



THE MEASURE OF SUCCESS

MILITARY FLIGHT TESTING AT NLR



J-0666

WHO WE ARE

For nearly 90 years, the Netherlands National Aerospace Laboratory, or NLR, has driven applied research in aeronautics and space at a world-class level, setting the pace for the transition of technology from the human mind and test environment to the real world. NLR is a non-profit organisation whose mission is to make aviation and space transport safer and more efficient while providing its customers with objective, independent analysis and metrics for better-informed decision-making.

Over the decades, NLR has proven many times over that it possesses a unique expertise for solving the varied challenges of powered flight. It holds an unsurpassed body of knowledge, both institutionally and in personnel, that meets and exceeds the demands of its customers. As a result of NLR endeavours, aircraft are safer and more efficient, and pilots better-trained.

NLR is a partner of choice for research as well as direct support to aircraft manufacturing industries and operators. Its 700 employees, working in fields as diverse as mathematics, physics, and psychology are dedicated to helping boost innovation in both the civil and military sectors, from private companies to government ministries.

Never content to dwell on the theoretical, NLR has consistently focussed on problem solving for the real world by carrying out demand-driven research. Seventy-five percent of the institute's turnover is derived from contract work.

NLR manages a wealth of specialised facilities to carry out its work, from state-of-the-art flight simulators to wind tunnels and avionics and aircraft instrumentation design and manufacturing facilities, all supported by a powerful computer infrastructure.

This publication seeks to explain just one area of expertise at NLR: military flight testing and operational test and evaluation. It is a field of work that is "mission critical" for the Royal Netherlands Air Force (RNLAf) and the Royal Netherlands Navy (RNLN); aimed at saving lives, obtaining the most from the air fleet, and delivering the greatest value for money to the nation's taxpayers.

The future is a collaborative one and NLR is also well-placed to leverage technical cooperation both in Europe and across the globe. Whether it is a matter of teaming with government or industry, NLR stands ready to deliver objective, independent advice and innovative science and technology for a rapidly changing world.



Dedicated to innovation in aerospace



THE MEASURE OF SUCCESS

MILITARY FLIGHT TESTING AT NLR





THE REASON WHY

When we started working on this publication we had many visions of how we could communicate just what NLR has accomplished, and continues to accomplish, in flight testing. We are proud of our achievements and of our deep cooperation with the Royal Netherlands Air Force yet the challenge really lies in explaining what is essentially a highly technical subject. We believe we've reached a healthy compromise in the work you now hold. You'll find we tell our story through examples and anecdotes of the many projects we've been involved with over the years. The professional reader too will be able to understand the complexity of the actual activities.

At its core, this is a story about teamwork. NLR brings together professionals from a wide array of specialisations from aerodynamics to human psychology. All of them work to bring a project to fruition while meeting the everyday engineering challenges and technological pitfalls. But the teamwork is not solely a matter of internal organisation. NLR's chief partner throughout its existence, the Netherlands Ministry of Defence and especially the Royal Netherlands Air Force (RNLAf) and the Royal Netherlands Navy (RNLN), has been more than just a "customer". It has been an integral part of NLR's success story, its personnel working side by side with Defence engineers and technicians to find solutions.

Our chief purpose in writing this brochure is to tell this story of effective teamwork and to illustrate the unique expertise NLR possesses in the field of military flight test. Goal driven, budget conscious, and capable of delivering tailored solutions, NLR continues to innovate. The result: safer flight, extended fleet life, and mission success. It is a formula that can be replicated for many customers at home and abroad and we welcome the opportunity to help you solve your future challenges. Just contact us.

Amsterdam, September 2008



CONTENTS

1	Introduction	6
	Flight testing: It's not what you think	6
	Milestones	8
2	Measure to understand	10
	F-16 Orange Jumper: Dressed for the test	10
	Generic systems: One size fits all	12
	The civil side	14
	Good and bad vibrations	16
	Life savers: Systems for condition monitoring	17
3	Innovation on demand	20
	Providing capability enhancements	20
	Going it alone	20
	The historical role of aircraft: Reconnaissance	22
	Closing the loop	24
	From all-weather day to night fighter	26
	External stores separation	28
	Facing the unexpected	30
	Mating ships and helicopters	32
	Transports with a bite	35
4	A partner for progress	36
	Pushing the envelope	36
	Minding your own business	36
	New wine into old bottles	38
	Countering virtual threats	39
	Supporting industry	40
	Electronic Warfare: Protect & survive	42
5	NLR: A partner for your future	44

INTRODUCTION

FLIGHT TESTING: IT'S NOT WHAT YOU THINK

Mention “flight testing” and it conjures images of leather-jacketed pilots, steely-eyed and full of daring, climbing into unproven experimental aeroplanes and ready to break the sound barrier. But this stereotype is really only just part of the story. The reality is that there are different kinds of flight testing, each with a distinct purpose.

Experimental test flight has traditionally garnered the most public attention, going back to the early history of flight and at its most flamboyant with Howard Hughes in the 1930s and 40s. No matter how good a job a design engineer has done, it has taken a human pilot to prove whether a craft can actually fly and land again. But this is not where flight testing finishes. For military applications in particular, flight testing goes on for as long as an aircraft type remains in service. Every time an aircraft is modified, inside or out, it must face *airworthiness* and *operational* flight tests to demonstrate that it still meets the stringent safety standards as well as the user requirements.

While it may lack the derring-do of Chuck Yeager or Scott Crossfield, airworthiness testing, Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E), are a vital element of an Air Force's business. This very specialised flight testing has been a part of NLR's core mission from the very beginning. NLR assisted Fokker Aircraft in the testing of its early wooden-wing monoplanes, the F.II and F.VIIA in the 1920s and 1930s; and maintained this partnership with all Fokker's aircraft until the company's demise in 1996. In terms of military flight testing, the main subject of this brochure, NLR began assisting the Royal Netherlands Air Force (RNLAF) in its modification and upgrade projects back in the 1960s. In the process an outstanding domestic capability was created that included fully instrumented aircraft, trained flight test pilots and engineers.

So what does airworthiness and operational flight testing entail? Every time the avionics systems or aircraft software are changed, a new radar installed, or a new bomb rack, targeting pod, or fuel tank suspended on the aircraft, it is imperative that the aircraft be evaluated for changes that could affect aerodynamics, structural stability and performance: its *airworthiness*. It's a fundamental question of safety for pilots and people on the ground.



Moreover, military “operational” effectiveness must be demonstrated as well. Such evaluations show that modifications meet the functional and performance requirements of the user. To accomplish both aims requires precise measurements of minute changes in the behaviour of the aircraft and the airframe itself. This requires a test aircraft fully instrumented with special equipment to detect and record any changes in flight performance, military effectiveness and structural stresses. It’s precise, demanding work requiring state-of-the-art equipment and data handling facilities and the analytical skill and dedication of both hardware and software engineers.

The benefit? Having a domestic capability to test means that the RNLAf does not have to rely solely on an aircraft manufacturer for vital data or support. Such an independent voice also means that the Air Force can undertake modifications itself with NLR’s support and keep upgrade options open for the future. No one knows the environment and operational requirements better than the operator himself. There is a clear cost benefit as well—NLR can assure the government (and taxpayer) that it is getting the capability and equipment that the nation has invested its money in.

Over the years, NLR has helped the Air Force to develop and field a series of dedicated test aircraft, fully instrumented, to proof new avionics systems and aircraft-weapon configurations or to demonstrate new or expended operational capabilities. This is a technical treasure that few European air forces can boast, a near unique capability to objectively measure performance and physical condition for the life of a jet fighter, helicopter, or transport aircraft. And while air force personnel often rotate within or out of the service after just a few years, NLR’s intellectual talent has remained intact, thus ensuring an institutional memory in all its work.

The following pages testify to the valuable contribution that NLR’s flight testing programmes have made to aeronautics in the Netherlands and beyond.



Chuck Yeager in front of the Bell X-1



Lieutenant Colonel Tjebbe “Speedy” Haringa
the RNLAf’s Chief Test Pilot

MILESTONES



SHOL (Ship Helicopter Operating Limits)

1964



F-104 Starfighter

New weapons for F-104

1968



Orpheus

Introduction of the Orpheus reconnaissance camera pod on F-104

1975



TERPROM

Introduction Terrain Navigation system (*night vision*) on F-16

1984



1986



NF-5

Foundation of the flight test group NF-5 and instrumentation of the K-3001

Orange Jumper

First Orange Jumper F-16 fully instrumented test aircraft

Multi-national Operational Test & Evaluation

MOT&E programme: test programme F-16



Lantirn

Certification
targeting pod

1995

2000

Embedded Training

Live demonstration on F-16
of virtual training system

2003

2007

GIS

Generic Instrumentation
System for transport aircraft
and helicopters

2008

20XX

Introduction
replacement F-16

20XX



MARS

Introduction camera
reconnaissance pod F-16



RecceLite

Reconnaissance system
F-16: pod certification
and ground station
development



Heli Ship

Future helicopter-ship
qualification tests for
NH90 and Chinook



MEASURE TO UNDERSTAND

F-16 ORANGE JUMPER: DRESSED FOR THE TEST

The RNLAF is in the privileged position of having its very own dedicated F-16 test aircraft -- a two-seater known as "Orange Jumper". "Orange" because it is equipped with test flight equipment and wiring which is traditionally painted orange, and "Jumper" because the test equipment is installed inside the existing architecture and as such has "jumped" into the system. Although there are other F-16 test aircraft elsewhere, Orange Jumper is unique, thanks to the additional capability the extra seat offers and the fact that it is also an operational aircraft, used for training duties by 323 Tactical Training, Evaluation and Standardisation Squadron (TACTESS) at Leeuwarden Air Force Base when it is not involved in test flying. The aircraft is easy to spot as it sports a jumping orange kangaroo on its vertical tail plane.

