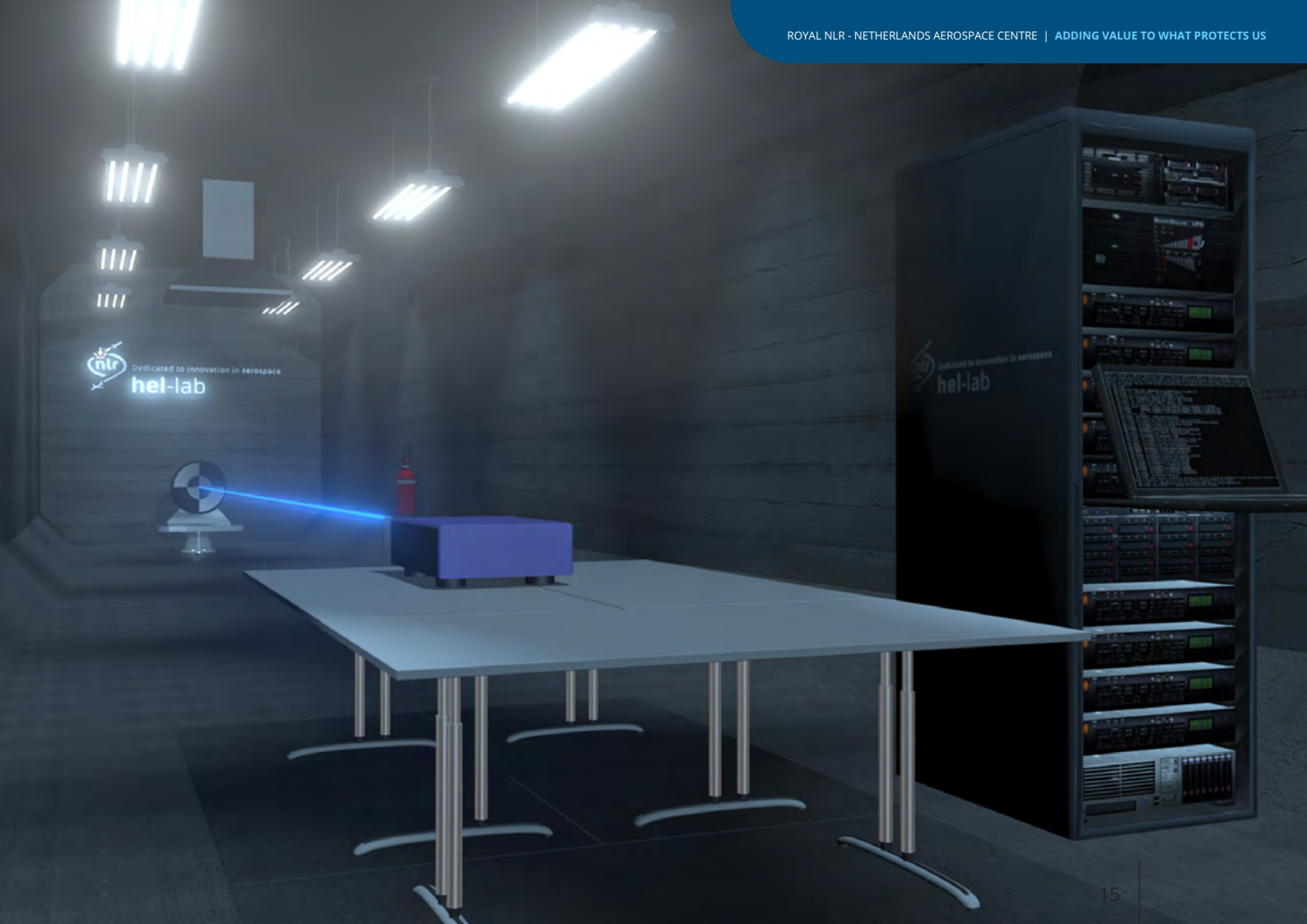
HOW?

Research relevant aspects of the HEL technology, system integration and operational deployment. Since July 2018 Royal NLR is conducting tests in its HEL LAB to research the effects of laser energy on different types of materials (e.g. aluminum, composites). Each material has its own properties that result in a required amount of energy over a minimal dwell time. The essence of our research is to determine the most efficient way of effecting an object.

WHAT?

The main R&D activities of the project are:

- The effects of laser energy on materials.
- Developing an interaction model in which materials and the effect of laser energy are calculated.
- The impact of the way of targeting an intruding object with laser energy.
- Safety issues of the use of laser energy in an environment (civil and military).
- Integration of potential systems on aircraft platforms


Dedicated to innovation in aerospace
hel-lab

Project partners
Defence Science en Technologie (S&T)
Defense Equipment Organisation (DMO)
Defense Expertise Centre Counter-IED (DEC-CIED)

Start: January 1st 2020
Duration: 2.5 years

ARTEX: Augmented Reality for Technical Exploitation in C-IED Operations

WHY?

Improvised Explosive Devices (IEDs) are a day-to-day reality in conflicts and are regarded by the armed forces as tactical weapons with a strategic effect. IEDs inflict fatal or serious injury and damage to personnel and equipment, limit the freedom of movement and mobility of military units, and pose a serious threat to the success of and support for missions. In order to provide insight into information about IEDs and the IED network, information from IED components or remnants, documents, electronic data carriers and detainees is secured, gathered, analyzed and processed. This multi-stage process is called Technical Exploitation (TE). Communication between operational TE experts, gathering information and sharing knowledge and resources are among the numerous urgent challenges in this process.

HOW?

The goal of this project is to consider the way Augmented Reality (AR) can improve and speed up the TE process in Counter-IED operations, while decreasing operational risks. To attain this goal, three technology demonstrators (TRL 6-7) are developed, aiming to rise to the aforementioned challenges.

WHAT?

The first demonstrator aims to support the TE level 1 specialists, who are responsible for the identification and collection of objects of interest in non-permissive environments. The ARTEX demonstrator supports them, amongst others, by automatically creating a map of the building that is being exploited and the ability to digitally record and collect information about the encountered objects. This enhances the shared situational (and spatial) awareness, which could enhance the communication between experts. The second demonstrator focusses on the TE level 2 specialists, who work in an in-theatre laboratory to exploit the objects their colleagues at level 1 have collected earlier. Different cases can be compared in a situational AR overview, identifying matching components. The third demonstrator focusses on the (real-time) interaction between TE level 1 and 2 experts.

Three Levels of Technical Exploitation

1. Tactical – level 1 (field)
2. Operational – level 2 (in-theatre)
3. Strategic – level 3 (out-of-theatre)

Expertise

Capability

Capacity

Specialist Equipment

Assurance, Rigour and Confidence

Time →

Level 1	Level 2	Level 3
Non Permissive		Permissive

Three technology demonstrators:
A – level 2

Three technology demonstrators:
B – level 1

Three technology demonstrators:
C – interaction between levels 1, 2 and 3


Timeline: 4-2-2019 14:58:40
Map Controls
IED #3
Viewing IED Mode:
Disassembled
Plan executed
Message received
Target approved
foster+freeman

Virtual Cockpit

WHY?

Training devices that fit your training needs often require large investments and are usually type specific. There are currently no training devices that allow a highly realistic interaction between the pilot and cockpit instruments, without the disadvantages associated with expensive high-end devices. Virtual Cockpit bridges this gap by providing the technology to do just that: low-cost and high-fidelity training technology.

HOW?

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

The concept was evaluated and improved with operational experts in several iterations throughout the project.

WHAT?

The result is a concept demonstrator that allows highly realistic interaction and provides pilots with all the visual, auditory and haptic experience and feedback that they need for a high-fidelity training experience. This technology concept also provides the ability to build a highly configurable and mobile setup with a small footprint that is still low-cost.

Project partners
Industry (NL):
Cinoptics, provision of high-res VR-optics

Start: October 2016
Duration: 2.5 years

Smart Bandits

Intelligent opponents in mission simulation

WHY?

In military simulations, computer-generated forces (CGFs) are autonomous entities that represent friendly, neutral or hostile air, ground surface, or sub surface-based units, platforms or individuals. The behaviour that CGFs display in the simulations is modelled to resemble realistic human behaviour. CGFs are typically used in application areas such as training, mission rehearsal, concept development and experimentation (CD&E) or decision support. For each application, the CGFs require different behaviour models. However, traditional modelling techniques do not give scope for expression and keep modellers from quickly developing new models. Therefore, new approaches to behaviour modelling are required.

Project partners
Research organisations:
NLR, VU University Amsterdam

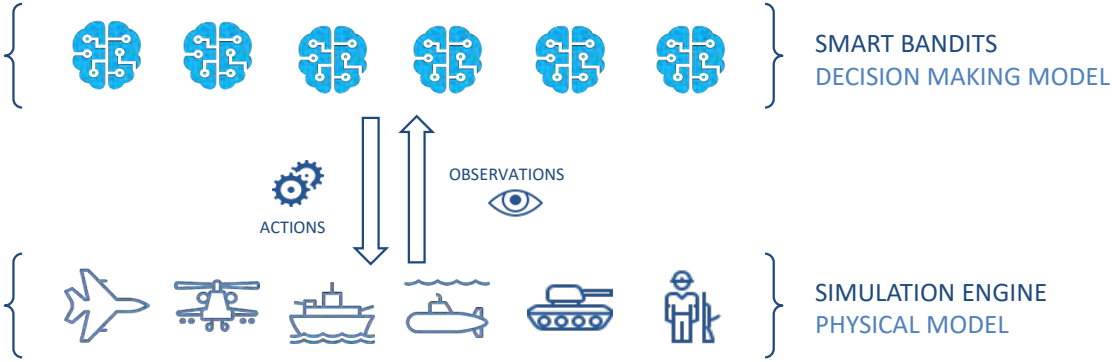
Start: 2010
Duration: improvements ongoing

HOW?

The aim of the Smart Bandits project is to explore various approaches to modelling human-like behaviour. To this end, we carried out research in two main directions, namely human behaviour and computational modelling. In the area of human behaviour, we specifically studied situational awareness (i.e. the perception of the environment) and theory of mind (i.e. beliefs, desires and intentions). In the area of computational modelling, we studied the use of machine learning techniques for enhancing classical modelling techniques such as finite-state machines and behaviour trees. A key component of the Smart Bandits project was the evaluation of newly developed techniques in human-in-the-loop simulations, such as in NLR's Fighter 4-Ship networked F-16 simulator.

WHAT?