Its origins go back to 1983 when the RNLAF contracted NLR to design, build and install a data acquisition system in one of their F-16As to help develop and introduce new combat tactics, as well as for certifying new equipment. Having installed the equipment in a single-seater it was later decided that a two-seat F-16B model (tailnumber J-653) better suited the requirements of the RNLAF. The current Orange Jumper (J-066) was chosen when the RNLAF decided to instrument an F-16 MLU (Mid-Life Update) standard aircraft with a whole new data acquisition system.

The flight testing is very much a team effort between the pilot and the Flight Test Engineer (FTE) in the back seat. The back-seater takes an active part in the process, using his own NLR-designed onboard computer display system to monitor the progress of the test flight and make sure that everything is being recorded. He is also able to send the same computer page





he is looking at to the pilot's display so that they can both see the same data at the same time and decide on the best course of action. The high costs of flight testing are such that every flight must achieve its objectives. Follow-on flights to gather data missed on the initial one are no longer an option.

Recorded data can be processed by the RNLAf or NLR, using a ground station, immediately after the test flight for "quick-look" purposes. The detailed in-depth analysis of performance, structure and system data is performed at and by NLR using its flight test data archiving and processing facility and analytical tools.

INSTRUMENTING TEST AIRCRAFT

Flight testing requires an instrumented test aircraft. Instrumenting an aircraft requires understanding of the aircraft and its systems, the ability to design specific electronic interfaces to monitor aircraft systems, and the ability to install sensors on an aircraft to collect data and record what is happening during flight. Analysing the data requires the expertise to understand what those sensors are trying to tell you.

Flight test sensors record exactly where the aircraft is at any given time, how fast it is flying, how much vibration there is at specific positions across the aircraft, what happens when you drop something off the aircraft and how much stress is caused by bolting things onto it. Individually, they're an assortment of high-speed cameras, video recorders, accelerometers, strain gauges and data acquisition devices. Vital to the process of flight test sensor data gathering is the data acquisition and recording system to collect and store the data. Space has to be found for these additional systems and the cabling that is used to connect it all together. Modern fast-jets, designed to put the maximum amount of capability into the minimum amount of space, make this an extremely intricate, complex and sometimes frustrating task. Moreover, at all times it has to be assured that the installed instrumentation is safe in itself, that it does not interfere with the aircraft systems and that it keeps functioning in the adverse environmental conditions in the aircraft.

MEASURE TO UNDERSTAND

GENERIC SYSTEMS: ONE SIZE FITS ALL

The RNLAf and RNLN helicopter fleets are much smaller than the F-16 fleet and it is not possible to have a dedicated test aircraft like the Orange Jumper for each of the helicopter types: Apache, Chinook, Cougar, Lynx and NH90. However, these aircraft frequently undergo modification work to increase survivability, enhance capability or expand their operational limits. Operations in Afghanistan and Iraq have made it even more important that a test capability exists for these aircraft so that problems encountered in the field can be flight tested and resolved as quickly as possible.

Up until recently, whenever a test programme was requested for helicopters or transport aircraft, a tailored set of instruments was put together for that individual project alone. This was recognised to be a costly and inefficient way of doing business. To save money, NLR was contracted to come up with a Generic Instrumentation System (GIS), which could be used on *all* Dutch military helicopters and fixed-wing transport aircraft. The solution is a unique and extraordinary product. It meets all of the RNLAf's requirements and can be rapidly installed and uninstalled. According to Ger Belgraver, Senior R&D Manager in NLR's Flight Test Systems and Applications Department, "It can be easily taken on and off each aircraft. In the Apache it is installed in the tail storage bay with a remote control unit in the cockpit. In the larger aircraft it goes in the main cabin and can be operated from there."

The RNLAf asked for it to be simple enough for them to use by themselves without the need for NLR back-up. This has been accomplished with a result that the engineers can run a whole spectrum of tests on their aircraft without having to involve anyone else, thereby avoiding additional delay and extra strain on already tight budgets. Captain Henno Gemmink, an RNLAf helicopter Flight Test Engineer explains, "The Generic Instrumentation System is a standard modification work package and





every RNLAf helicopter technician can put it in the aircraft himself without the help of NLR. That was the original idea—we had to keep it simple.” NLR experts are still on hand for more complicated evaluations, which require specialist knowledge, such as measuring structural loads and for Electronic Warfare (EW) testing.

Over the last two years GIS has been used for measurements to quantify the installation of the Apache Modular Aircraft Self-protection Equipment (AMASE) on the AH-64 stub wings. After initial structural load testing, this resulted in the successful integration trials of a Directional Infra Red Counter Measures (DIRCM) subsystem on the AMASE pod in the spring of 2007. After completing the Apache trials, the system was reconfigured for load measurements on the Chinook CH-47D for the installation of a similar pod on this helicopter.

An example of the quick deployability of the GIS was demonstrated when there were engine problems with several Apache helicopters in Italy. The mission for crew training in mountainous areas was aborted and an investigation was started to identify the problem. Within days after the request for assistance, the GIS was configured and installed in the aircraft, ready for the tests. Soon the problem was attributed to fuel contamination and the test programme was cancelled, saving time and money.

MEASURE TO UNDERSTAND

THE CIVIL SIDE

Walking the corridor to the room of the NLR director you will see many pictures of all kinds of aircraft. This gallery ranges from a very old Fokker F.II (1920-1936) to a Cessna Citation II (1993-present). All these aircraft share a common link: they have been used by NLR for research on aerodynamics, flight handling, airworthiness, flight procedures and new avionics. In between this series you will find the Hawker Hunter, the only military test aircraft owned by NLR. In the corridor you will also find relics of historical flight test instrumentation that testify to the real synergy from the development of flight test systems for military and civil use.

After the Second World War NLR restarted the civil flight test work with a Siebel 204 donated in 1946 by His Royal Highness Prince Bernard of the Netherlands. At the same time the Fokker Aircraft Company started the development and production of larger passenger aircraft like the Fokker 27 and later the Fokker 28. Prototype testing of Fokker aircraft required many hours of flight testing. Many thousands of different parameters had to be recorded for final analysis by the specialist designers on the ground. Vibrations, forces, accelerations, pressures, angles, velocities, flow and many other physical quantities had to be measured accurately, often hundreds or thousands times a second. For these aircraft NLR developed new digital acquisition and recording techniques to assist Fokker with their flight test programmes. With this new technology and the ever increasing computer power for data processing and analysis it became possible to dramatically increase the number of parameters to be measured and to present results in real-time.



The NLR flight test instrumentation (FTI) and data acquisition systems were used for the Fokker F27, the F28, the Fokker 50, 60, 70 and 100 aircraft. High reliability figures were a must, the flight test data for no more than one out of every 1000 flight hours was allowed to be lost due to malfunctioning of the FTI system. NLR's systems easily met that requirement. Special instrumentation and data analysis systems were designed for the Automatic Landing System tests of the Fokker 100. The accuracies of the aircraft trajectory measurements had to be in the 15 cm class in all three dimensions. And, remember this was in an era before GPS/Galileo.



Many civil flight test programmes have been executed with the involvement of NLR employees. After the demise of Fokker in 1996 the NLR civil flight test activities were limited to its own research aircraft. Presently NLR operates a twin turboprop, the Fairchild Metro II, and a twin engine business jet, the Cessna Citation II. These aircraft are primarily used for the development and operational test of new flight test systems and flight test (measurement) methods to be used on for example Airbus aircraft. A recent example is the development of a wing distortion measurement method using the Image Pattern Correlation Technique that delivers remarkable accuracies of 0.2 mm.

The role of these aircraft as a means to conduct experimental tests for new Air Traffic Management (ATM) procedures and systems becomes ever more important. Modern ATM concepts, data links and satellite navigation and guidance display concepts are thus better evaluated. A good example is the Continuous Descent Approach. This procedure contributes to the reduction of noise around airports and is now implemented as a standard approach procedure at Amsterdam Airport Schiphol at night. The CDA concept has gone through a series tests in flight simulators and research aircraft.

MEASURE TO UNDERSTAND

GOOD AND BAD VIBRATIONS

It's a given for military forces in the current age: aircraft fleets need to stay in service longer and the days of rapid equipment replacement are long over. Understanding how to operate and monitor aging fighters, transports, and helicopters has therefore become increasingly crucial to customers around the world.

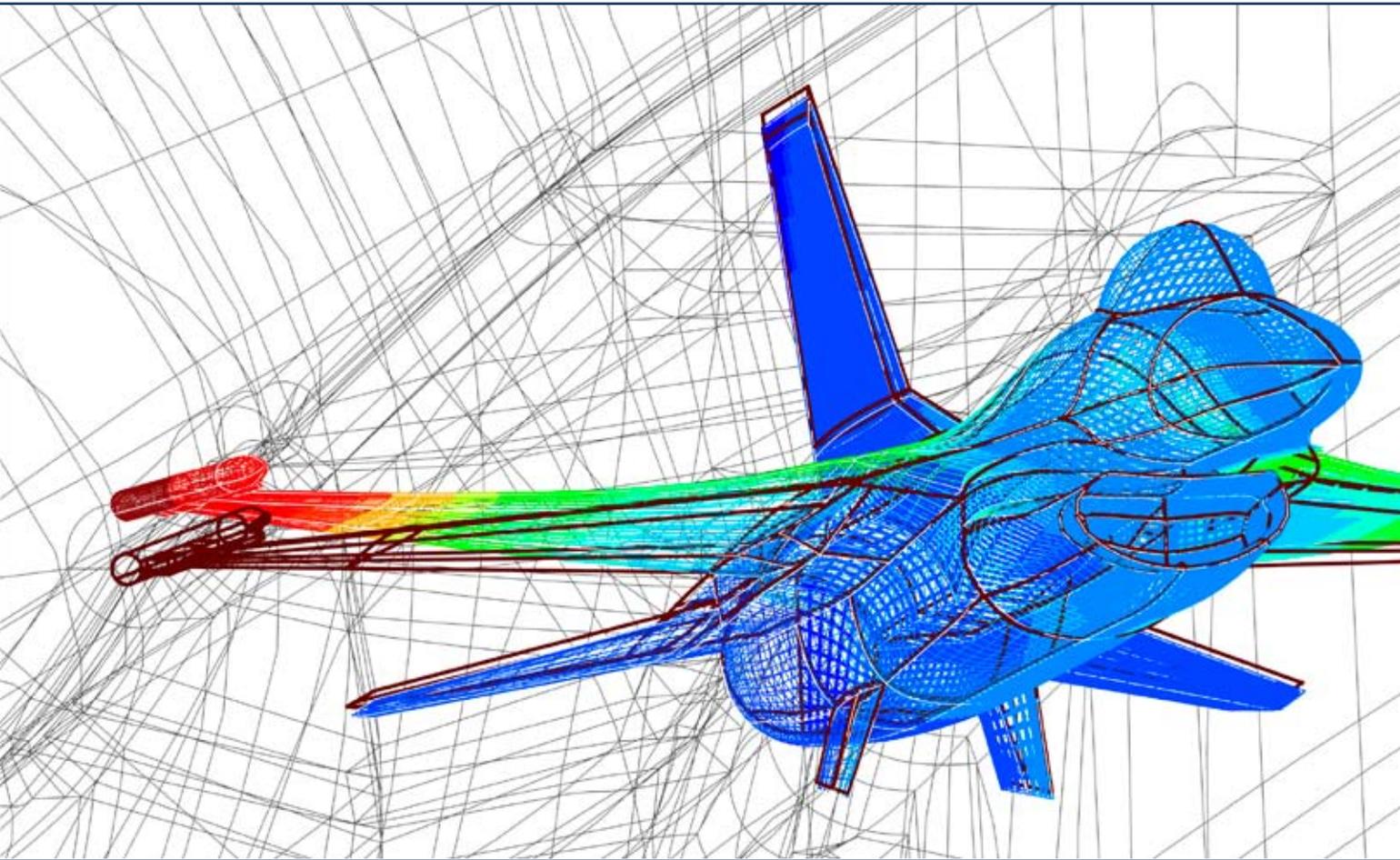
NLR began work in this area when it assisted the Royal Netherlands Air Force in the 1970s on how to accurately determine wing-loading on fighters and how to measure Limit Cycle Oscillation (LCO), to prevent the aircraft from entering the fatal wing flutter area. Bart Eussen, Senior R&D Manager in NLR's Flight Physics and Loads Department: "Any wing in an airflow will warp and move as the aircraft flies, it is normal behaviour of the wing. The question is, just how much can be tolerated given changes in manoeuvring and with stores that are hanging from underneath the wings." Given certain conditions, the aircraft in flight reaches a crossover point where it becomes unstable and enters LCO. These are obvious concerns in aircraft design, concerns that continue to be important whenever an aircraft configuration is changed throughout its service life.

NLR began "flutter" trials on an F-5A that had been instrumented with strain gauges to measure and record minute flexing action in the wings, the data tapes later being analysed by computers and engineers. With the arrival of the F-16 Orange Jumper test aircraft, similar gauges were employed to measure LCO characteristics. The main goal of this work was to educate pilots as to the risks when flying, and several simulation tools were developed to predict and analyse wing-bending before test flights were undertaken.



Over the years, NLR's expertise has grown and its techniques have increased in sophistication. For example, NLR has developed its own unique "speckle" and "stripe" paint patterns to put on the outer wings of its test aircraft. Using image pattern correlation techniques, the wing is imaged in flight with a high-resolution digital camera system and later analysed to detect wing deformation under different stresses. This new method is an improvement over earlier methods as it provides continuous and contiguous results over the whole covered area and provides higher levels of measurement accuracy.

NLR's in-house knowledge is valued beyond the Netherlands: the international Eurofighter consortium has utilised NLR's models and systems during the development of the new fighter to test aeroelastic characteristics. Extending beyond measuring wing stresses, NLR has developed a full-range of tools and techniques to measure the structural health of aircraft



from the time they enter service until they end their operational lives. Such load and usage monitoring is necessary not just for flight safety, but to gain maximum value from assets that must remain in service for decades.

LIFE SAVERS: SYSTEMS FOR CONDITION MONITORING

“The world is hungry for structural health and usage monitoring and fleet life-management,” says Marcel Bos, Senior R&D Manager in NLR’s Gas Turbine and Structural Integrity Department. Real life operations naturally lead to aging of an aircraft (corrosion, humidity, mechanical loading leading to fatigue damage, etc) and operators need to know not just operational limitations, but when periodic inspections, replacements, and modifications should be undertaken to preserve the life of the aircraft—and hopefully extend it. NLR is at the forefront of providing its many customers with tools and procedures to wring maximum value from expensive equipment. Some of these are stand-alone systems that the operator can manage himself while others can be totally contracted out to NLR to conduct analysis. The NLR “toolbox” contains software packages developed in-house, onboard instrumentation sensors for aircraft, data recording units, and web-based reporting and visualisation.

Every single F-16 fighter in the Netherlands, Belgian and Chilean Air Forces has permanent strain gauges installed by NLR to monitor usage. When the unexpected is discovered, NLR is often brought in to troubleshoot a situation.

MEASURE TO UNDERSTAND

As Lex ten Have (Senior R&D Manager in NLR's Gas Turbine and Structural Integrity Department) points out, "various innovative NLR Health and Usage Monitoring System [HUMS] applications are in service with customers around the world, often with elaborate names like SALSA, AIDA, RAVIOLI, and FACE." Often, NLR systems can improve upon embedded systems provided by the aircraft manufacturer. In both the fixed-wing and rotor world, NLR has assisted not only the RNLAf but also the air forces of Belgium, Chile, Germany, Norway, Portugal, and Spain. It has also worked with US and German naval aviation, the US Army, and Canadian Forces. Besides the universal F-16, NLR has serviced the C-130 Hercules, P-3 Orion, PC-7, and KDC-10 fixed-wing aircraft. It has been involved with many helicopter types including the Apache, Chinook, Alouette, Cougar, as well as the Lynx. In the coming years, NLR will have major involvement with the NH90 and the successor aircraft of the F-16.

The true value of NLR's contribution to HUMS is not just in providing the military operator a set of hardware or software tools, it is in the *analysis* that it can provide an operator. For example, its independently developed Flight Regime Recognition capabilities can couple strain measurements to provide a picture of the actual flight profile for different types of operations and utilisation modes. The lesson is that through such work, the customer becomes empowered by the knowledge. This helps to better communicate with the aircraft manufacturer in perhaps leading to adaptations in its operational procedures.





Products such as AIDA (Aircraft Integrated Data Analysis), installed fleetwide in RNLN Lynx helicopters, will objectively establish just how much service life remains to these aircraft. As Ten Have points out, NLR has already discovered that Netherlands Navy Lynx engine usage is 50 percent less severe than previously estimated by the engine manufacturer. This revelation resulted in significantly longer on-aircraft periods of critical and expensive engine components, such as the gas generator. NLR tools and techniques continue to give fleet operators the knowledge they need on failure modes and the modelling for prognostic capabilities to offset these. "Our armed forces are smart operators," says Bos. "It benefits from the efforts and investments in terms of safety, economy, and increased levels of readiness." In today's financially constrained armed forces, it's a result that can be seen on the bottom line.

INNOVATION ON DEMAND

PROVIDING CAPABILITY ENHANCEMENTS

Military forces must be able to change tactics and adopt new strategies as the times dictate. Political requirements can demand fundamental changes to equipment as threat levels vary. Technological advances must also be countered, either with new equipment, enhanced hardware or different tactical deployment strategies. NLR has been assisting the RNLAf and partner air forces tackle these challenges for more than four decades.

In the late 1960s, the RNLAf suddenly found itself with a huge challenge. The RNLAf was asked to employ a flexible approach whereby initial attacks with its F-104 Starfighter fleet would be made with conventional rather than nuclear weapons. However, Dutch F-104Gs were not then certified to drop conventional weapons. NLR was therefore tasked, in 1968, with getting these bombs onto the fleet and it was this requirement that kick-started NLR's fighter aircraft weapons configurations qualification work with the RNLAf. "Every time you hang something new on an aircraft," says Gerard Alders (NLR Test Engineer, retired), "it has to be re-certified." Expanding the capability of an aircraft takes time, money and expertise. Time and money are relatively simple to obtain but the expertise is extremely hard to come by and preserve.