The results of the studies are combined in a user-friendly graphical behaviour modeling tool. The tool is named Smart Bandits after the project. It enables modelers to quickly implement behaviour models and to link the new models to the CGFs in a simulation engine. While the CGFs make their observations in the simulated world, the Smart Bandits tool calculates their next actions. During simulations, the behaviour models can easily be inspected to see what the CGFs are thinking. Apart from being an intuitive modeling tool, Smart Bandits continues to be a platform for behaviour modelling research. NLR is continuously experimenting with new modelling techniques and new ways of interacting with CGFs.




VIPER 3
VIPER 4
MISSILE 2
COBRA 2
COBRA 1
MISSILE 1
SA-10

Embedded Training and LVC:

Effective training for Joint and Combined Airpower

WHY?

One of the major issues in conducting live training with 5th generation fighters (like the F-35) is training range space and how to create an tactical threat environment that challenge the capabilities of these modern fighters. These fighters have long-range sensor and weapon delivery capabilities. Training and exercises take therefore more and more place in an environment where live systems operate together with man-in-the-loop simulators or in a live environment that is enriched and stimulated by computer generated players and events. Such a Live Virtual Constructive environment opens up new opportunities but at the same time it calls for other demands than traditional live or simulation environments.

HOW?

NLR investigates and implements training solutions that include live, embedded, and virtual mission training. We play a major role in international working groups (NATO, EDA, SISO) in solving interoperability issues and defining standards and reference architectures for LVC environments. We facilitate the integration of Live Virtual Constructive components to support the military operator during battlefield operations, mission planning/rehearsal, joint exercises and mission training.

WHAT?

We can combine live, virtual, and constructive training in a fully interconnected exercise. We promote downscaling where possible, and fit for purpose training solutions. NLR offers a combination of education and training expertise with all the technological knowledge available to offer you the best advice on the employment of Live Virtual Constructive training. We have, with our partner Airbus Defence and Space Netherlands, developed an Embedded Training (ET) software system for fighter and trainer aircraft. With this ET system the pilot interacts with the synthetic threats by using his unmodified cockpit controls and displays. For example, he or she performs identification, fires weapons, and applies countermeasures. Synthetic threats will show a realistic intelligent behavior. For example, they fire missiles at the real aircraft and apply countermeasures when they are attacked.

Project partners

Partners: NLR and Airbus Defence and Space Netherlands

WEST: Weapon Engagement Simulation Tool

Thanks to WEST (Weapon Engagement Simulation Tool), NLR has a validated simulation environment available for detailed modelling and simulation of weapons systems. Air-to-air, air-to-surface and surface-to-air systems, sensors and weapons are all covered. WEST has its own interface for defining scenarios and engagements and for visualising and analysing the results. In addition, both single engagements and batch runs or scenarios with multiple entities can be handled. The models in WEST are however also available to use separately. This has already been done in the F4S environment, where the missile fly-outs are generated by WEST and the DLZ (dynamic launch zone) in the HUD (heads-up display) is also directly linked to the WEST missile models. Embedded training (ET) also utilises models from WEST.

STK: Satellite/Systems Tool Kit

NLR has STK (Satellite/Systems Tool Kit) as a simulation environment for operational space scenarios. This allows both single satellite systems and constellations for the military use of space to be modelled, including the sensors. In addition to models of the space domain, STK is integrated with objects specific to the land-based, maritime and airborne domains for purposes of observation (of the Earth), communication and navigation. Operational issues relating to line-of-sight calculations, overfly times and communications links can then be calculated and visualised.

A user-friendly MMI lets the user set up operational scenarios rapidly using the objects from the various domains.

MUST: Multi-UAS Supervision Testbed

MUST is NLR's testbed for operating unmanned systems. It provides a workplace for an RPAS crew that can be used for controlling multiple RPAS craft at the same time. MUST offers standard functionalities, while additionally being fully customisable as required. The architecture of MUST supports control of operational and simulated RPAS; this has also been demonstrated in practice. One aspect that makes this possible is the STANAG 4586 compatibility.

MUST is an integrated component of NLR's Airpower Simulation, in which all the NLR simulators can be linked flexibly as required for a variety of missions. For example, MUST has connections to Fighter 4-Ship (F4S), Helicopter Pilot Station (HPS) and Virtual Battlespace (VBS). This makes manned-unmanned teaming (MUM-T) concepts possible, for instance.

In addition, MUST can be coupled to NLR's Video Exploitation System (VES), allowing MUST to be utilised as an element of an actual or simulated data-to-decision chain. Moreover, for carrying out tests for the integration of RPAS craft in controlled airspace, MUST is also linked to NARSIM. NARSIM is NLR's simulation environment for radar and ATC towers. This connection offers options for testing new concepts with RPAS, from the perspectives of both the ATC (e.g. in a tower) and the RPAS crew.

Air Operations as a Team

The Air Operations as a Team uses Virtual Battlespace 3 (VBS3) as a simulation environment for executing tactically relevant helicopter scenarios. The project was typically CD&E in nature and involved the end users closely. In three experiments, up to 21 participants at the same time (AH and TH pilots, load masters and commando troop staff) carried out simulated missions. This determined the added value of mutual data exchange, both of live remotely-piloted aircraft systems (RPAS) during operations and for being able to control the RPAS (sensor and flight path) from the helicopter.


PEN E
NL23
0.6 ft
STBY
L7 PQ7
OFF
TMB86
79Kt
STBY
L9 FF-1
TU187
10Kt
STBY
TMB83
19Kt
-1.4 ft
STBY
NL13
TUC88
11Kt
STBY
R4
TMB69
15Kt
-1.5 ft
STBY
TMB85
TUC1
10Kt
STBY
TMC81
19Kt
9.8 ft
TMB73
16Kt
-3.0 ft
STBY
TU67
10Kt
-3.2 ft
TUC78
10Kt
STBY

Threat Environment NH-90 FMFT

WHY?

The Royal Netherlands Air Force (RNLAF) owns a NH-90 Full Mission Flight Trainer (FMFT) to train their NH-90 crew. The threat environment can be simulated in high detail and consists of complex databases. For realistic training the simulator databases need to be filled with specific data. To maintain these databases (threat environment, entity data, etc.) simulator knowledge is needed. The RNLAF has outsourced their NH-90 simulator database maintenance to NLR.

HOW?

NLR maintains the NH-90 FMFT threat environment databases based on:

- The requirements provided by the NH-90 simulator instructors
- Simulator knowledge that has been accumulated by NLR over the past decades

WHAT?

Threat Environment databases:

- Compatible with the NH-90 FMFT
- Correlated which each other
- Continuously expanded and improved

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

Start: 2009
Duration: ongoing

Project partners
Industry (EU): Leonardo Helicopters, GIEI
Research organisations: NLR, DLR
Universities: UoL, POLIMI, JMUL

Start: May 2019
Duration: 3 years

RoCS is a EU funded project. This message doesn't necessarily reflect the views of the EU.

RoCS: Rotorcraft Certification by Simulation

WHY?

Before an aircraft may enter into operation in civil airspace, it must obtain a type certificate from the responsible aviation regulatory authority. The compliance demonstration is the lengthiest and most expensive part of the certification process. The driving factor for the cost and duration is the amount of ground and flight testing required. Moreover, certain certification flight test activities, particularly those involving demonstrations of control system or engine failures, can be classified as high-risk. The reduction in the scope of the test activities made possible by the exploitation of advanced analysis methods such as flight simulation, therefore, offers an immediate benefit in terms of the overall certification cost, schedule and safety.

HOW?

The RoCS consortium aims to explore the possibilities, limitations, and guidelines for best practices for the application of flight simulation to demonstrate compliance to the airworthiness regulations related to helicopters and tiltrotors. First, the paragraphs that are potentially suitable for compliance demonstration via piloted flight simulation are selected in consultation with the European Aviation Safety Agency.

Next, metrics will be proposed and evaluated to measure the simulation model predictive fidelity and simulator facility cueing fidelity. These metrics will be the basis for the RoCS open-access guidelines on fidelity requirements and best practices. Finally, the proposed guidelines will be verified through a simulator flight test campaign at Leonardo Helicopters using the LH AWARE simulator that will be upgraded in the course of the project.

WHAT?

The use of flight simulation to support rotorcraft certification activities has potential benefits in terms of safety, economy, time, and effectiveness. Flight test safety is increased by virtue of providing the option to perform high-risk demonstrations in a simulated environment. The economy of rotorcraft certification is improved by reducing the amount of flight test time and reducing the risk of damages. The relatively swift turnaround of a simulator campaign compared to flight testing improves the time-to-market and, therefore, the competitiveness of the European rotorcraft industry. Finally, the possibility to test numerous configurations and easily gather test data at a marginal increase in cost and time contributes to the overall effectiveness of the compliance demonstration process.

Project partners
Defence Helicopter Command (DHC) of the Royal Netherlands Air Force
Joint IV Commando (JIVC) of the Ministry of Defence

Start: June 2016
Duration: 2.5 years

Redesign of helicopter training

WHY?

The Defence Helicopter Command of the Royal Netherlands Airforce expressed a need for a common, modernized approach for the qualification training of all their platforms.

HOW?

In cooperation with Subject Matter Experts (operational pilots/load masters and instructors), a competency based training needs analysis was performed. Competency profiles were identified for CH-47 pilots and load masters and for the AH-64 pilots. Idealized Mission Qualification Training (MQT) outlines were designed, that would lead to fully combat-ready pilots and loadmasters for a wide range of (adverse) operational conditions. This is based on the assumption that modern tactical simulators are available, suitable live ranges are available and scheduling issues do not exist. Such ideal training conditions are important for creating and working with a clear vision of training.

With the idealized training setups in mind, actual MQT were developed, implemented and evaluated.

User requirements for a multi-ship/multi-type (MSMT) simulation facility were also identified and a roadmap to a future idealised MSMT system concept was suggested.

All activities were facilitated by NLR and new, science-based approaches were applied as far as acceptable for the SMEs, who are the 'owners' of the products.

WHAT?

The project produced ideal and actual MQT for AH-64 and CH-47 crews. Furthermore, user requirements, a system concept and a roadmap for an MSMT simulation facility was provided.

The method applied is a competency-based training approach that applies the train-as-you-fight principle from the start. This primarily whole-task training setup is built up according to principles (for example gradually increasing complexity) that optimize cognitive load throughout the training.

Competency based maintenance training

WHY?

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.

HOW?

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?