NLR successfully carried out a series of test flight programmes to enable the F-104G to carry the new weapons fit, having first fitted the required instrumentation to the aircraft. A major constraint was, however, that whenever an RNLAf Starfighter was borrowed for test flights it had to be stripped of its instrumentation by the end of the day so that it could, once again, be considered ready for action. Struggling with this restriction dictated how NLR approached its next major capability enhancement challenge.

GOING IT ALONE

Having built up a significant expertise in certifying weapons upgrades for the Air Force, NLR was asked to support the introduction of the NF-5 Freedom Fighter. This customised variant of the F-5 was chosen because of its strengthened wing, which could carry additional fuel tanks and weapon stores, enabling pilots to attack targets deep in Warsaw Pact territory. Confident that it would be able to configure the aircraft according to its own requirements, the RNLAf only asked for five basic configurations to be certified by the manufacturer, as it intended to work alongside NLR on the rest. The immense scale of the work that the RNLAf intended to carry out persuaded the Air Force to purchase a test aircraft from Canadair/Northrop as well. This became the RNLAf's first dedicated test aircraft and was used to work out how to implement the best weapons configurations and to make sure they could be safely deployed.

Alders recalls, "We had a number of people who went to Northrop for about six months to familiarise themselves with the aircraft and take part in the initial flight test programme, which started in California before moving to Cold Lake in Canada. We used these tests to get information on bombing tables and to calibrate aircraft angle-of-attack for bomb drops." Once this was completed the flight tests were moved to the Netherlands, in 1971.

The test programme was so successful that NLR was able to identify and correct one or two inaccuracies in the original manuals. There was a greater significance to this work however, as Alders explains. "We did the full package, the testing, the analysis -- everything. All the capabilities, which were generated through the programmes on the NF-5, were the basis for all future programmes in terms of weapons separation and safe carriage."

Moreover, much of the findings gained from this work were fed back into the F-5 community in order to assist partners like the Canadian, Norwegian and Greek Air Forces. Not only that, when the US set up the Seek Eagle programme at Eglin Air Force Base, they copied many of the methods NLR had developed for studying aero-elasticity (how the aircraft vibrates in flight) and, according to Alders, "They also used the calculation methods that we had developed for calculating airflows around the NF-5, to help with the design of the F-16." This was to prove extremely beneficial to the RNLAF later, when they selected the F-16, as they were also supplied with a lot of additional information about the aircraft on the back of earlier collaborations.

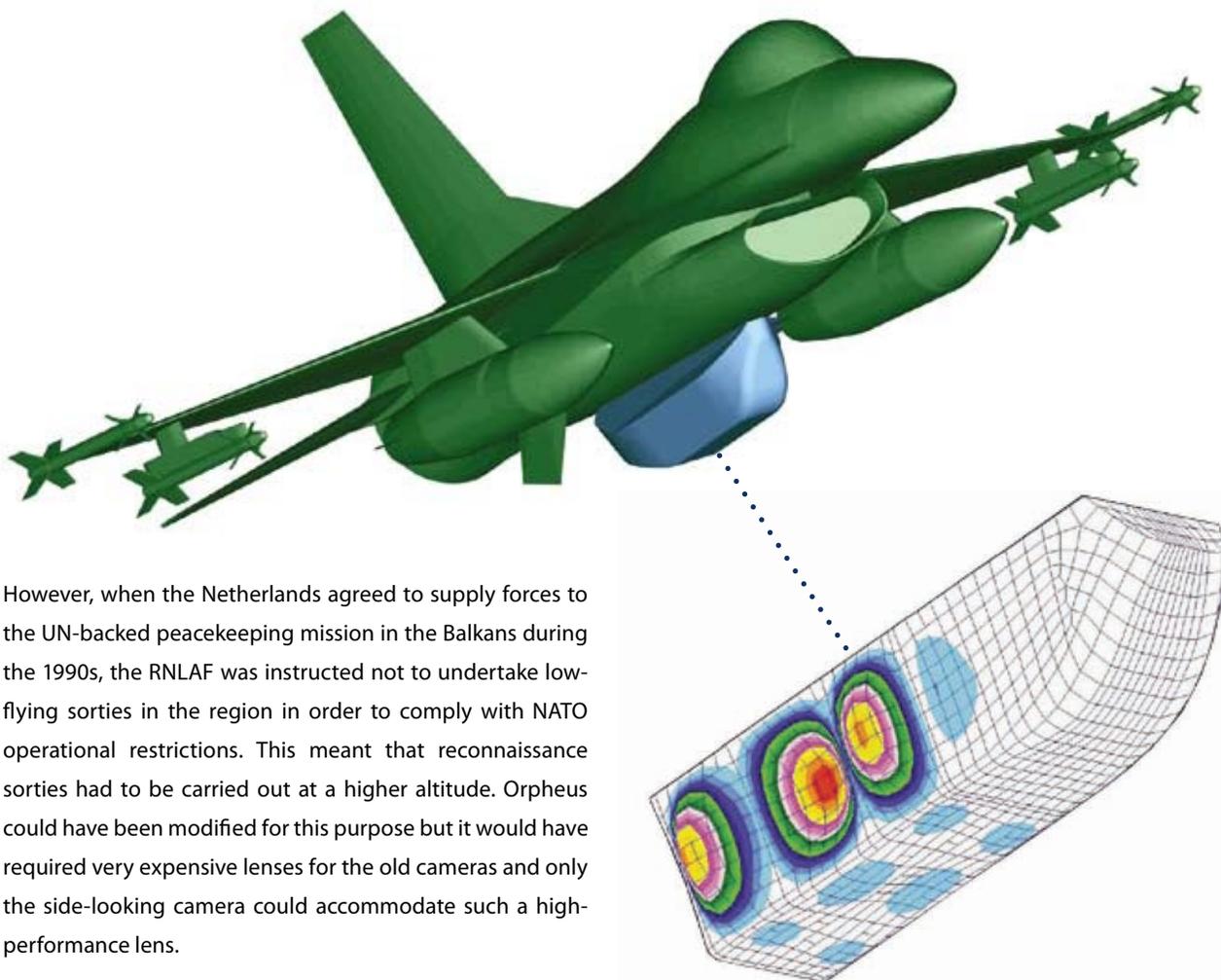


INNOVATION ON DEMAND

THE HISTORICAL ROLE OF AIRCRAFT: RECONNAISSANCE

When the RNLAF procured the F-104G they decided not to use the reconnaissance version's camera system. Instead, they set about developing a custom reconnaissance pod to suit their more demanding requirements. Accordingly, a team was put together consisting of Fokker (now Stork), Oldelft and NLR. Fokker supplied the pod, Oldelft the cameras and NLR coordinated the programme for the RNLAF, and certified the pod for use on the aircraft. The system, called Orpheus, after the Greek hero - a skilled interpreter of signs and omens - contained five wet film cameras and an infrared linescanner designed specifically for high-speed low-altitude reconnaissance. The technical expertise gained from this work remains at NLR and proved invaluable over a decade later when the RNLAF became involved in the peacekeeping missions in Bosnia.

After the F-104G was withdrawn from service and replaced by the F-16 the Orpheus pod proved so good at its job that it was decided to put it on the F-16. NLR carried out the flight tests to enable this and, later on, helped to ensure that the system could be retained on the F-16 Mid-Life Update (MLU) standard.



However, when the Netherlands agreed to supply forces to the UN-backed peacekeeping mission in the Balkans during the 1990s, the RNLAF was instructed not to undertake low-flying sorties in the region in order to comply with NATO operational restrictions. This meant that reconnaissance sorties had to be carried out at a higher altitude. Orpheus could have been modified for this purpose but it would have required very expensive lenses for the old cameras and only the side-looking camera could accommodate such a high-performance lens.



Result of First Flight with Digital IRLS Orpheus 3-10-2000 Altitude 1000 ft speed 450 kt

Again, rather than go out and buy 'off-the-shelf' equipment to replace Orpheus, the RNLAf created another team in 1995 to build yet another reconnaissance system, the Medium Altitude Reconnaissance System (MARS). NLR worked with the US camera company, Recon Optical, and the Danish pod manufacturer, Per Udsen (now part of TERMA), to get the system designed, built, installed on the aircraft and fully tested in as short a time as possible.

Creating MARS used a broad spectrum of the talents at NLR. The computer system was designed at NLR and as Pieter Hollestelle, Senior R&D Manager in NLR's Flight Test Systems and Applications Department, says, "Our knowledge of the F-16 proved vital as the F-16's own systems were used to control the new unit." NLR also designed the entire electrical system as well as the connections between the cameras and the management system and between the management system and the aircraft itself. Software engineers from the Flight Test Department wrote the code. Once the system had been built, it had to be tested and so NLR experts began the process of planning the test programme with the suppliers and the air force. Then a series of extensive trials were done on the ground to make sure it was safe to test the system on the F-16. Hollestelle remembers the process very well, "The first flight test went very smoothly. The pod was already designed for potential use on the F-16 which helped." He goes on, "You still have to verify that everything that has been installed onto the aircraft is behaving exactly as described in the aircraft's interface documents." Eventually, the system was ready to go into operation in just under a year, representing an astonishing achievement for all involved.