First, a competency based training concept wasdefined 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)

Start: May 2014
Duration: 3 years

Fighter 4-Ship for Tactical Intercepts (TI)

For a variety of reasons, it can be useful to provide elements of BVR (beyond visual range) aerial combat in a simulated environment. Firstly, it often turns out to be difficult in practice to get enough aircraft into the air to handle more complex setups (such as 4 versus 4). In addition, aspects that are not possible in reality can be approximated in a simulator. The performance and behaviour of enemy aircraft and the associated systems such as radar and IRST can for instance be modelled realistically. Using computer-generated forces (CGF) eliminates the dependency on scarce human and other resources for generating opponents. It is also possible to insert fly-outs of missiles – both friendly fire and from the opponents – into the scenarios. Integrating fighter controllers into the simulation creates an environment in which not only pilots but also combat leaders are involved, for instance through joint debriefing.

Integrating Fighter 4-Ship (F4S), with other simulators creates an environment in which tactical actions can be evaluated effectively. This environment can for instance be used for experimenting with various presentations and for modifying tactics.

Detect and Avoid development

2012 > 2013 > 2014 > 2015 > 2016 > 2017 > 2018 > 2019 > 2020 > 2021

AIRPASS
Feasibility study of required (on-board) equipment for integration in u-space

B-VLOS
BVLOS flights planned to gather experience, support rule-making in the Netherlands and develop the market potential.

DAA Miniaturization

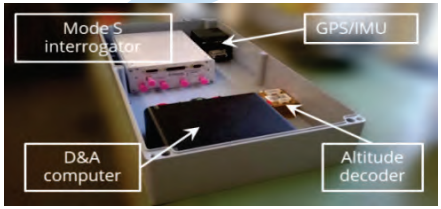
AIRICA
Interface design with RPAS BVLOS without visual observers
Flown with manned aircraft to evaluate Detect And Avoid measures

PODIUM
Demonstrate U-space services with today's technology in 'unexpected' situations (incl. BVLOS flights)

Fuel cell Drone

VUTURA
Validation of U-Space by Tests in Urban and Rural Areas. Combination of different U-Space systems

Explorer
System Development & Testing



Integration of MALE RPAS into European Airspace

WHY?

To test and validate the airspace integration CONOPS, NLR has developed the MALE RPAS Real-time simulation Facility (MRRF). The MRRF consists of two pre-existing NLR simulators, namely the NLR ATM Research Simulator (NARSIM) and the Multi UAS Supervision Testbed (MUST). Here, NARSIM is used to simulate air traffic, and provides working positions for air traffic controllers and aircraft pilots. MUST, on the other hand, is the RPAS simulator, and it functions as the pilot ground control station. For CONOPS development, the well-known GA-ASI SkyGuardian aircraft, which has been procured by several European air forces, is used as a representative MALE RPAS.

HOW?

At present, the regulatory environment in Europe requires Medium Altitude Long Endurance (MALE) Remotely Piloted Aircraft Systems (RPAS) to fly in segregated airspace. Furthermore, each and every MALE RPAS flight needs to be approved by National Aviation Authorities (NAAs), and this process can be time consuming. Such restrictions limit the operational efficiency of MALE RPAS operations in Europe.

To overcome these issues, and regularize MALE RPAS operations in Europe, it is necessary to develop and validate a comprehensive Concept of Operations (CONOPS) to enable the safe and efficient integration of MALE RPAS into controlled and uncontrolled European airspace. To this end, NLR has partnered with General Atomics – Aeronautical Systems Inc. (GA-ASI) to:

1. Develop and test CONOPS to integrate MALE RPAS into European airspace, taking into account both nominal and non-nominal conditions
2. Provide empirical evidence to convince all relevant stakeholders that MALE RPAS operations are safe and efficient to fly in European airspace

Project partners
General Atomics - Aeronautical Systems Inc. (GA-ASI)

Start: October 2018
Duration: 2 years

WHAT?

An iterative, step-by-step, approach has been adopted for CONOPS development. The project has just completed Step 1(Q4 '18 – Q2 '19), which focused on developing procedures to mitigate several contingency scenarios that can occur in unsegregated airspace in the vicinity of a civilian airport. The considered scenarios included loss of link between the pilot and the RPAS and engine failure, amongst others. The developed procedures were tested using a real-time simulation experiment in the MRRF with real air traffic controllers, as well as real RPAS and airliner pilots. The results strongly indicate that the new procedures developed in this project make it possible for MALE RPAS to fly safely and efficiently in civil European airspace alongside other manned air traffic.

Future steps are planned to further improve the fidelity of the MALE RPAS airspace integration CONOPS. This includes testing the effectiveness of TCAS II, as well as to also consider the use of novel technologies such as Detect and Avoid (DAA). The onboard DAA radar provides RPAS pilots with additional situational awareness of the non-cooperative traffic situation around their aircraft, and it is intended to further increase the safety of RPAS operations.

Maintenance Engineering, Management and Technology (MRO)

AIRPOWER is dependent on the number of fighters, helicopters and transporters you can deploy at any time, also on short notice. It requires top-notch availability, even in peace time, because conflicts can escalate quicker than you can push aircraft in maintenance out of the hangar. If your fleet spends too much time in maintenance and if you are seeking higher availability, talk to Royal NLR with its proven track record in military aircraft Maintenance Repair and Overhaul (MRO).

NLR delivers, based on unique and high-quality knowledge, practical solutions for excellence in maintenance operations, and innovative maintenance technologies to improve availability and affordability with standard and tailored solutions for maintenance organizations, airlines and OEMs in civil and military domain. So, what can NLR do for your availability?

MAINTENANCE ENGINEERING – NLR can help you improve the effectiveness of your maintenance activities. We can help you to (i) set up reliability programs to measure your performance, and (ii) assess the effectiveness of your Aircraft Maintenance Programs. And we can help you to improve your availability by adjusting maintenance task intervals. Or we can help you improve your system reliability. NLR offers Root Cause Analyses to (i) expose the root cause, and (ii) develop practical measures to eliminate root causes. NLR performs RCAs for the RNLAF and we are successful with quick wins, constantly improving the annual availability and affordability of the RNLAF fleet.

MAINTENANCE MANAGEMENT – NLR offers you practical solutions for excellence in maintenance operations. We can help you with your regulatory processes, such as the implementation of the European Military Airworthiness Regulations or EMARs. You benefit from our civil and military expertise, opening the door to efficient and effective regulatory processes in military operations. If you want insight in the cost-effectiveness of your operations, you can evaluate your operations with our Aircraft Availability and Resource Estimator, a decision support system to evaluate your budget and resources against your on-time performance. Or if you want to maximise your availability and affordability, we can optimise your maintenance schedule by repackaging your maintenance tasks and your planning using our state-of-the-art optimisation tool FlexPlan. NLR helps the RNLAF with the implementation of EMARs and planning optimisation using FlexPlan.

MAINTENANCE TECHNOLOGY – NLR develops innovative maintenance technologies to improve availability and affordability. NLR offers a tool to determine the failure modes of components about to fail. This helps you troubleshooting problems at the line and in the backshops. Our tool Failure Diagnoses using eXplainable Artificial Intelligence or FD XAI also offers predictive capabilities, giving you indications about the remaining life of components. NLR also develops robot technologies to overcome manpower shortages. We develop robots to perform maintenance inspections, focussing on sensors and platforms for inspection purposes. For example, we currently work on a helicopter main rotor blade inspection robot. We minimise the workload of blade inspections and improve the track and balance of the blades.

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

Chromate Containing Dust Analysis

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

THE CHALLENGE

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

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

THE SOLUTION

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

WHAT DID WE DO?

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

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

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.

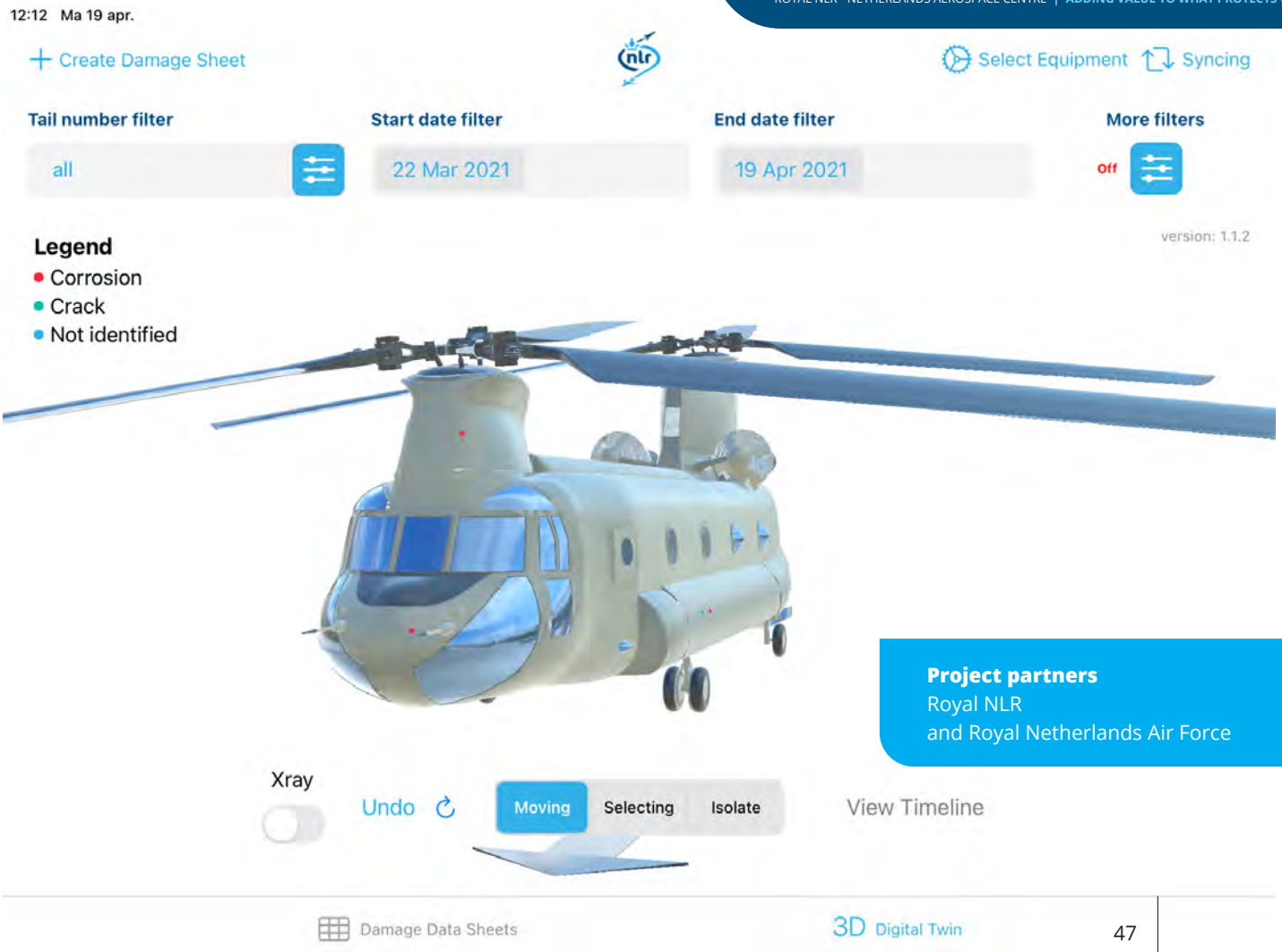
THE SOLUTION

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.