INNOVATION ON DEMAND

CLOSING THE LOOP

NLR maintains its support to the RNLAf's fast-jet reconnaissance capability by assisting in the programme to replace MARS in anticipation for its eventual withdrawal, which began in 2007. This time however, NLR did not provide a custom-built system; instead it supported the air force throughout the selection and procurement process of the Rafael RecceLite pod. Again, timelines are tight; having signed the procurement contract in November 2005, the intention is to have RecceLite installed and operational by the end of 2008.

To do this NLR has had to apply their skills not just to the airborne element of the pod-mounted system, but also to the associated ground station. As Piet Hoogeboom, Senior R&D Manager in NLR's Military Operations Research Department, is quick to point out, "It is one thing getting something technically correct but it is more important to make sure that you are helping to deliver proper and timely combat information to the frontline." This is where a less well known aspect of NLR's capabilities came in. Besides improving handling of the RecceLite pod, NLR technicians helped to reconfigure the Rafael ground stations to optimise the data analysis workflow and information throughput, in-line with NATO procedures and data dissemination protocols. Another crucial element of this programme was securing the used data link, including programming by NLR of the encryption algorithms and implementation of dedicated keyloaders.



INNOVATION ON DEMAND

FROM ALL-WEATHER DAY TO NIGHT FIGHTER

Low-flight at night is a particularly taxing and potentially dangerous form of flying, and when it was first proposed for NATO Air Forces, the idea was not met with universal approval. The job of convincing the RNLAf that this tactic should be incorporated into their operational capabilities fell to the now retired Major-General and former Test Pilot Tom Bakker. He was certain that it was feasible to fly fast-jets at night using the same contour-hugging techniques, which were standard practice for avoiding detection during the day. However as he insisted at the time, "It is a doable job, but there are constraints. If you want to do this, you have to invest in the proper equipment. If you are not prepared to, you should not go ahead."

Therefore, in 1986, the RNLAf decided to procure the British TERPROM digital terrain guidance system for their F-16 aircraft. Although perceived wisdom was that you should not touch the internal workings of the F-16, true to the Dutch spirit of innovation, NLR came up with the idea of installing TERPROM as a stand-alone system on the aircraft, but interfaced with the F-16's multiplex data bus (Mux bus) so that it could connect to the embedded Inertial Navigation System (INS). Once installed and working, the system was painstakingly tested by NLR, using the Orpheus reconnaissance pod to verify its navigational accuracy.

This was a ground-breaking programme in many ways. It showed that an independent body could work with aircraft and component manufacturers to install equipment on the F-16. As Bakker points out, "We were the first to fly a non-standard system on an F-16, something, which even today is not a normal thing." It also created excitement amongst the worldwide F-16 operators with NLR test data widely distributed throughout the community. Furthermore, it helped to establish the RNLAf as a leading proponent of low-level flying at night.





INNOVATION ON DEMAND

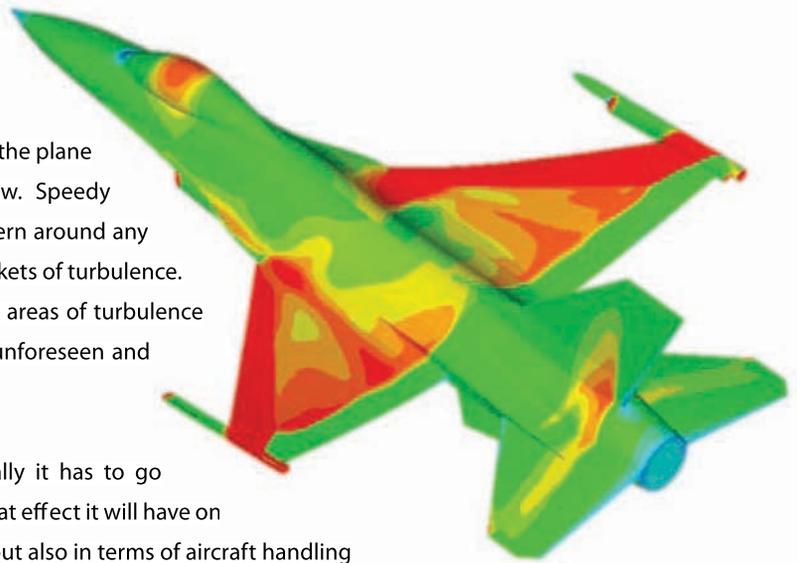
EXTERNAL STORES SEPARATION

"A big difference between civil and military flight testing is that we drop things from our aircraft," says Lieutenant Colonel Tjebbe "Speedy" Haringa, the RNLAF's Chief Test Pilot.

The underside of a military fast jet is not as sleek and smooth as the top. It is generally covered with an assortment of antennae, bombs, fins, fuel tanks, missiles, pods and rockets, closely huddling together. Apart from those bits which are permanently fixed to the aircraft, the rest can be dropped or jettisoned. It has to be assured however, that the separation does not result in damage to the aircraft or other stores. In military parlance, this is known as safe separation.



The addition of a new object to the underside of the plane can create unexpected changes to the airflow. Speedy explains, "It is a bit of a 'black art'. The flow pattern around any aircraft is very complex, with numerous little pockets of turbulence. It all depends on the interaction between those areas of turbulence and the introduction of a new shape can have unforeseen and dramatic consequences."



Before a new system can be flown operationally it has to go through a rigorous testing process to find out what effect it will have on the aircraft, not just in terms of safe separation, but also in terms of aircraft handling characteristics and the potential for structural damage. Ordinarily, every time an air force wants to use a piece of hardware on the F-16 that has not yet been certified by the USAF, it needs to request that the Seek Eagle Office at Eglin Air Force Base (and manufacturer Lockheed Martin) begin the certification process. However, as is usually the case, resources are finite and priorities are set with a certain amount of self-interest. It costs a lot of money to jump the queue. Comments Speedy, "Instead of being dependent on the people at Eglin we want to be able to do things quicker and cheaper ourselves. But, the bottom line is this; we would not be able to do these sorts of domestic certification programmes without NLR."

Once Air Materiel Command publishes a requirement for a new system, and it is subsequently awarded, the certification process starts. "What happens next," says Speedy "is our operational people take over. They define the configurations the system will be flown in, the role in which it will be used and the desired flight envelope."

The kit is then handed over to the RNLAf Test Flight Department and they work with NLR to come up with the necessary flight test programme to evaluate the system and find out how to use it safely. Speedy explains, "We divide things into two baskets; that which can be done on the computer using Computational Fluid Dynamics techniques for example and the remainder which will need to be evaluated as part of a flight test programme. To save time and money we look at worst case scenarios. We predict when things are likely to happen and what configurations are likely to be a problem. These are the profiles we test in flight."

If a piece of hardware is the same shape and has similar inertial properties as something that has already been certified, only a limited test flight programme may be required.

INNOVATION ON DEMAND

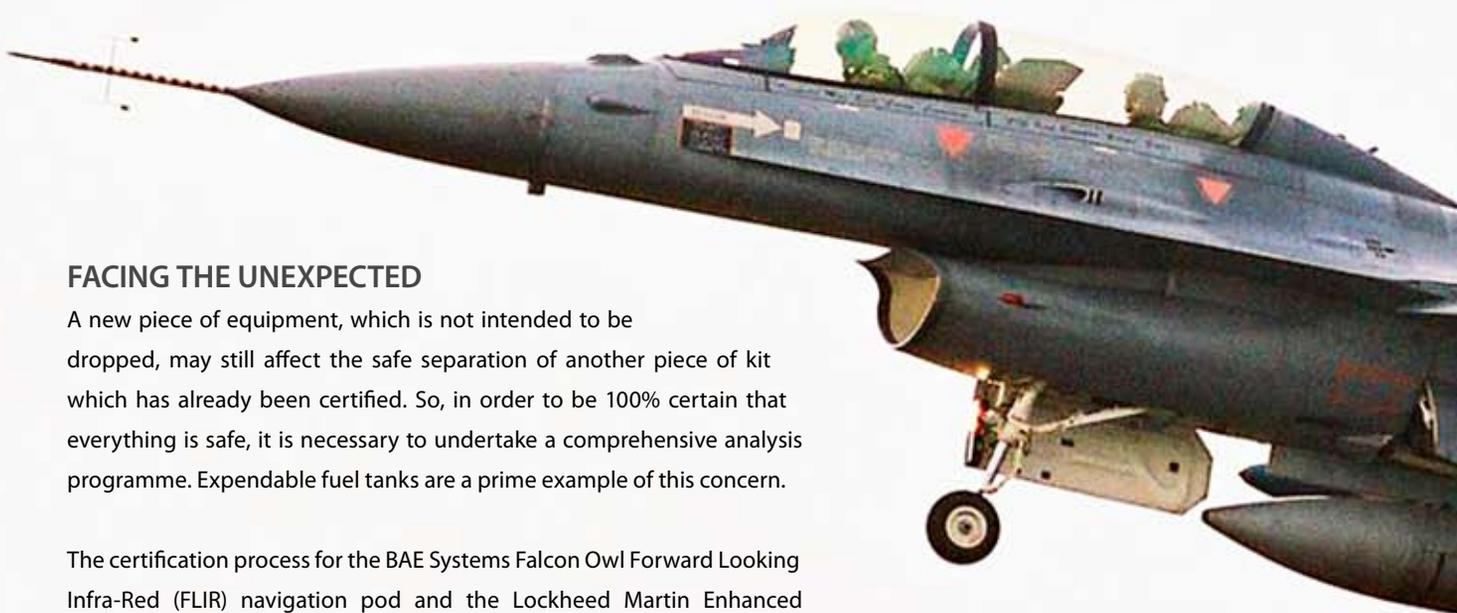
FACING THE UNEXPECTED

A new piece of equipment, which is not intended to be dropped, may still affect the safe separation of another piece of kit which has already been certified. So, in order to be 100% certain that everything is safe, it is necessary to undertake a comprehensive analysis programme. Expendable fuel tanks are a prime example of this concern.

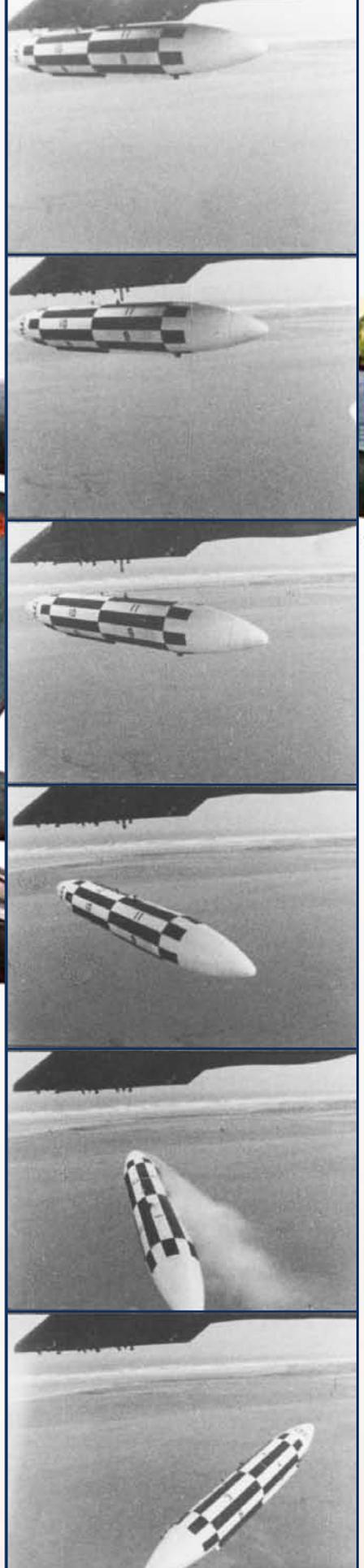
The certification process for the BAE Systems Falcon Owl Forward Looking Infra-Red (FLIR) navigation pod and the Lockheed Martin Enhanced Targeting pod, procured for the Dutch F-16 MLU aircraft in the late 1990s, revealed just such a circumstance.

Lockheed Martin's Enhanced Targeting pod was exactly the same shape and had a very similar mass as the LANTIRN Sharpshooter pod on which it was based. This was already in use with USAF F-16C/Ds meaning that the qualification programme could be done entirely on paper, saving funds. Furthermore, a 'quick action qualification' with the original LANTIRN variant had already been carried out on RNLA F-16A aircraft to allow the pod to be rushed into service for use in NATO operations in Kosovo. Nevertheless, analysis did confirm that the integration of the Lockheed pod could lead to additional wear on the ventral fins at certain speeds due to increased vibration.

However, during tests with Falcon Owl, mounted on the left-hand side of the air-intake, the fuel tank on the *left* wing clipped the left ventral fin on release. A follow-up test without the Falcon Owl also resulted in the fin sustaining damage from the 370 gallon tank. So it was not Falcon Owl that was to blame. Something else was happening.



Fuel tank separation tests, carried out in the US on the *right* wing showed that nothing unusual would happen if the correct procedures were adhered to. It was assumed that the airflow characteristics were the same on both sides of the aircraft and therefore the limits for separation should also have been the same. Crucially, NLR's tests proved this assumption to be wrong, with a result that the US authorities were required to set new, lower, safer tank jettison release limits to the whole F-16 community.



INNOVATION ON DEMAND

MATING SHIPS AND HELICOPTERS

Naval doctrine is changing across the globe. The emphasis has moved from a reliance on shipborne weaponry to the ability to transport an independent military capability into an operational theatre by sea. But getting decisive manpower and equipment from ship to shore rapidly requires a different mixture of ships in the fleet, with transport vessels becoming increasingly important. At the same time, helicopter operations are evolving into a vital element of this new military mission. The ability to operate a mixture of transport, attack and utility helicopters from ships has become key.

As a rule, helicopters have limitations placed on them by the manufacturer and operator, known as Ship Helicopter Operating Limits (SHOL), which restrict them from flying on and off ships in certain weather conditions. NATO joint operations are restricted even further. They have very conservative so-called cross-operational ("cross-ops") limitations. The SHOL's describe an 'envelope' or set of conditions under which helicopters can be expected to land on, or fly off, a ship's moving deck. Wind and ship motion are the two main parameters which determine whether flying is possible at any particular time. Furthermore, helicopters must land and take off from pre-selected locations or 'spots' on the deck as these have markings painted on them to assist the pilot and are equipped with mechanisms to lock the helicopter firmly to the deck once it has landed. All this makes landing on a pitching ship in turbulent wind conditions, a far more difficult task than landing on the ground and the pilot's workload is greatly increased. NLR's SHOL's increase safety whilst enhancing operational limits and creating flexibility, providing the improved ability to conduct flight operations while continuing the ship's mission.

The RNLN however, is constantly pushing back the boundaries. It is always looking for ways to make the most use of its men and equipment. The Navy works hand-in-hand with NLR, whose 40-year experience gained in certifying and qualifying helicopters for shipborne operations, has resulted in a unique capability to expand the SHOL envelope. Joost Hakkaart, Principal R&D Manager in NLR's Helicopters and Aeroacoustics Department, says, "Helicopter operations at sea require dedicated trials to determine the maximum operational capabilities. The NATO cross-operational limitations, defining the minimum envelope, are quite restricting as they only allow low wind-speeds, sometimes even zero wind-speed. The problem with that is that zero wind is not always the best condition for doing things, because the helicopter can be power limited in those conditions. In addition, a restricted wind direction envelope can result in too many operational limitations for the ship's mission."