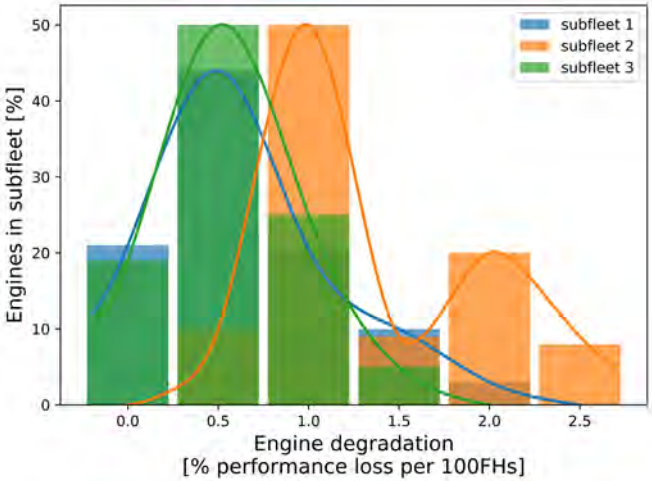
WHAT DID WE DO?

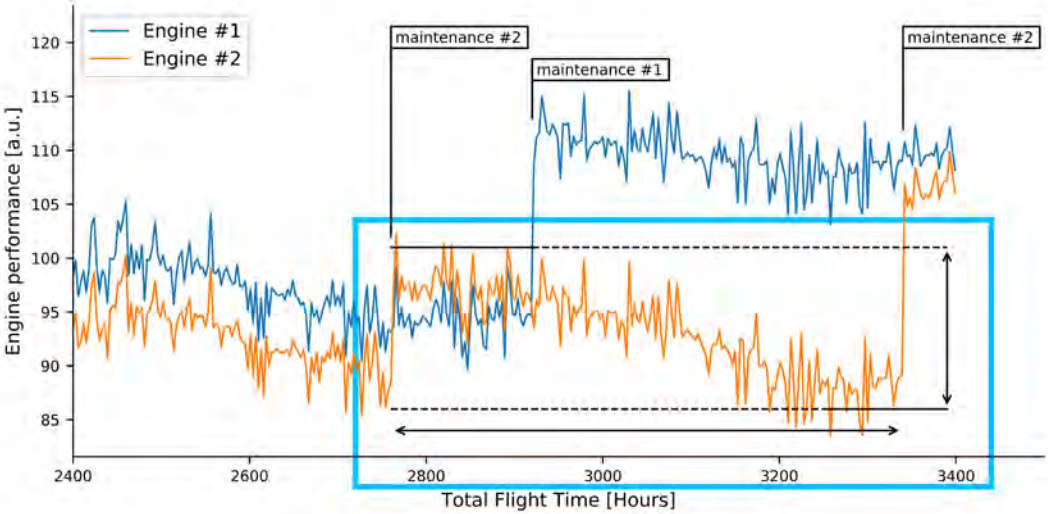
The d-CCL is an app that runs on a tablet computer and features an intuitive 3D web interface. The inspection findings can be entered either graphically, through a 3D model of the aircraft at hand, or by means of pull-down menus. The app connects to a server as soon as an internet connection is available,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



Project partners
Royal NLR
and Royal Netherlands Air Force





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).


MM-A2-6-2
MM-A2-7-2
MM-A2-9-2
MM-A2-10-2
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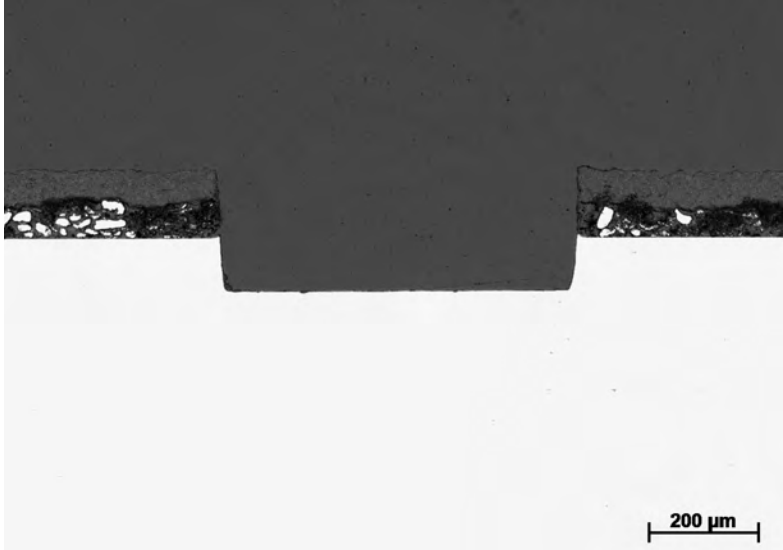
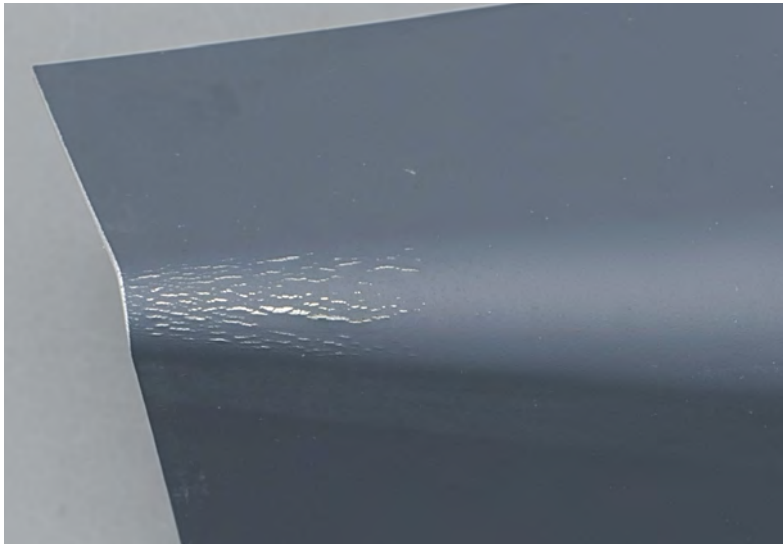

200 µm



Development of chromate free primer technology

WHY?

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.

HOW?

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.

WHAT?

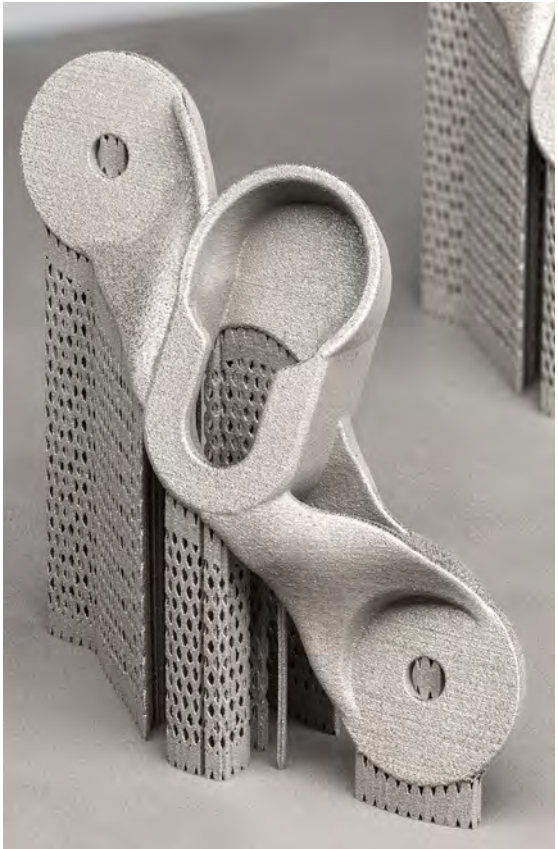
The main R&D activities of the project are:

- 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

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

Additive Manufacturing for Netherlands Royal Air Force

NLR has more than 50 years of experience of metals which is incredibly important for additive manufacturing research, together with knowledge of aircraft certification. With the increased understanding of the printing process and subsequent reproducibility, applications using metal printed parts in aircraft components are becoming feasible from an economic point of view are now much closer. Of course, you can print the same thing twelve times in one print job, then test eleven of them and put the twelfth in the aircraft. But that obviously makes the twelfth component far too expensive. You want to be able to print such a component in large numbers, be able to detect production faults, and know for certain that approved components can be fitted in the aircraft.



First for the Royal Netherlands Air Force

The first printed product in the Netherlands by metal additive manufacturing that actually flew on a helicopter at year-end 2016 was a ladder mount for the NH90 helicopter of the Royal Netherlands Air Force.

It is a coupling that is affixed to the helicopter and to which a ladder can be mounted so as to perform maintenance. Although hardly a critical part from an operational point of view, it was a good case to start with. It showed how it could be useful for an organisation like the air force. Metal additive manufacturing also raises an important logistics-critical question for the air force, namely whether on a mission you can print parts locally instead of taking them with you or having them sent out.

The 3D-printed ladder bracket is 40% lighter but stronger and more durable than the original design. 3D printing enables the Royal Netherlands Air Force to have parts produced faster, reduce maintenance costs, and at the end improve the deployability of her weapon systems. The Royal Netherlands Air Force commissioned the development of the ladder bracket. The project was a collaborative venture, with Fokker Aerostructures responsible for engineering, NLR-Netherlands Aerospace Centre for 3D printing and testing, BPO-Delft for redesign and the Defence Materiel Organisation for certification.

NLR in brief

One-stop-shop

Global player with Dutch roots

100+
Since 1919

Amsterdam, Noordwijk Marknesse, Rotterdam

Innovative, engaged and practical

For industry and government

For fixed and rotary wing

650 employees

€ 92 M turnover

72% Dutch, 22% EU and 6% international

Active in 30 countries

Extremely high client satisfaction

About NLR

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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