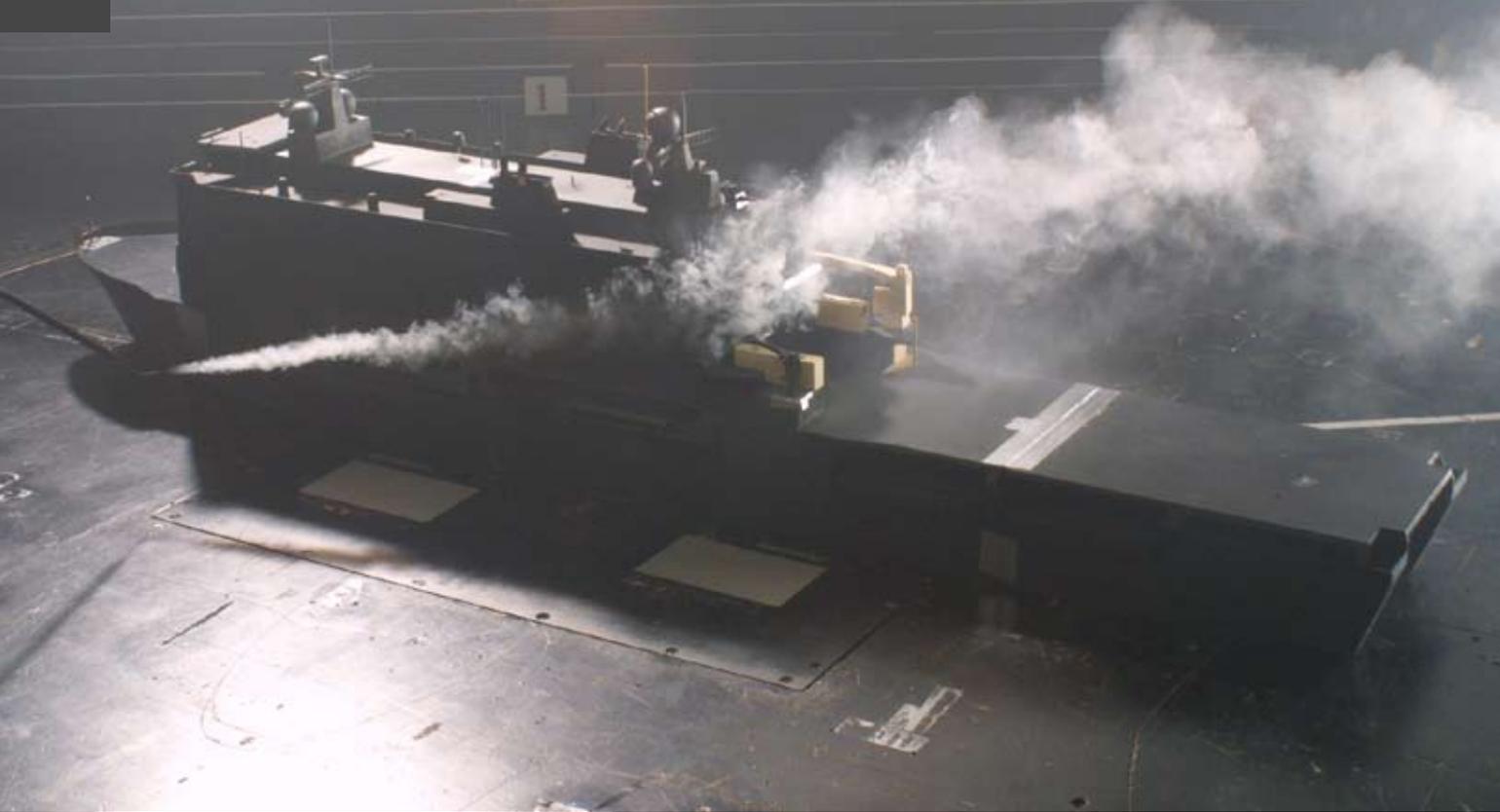




The flight test experts at NLR have adopted a radical approach to expanding the operational envelope. Before any helicopter gets near a deck, a model of the ship is examined inside a wind tunnel. The latest Dutch transport ships like the Landing Platform Docks (LPDs) and the Joint Support Vessel (JSS) have wide super structures in the region of 100 feet high in front of the helicopter deck. "Having these huge obstacles in front of the deck causes problems for helicopters," says Hakkaart. "Not only do they produce a big wake behind them, they also generate very dominant vortices and turbulence. These limit helicopter operations and create conditions which are not catered for in the NATO cross-operational standards."

Having built a picture of what is going on with the wind around the helicopter flight decks, NLR teams then analyse the way the ship moves in different sea conditions. Next, the flight test specialists determine the helicopter's low-speed characteristics through a series of flight tests carried out on shore that produce far more detail on performance and controllability than the manufacturer's flight manual. The information obtained from the wind tunnel and shore-based flight tests is then merged and used to define 'candidate' flight envelopes. According to Hakkaart, these are "our best estimates of the helicopter performance on board a specific ship. We use them to define the flight trial test programme." The ship-based flights are performed in a range of weather conditions, by day and night. As well as verifying the expanded envelope, they also determine the effects on the pilot's workload of reduced visibility over the flight deck, of ship motion and of turbulence.

INNOVATION ON DEMAND



Having already helped the Royal Netherlands Navy and Air Force develop more effective operational procedures for the Lynx and Cougar helicopters, NLR's next step is to assist in the effort to embed the new expeditionary capability concept into Navy doctrine by undertaking SHOL programmes for the Apache, Chinook and NH90 helicopters.

In addition R&D work is undertaken to improve the complex modelling and simulation of helicopter ship operation and implement those in the flight simulators and pilot training programmes.

Defence budgets worldwide are under increasing pressure and it is important that efficiencies can be achieved wherever possible. The SHOL work that NLR carries out has spin-off benefits in other areas of defence expenditure. As Hakkaart points out, "It is important to recognise that you have the ability to influence your own environment on board ship. Not only is it ensured that the ship design is optimised for helicopter flight but for example it is equally important to prevent the exhaust from re-entering the crew's quarters and affecting them."



TRANSPORTS WITH A BITE

Dutch operations in Afghanistan and Iraq have called for more aggressive and innovative capabilities from the helicopter fleet. Transport helicopters must now be able to protect themselves not just with defensive aids suites but also by engaging the enemy directly. NLR was therefore called upon to help the RNLAF install a general-purpose machine gun in its Chinook helicopters to provide additional protection for the aircraft – especially at low level. A test flight programme was devised by NLR in which technicians used strain gauges to see whether placing the gun in a particular location generated too much stress and could lead to structural damage.

More importantly however, they also attached small cameras to track the rounds as they leave the muzzle since it was imperative that the gunner should not inadvertently shoot down his own aircraft. NLR had to prove that they could prevent the gun from being pointed in such a way that rounds could end up hitting any part of the fuselage or the rotor blades. Various different flight profiles were flown with live firing under very strict rules, until the RNLAF and NLR were satisfied that the gun-mounting was safe.



A PARTNER FOR PROGRESS

PUSHING THE ENVELOPE

Operated by air forces in Europe, the Middle-East, Asia and North and South America, the F-16 Fighting Falcon is without doubt the world's most successful jet fighter. When the Royal Netherlands Air Force (RNLAf) selected the aircraft, along with its partners in the European Participating Air Forces (EPAf) group, it triggered the immediate requirement for these countries to set in place a mechanism to introduce the aircraft in the European theatre. The EPAf nations all had specific requirements centred around their NATO responsibilities and each of these countries needed to ensure that the aircraft would be able to defend alliance airspace and attack enemy ground forces.

MINDING YOUR OWN BUSINESS

The thorough testing undertaken by the manufacturer, General Dynamics (now Lockheed Martin) ensured that the aircraft was airworthy and all its systems operated properly. However, no nation can spend such a vast amount of money on a combat capability without running its own test programme to ensure that the product does indeed conform to the user requirements in the intended theatre of operations. Moreover, testing an aircraft above the deserts of North America can only tell you part of the story. Once you introduce that aircraft into the temperate European climate and into an environment that is full of different sorts of radar "clutter", both in the air and on the ground, you have to retest its systems to see exactly how they react in their new home. Perhaps most importantly, you have to see what the crowded RF (radio frequency) environment in Europe does to the aircraft's avionics systems and radar sensors.



The flight test process for the EPAf nations was the Multinational Operational Test and Evaluation (MOT&E) programme. NLR was an obvious choice to participate in this programme, as not only did it already have several decades of aircraft test flight experience, assisting the RNLAf with its previous fighter aircraft the F-104G and the NF-5A/B, but its analysts had also built up considerable expertise in operational air-to-air and air-to-ground mission profiles. The MOT&E group, which was formed in 1980, consisted of one or two test pilots from each of the EPAf nations alongside the analysts and ground crew. The two NLR analysts became a significant asset within this group, particularly as Norway and Belgium had no equivalent test and evaluation institutions like NLR.

One of NLR analysts seconded to the group, René Ladiges, remembers the Dutch element of the programme well. "There was a lot of flying," he says. "It was a very busy time as all the initial test flight data was collected using paper questionnaires. It was not until the final phase that all the data was put into the NLR mainframe computer." During this period, Ladiges recalls there was a regular flow of pilots flying, analysts debriefing pilots, programme people debriefing analysts, others noting down and checking the data before it was eventually put into the computer.

Such work has to be carefully prepared, managed and monitored. According to Ladiges, "First you start with a master test plan. This contains all the operational issues you want to check. In essence the plan covers the reasons you selected the aircraft in the first place. You want to use the aircraft to defend airspace by shooting down enemy aircraft or to attack ground targets; it has to be demonstrated that this is exactly what the aircraft can do and any limitations need to be identified."



Not long after the RNLAf had started flying the F-16 operationally, it began a continuous process of upgrading the aircraft's systems. The Dutch tradition of self-reliance and innovation has meant that the RNLAf is constantly looking for ways to make the F-16 a more potent weapon system. The RNLAf is also keen for testing in any theatre of operations and for continuously evolving its operational concept and tactical doctrines. Sometimes this entails going it alone, as in the early upgrades to install the Orpheus reconnaissance pod. Sometimes it involves all of the EPAF nations as with the F-16 Block 15S fire-control computer and radar upgrades.

The fire-control computer and radar upgrade, essentially a software enhancement, meant that the two systems had to be retested within the European environment to confirm that they still worked and that they had in fact been improved. Eddy Pijpers, Division Manager for Aerospace Systems & Applications, helped to run these tests in the early 1980's. He is convinced of the need for testing in the European climate. He explains, "Europe is very different and the RF traffic is also more complex and denser, with various modern communications equipment (mobile phones, radios, TV, commercial air transport) all sharing and crowding the same radio frequency spectrum."

It is not unknown for aircraft to interfere with this traffic and vice versa. There have even been cases where airborne data links signals inadvertently opened garage doors! Similarly, military radars sometimes interfere with ground based civilian weather radars. There are also small but important details sometimes overlooked in the initial testing by the manufacturer. One such example involves air-to-air radar modes. Testing of F-16 radar software had been carried out in the US where the speed limit on the motorways is much lower than it is in Germany or other European countries. This resulted in multiple false target alerts due to unsatisfactory Doppler filtering when flying over European motorways as automobiles hurtled at speeds well in excess of the US speed limit, triggering the F-16 radar.

A PARTNER FOR PROGRESS

NEW WINE INTO OLD BOTTLES

After having operated the F-16 for over a decade, the EAPF nations became concerned that the aircraft was no longer as state-of-the-art as it used to be. The manufacturer, Lockheed Martin, was still producing the aircraft and its latest variant of the Fighting Falcon, the Block 50, was a far more advanced aircraft, in terms of systems and weaponry, than the European group had bought 10 years earlier. Purchasing a new batch of Block 50 F-16s was out of the question for the EAPF group. So the idea of putting the Block 50 systems into their older airframes and upgrading the engines with a more powerful Pratt & Whitney F100-PW-220E configuration, complete with digital control systems, was proposed. This concept became known as the Mid-Life Update (MLU) and was one of the largest upgrade programmes of its type ever conducted in Europe.

A natural result of replacing the old systems was that the fleet had to be re-tested in a similar fashion to the original MOT&E programme. Since MLU kits were also ordered by the USAF, the USAF Seek Eagle programme office was responsible for ensuring that the package was airworthy and effective. But, just like the test programme carried out for EAPF's initial F-16 procurement, these tests were also mainly undertaken in the US. Therefore, Belgian, Dutch, Danish and Norwegian MLU F-16s began flight testing in July 1996 at the RNLAf base at Leeuwarden. The RNLAf played a leading role in the testing of the upgraded aircraft and requested NLR support with this intricate and complex task which lasted for over a year. During this time, a series of software enhancements was incorporated. NLR analysts were involved in ensuring these incremental upgrades were effective. By taking such a prominent role in such test programmes, NLR has become a unique resource when it comes to the future of the F-16. One example of an important test result was the discovery of an incorrect functioning of the ground collision warning indicator leading to a critical software modification.





COUNTERING VIRTUAL THREATS

Understanding how EW works has enabled the NLR Flight Test Department to go one step further than the rest of the EW community and create a unique system known as embedded training. This has the potential to make substantial reductions in the cost of preparing pilots for combat, by removing the need to fly against real aircraft and ground-based air-defence systems. Hooking up an aircraft's Radar Warning Receiver (RWR) to its Fire Control System (FCS) NLR technicians can display a virtual enemy force on the ground and in the air. These computer-generated units behave like real forces and are able to shoot at the pilot's aircraft. The pilot can also engage them with his own weapons. Embedded training has been implemented in prototype form called E-CATS (Embedded Combat Aircraft Training System) but has not been installed onto the F-16 fleet due to its impending withdrawal. However, there is a requirement for embedded training for the F-35 Joint Strike Fighter which is a possible replacement for the RNLAf's F-16. NLR has therefore begun discussions with Lockheed Martin to explore the possibilities of this type of system as a future solution.



A PARTNER FOR PROGRESS

SUPPORTING INDUSTRY

Having built up a reputation for flight testing, NLR is in a privileged position of being able to assist NATO allies when approached. In 1989 the Belgian aerospace company, SABCA, asked NLR to provide them with flight test instrumentation in order to certify the Matra Magic air-to-air missile onto Belgian Air Force F-16 aircraft. NLR supplied all the equipment necessary to record all the measurements needed to get the certification for deploying the missile. NLR also supplied instrumentation on the ground to handle the telemetry used to investigate flutter. This process was later repeated for the Aerospatiale AS-12 air-to-surface missile.

SABCA also requested NLR to carry out a series of flight tests when the Belgian C-130 Hercules aircraft were fitted with new air data computers. The company had been asked to provide evidence that the new system would be able to make it possible for the aircraft to meet the ICAO Reduced Vertical Separation Minima (RVSM) requirements, which were put in place to allow aircraft to fly closer together (within 300 metres). Flying closer together requires very accurate situational awareness and NLR was able to carry out a series of flight tests proving that the new computers were giving accurate readings and the C-130s would be able to fly at the new flight levels, and therefore be able to take advantage of fuel savings and reduction in delays made possible by the new air traffic management environment.





In December 2005, NLR was contracted by the RNLAF to help with the transition from the F-16 to the next-generation fighter. In 2008, the Dutch Government has expressed the intention to buy two F-35A aircraft so that the Netherlands can participate in the IOT&E (Initial Operational Test and Evaluation) programme. Naturally, NLR intends to be a major participant in this work, maintaining its intimate alliance with the RNLAF and providing professional support.

A PARTNER FOR PROGRESS

ELECTRONIC WARFARE: PROTECT & SURVIVE

Protecting one's aircraft from attack using electronic means or, indeed, giving one's fighter jets the ability to conduct an electronic attack is a harsh rule of modern combat. Combat aircraft must be fitted with self-protection systems to alert of an impending attack, eject flares to deflect infra-red homing missiles, jam air-defence radar systems electronically or confuse them with chaff. The defeat of air-defence systems, known as Electronic Warfare (EW) has become a complex and constantly changing process. As soon as one side produces a new way of attacking aircraft, the opponent designs a system to counter it.

NLR has worked for decades with the RNLAf to certify that its EW equipment is effective against all threats through testing on the ground and in the air. The roots of this activity stem from the early 70's when the first chaff/flare dispensers were installed on fighter aircraft. Early tests conducted in the Netherlands and bilateral tests with NATO partners resulted in a sequence of follow-on trials, known as Embow and Mace. These trials are still a feature of current collaborative NATO EW research efforts and in which NLR plays a major role. "Smart boxes," built by NLR into the existing self protection systems have been flown to evaluate advanced and integrated countermeasure techniques. Examples are in the automated coordinated start of radar jamming programs and the release of chaff when optimum conditions are met. Similarly, flares ejected by military aircraft are sometimes simply referred to as "fireworks" but are actually the result of decades of development and tests with advanced compositions of pyrotechnic materials.





The professionalism and operational capabilities of the Netherlands Armed Forces mean they are regularly called upon to assist with international peacekeeping, humanitarian missions and combat duties. So it was no surprise when the Dutch Apache unit was called up for duty in Afghanistan. In late 2003, NLR was asked to quickly assist with the installation of the AMASE (Apache Modular Aircraft Survivability Equipment) self-protection pod to the aircraft before they went on tour. AMASE is a pod fitted with a combination of the TERMA EW controller, flare dispensers and Northrop Grumman missile warning sensors. As a result of NLR expertise in the EW field, its design is highly effective against heat-seeking missiles.

The AMASE pod is installed on the Apaches stub wings using the attachment points for the air-to-air version of the Stinger missile. The prototype testing began early 2004. Captain Henno Gemmink, an RNLAf Flight Test Engineer, recalls how NLR worked with the Air Force to instrument the pod by putting gauges on it and on the wing stubs. As he says, "There was a requirement for NLR to prove that the Apache could handle the pod load. It took about five months, which for this type of programme, is an extremely short amount of time." NLR also assists in programming of the system and the tests designed to check the effectiveness when self-protection systems like AMASE are used in anger and flares are ejected. The cooperative programme conducted by the RNLAf, TERMA-Denmark, Per Udsen, Northrop Grumman and NLR received international recognition and was awarded with the 2004 Integrator of the Year Award by Defence Helicopter magazine.

"You cannot solely rely upon other nations to take care of your electronic warfare requirements," says Eddy Pijpers, Manager of NLR's Aerospace Systems & Applications Division. "It's a national responsibility." For this reason NLR developed national test capabilities known as the Seeker and Electronic Countermeasure Test Facilities. These facilities are used in actual system tests with RNLAf aircraft sometimes from obscure and predominantly desolate locations all over Europe and North America. The focus of the current activities is on the improvement of the protection against infra-red guided systems by the introduction of advanced technology flares.

As Captain Henno Gemmink explains, "Some flares burn very hot for a short time and others burn less intensely but for a longer time. Different flares burn in different parts of the electro-magnetic spectrum and some non-visible stealthy flares are better at night. This is very intricate work. You have to select the best means of defeating each missile threat. It is no exaggeration to say that there is no margin for error in this task and you have to be confident that whoever is tasked with this job knows exactly what they are doing."



NLR: A PARTNER FOR YOUR FUTURE

NLR is well-placed to leverage technical assistance and cooperation both in Europe and across the globe. Whether it is a matter of teaming with government or industry, NLR stands ready to deliver objective, independent advice and innovative science and technology.

Our belief is that defence agencies are more and more confronted with budget restrictions but at the same time are expected to solve aircraft obsolescence problems, comply with continuously stricter military and civil aviation standards, and meet urgent operational requirements stemming from peacekeeping deployments. Moreover, thanks to budget cuts, these defence agencies are confronted with the loss of 'corporate knowledge' through the departure of valuable personnel.

Our solutions stem from a conviction that the future is a collaborative one and that maximum benefits can be obtained by working closely together at an international level. NLR and its partners, the Royal Netherlands Air Force and Navy, are willing to effect such cooperation in order to help you meet your challenges and goals.



COLOPHON

Edited by:

Eddy Pijpers and Tjebbe Haringa

Compilation:

NLR / DSSB

NLR Division Aerospace Systems & Applications

Writers:

Clifford Beal and Simon Michell

Production & Art:

NLR Multimedia Group

Photography:

pag 4: © Mike Schoenmaker
pag 6-7: © Tech. Sgt. Beth Holliker
(U.S. Air Force)
pag 7 left under: © U.S. Air Force
pag 21 upper right: © U.S. Air Force
pag 26: © Christine Hammer
pag 27: © U.S. Department of Defence
pag 28: © Lockheed Martin
pag 35: © CAVDKM
pag 37: © James Shelbourn - Airliners.net
pag 37: © Peter Tonna - Airliners.net
pag 37: © Neil Jones - Airliners.net
pag 38: © J. van der Putten - Airliners.net
pag 40: © Michael Vaeremans - Airliners.net
pag 41: © Lockheed Martin
pag 43 upper left: © Philip Jones

Print:

Printing office WC den Ouden

**National Aerospace Laboratory NLR**

Anthony Fokkerweg 2
1059 CM Amsterdam
P.O. Box 90502
1006 BM Amsterdam
The Netherlands

Phone: +31 (0)20 511 31 33
E-mail: info@nlr.nl
Web site: www.nlr.nl

ISBN/EAN: 978-90-806343-8-1
© NLR - September 2008

