Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

NLR Annual Report **2004**

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FOREWORD

You have before you a new annual report, with a foreword from a new chairman.

2004 was a special year for NLR in many ways. First and foremost, it was the year in which we implemented the adjustments outlined in our reorientation — trimming our workforce where necessary, restructuring our organization, and adopting new working procedures. Despite all these changes, we are pleased to say we ended the year 2004 with a modest positive operating result.

2004 was also the year in which the Wijffels Committee issued its report. Most of the committee's recommendations have now been adopted by the Dutch government. NLR endorses the importance of demand-driven research, which is fully in line with current NLR policy. At present, we are engaged in constructive discussion with the authorities on how we can best implement their directives.

This annual report is another example of the new course set in 2004. To reach a broader spectrum of stakeholders and interested parties, we have included brief reviews of key NLR projects illustrating the diversity and significance of our activities.

Last but not least, 2004 was the year in which the first steps were taken to select a successor for (now former) chairman Mr. J. van Houwelingen. I was officially appointed in early 2005. Elsewhere in this report, we look back on my predecessor's achievements. However, I would like to take this opportunity to say that Mr. J. van Houwelingen played an essential role in developing NLR's position, both nationally and — more importantly — internationally. His supervision of our reorientation and the formulation of a new strategic plan ensured that NLR was well-positioned to enter the debate on how best to implement the recommendations of the Wijffels Committee.

Thanks to his groundwork, I look to the future with confidence.

Amsterdam, June 2005

Mr. A. Kraaijeveld
Chairman

MR J. VAN HOUWELINGEN FAREWELL AND THANK YOU

Mr. J. van Houwelingen succeeded Prof. O. H. Gerlach as chairman of the NLR Board in 1991. On March 1, 2005, he in turn was succeeded by Mr. A. Kraaijeveld. Mr. J. van Houwelingen was a deeply committed chairman from the very beginning. This was apparent the moment he assumed his post and decided to move his office from Delft to Amsterdam.

Mr. J. van Houwelingen took a great interest in NLR activities. He kept a close eye on congress reports to gain insight into the full spectrum of NLR projects undertaken and contacts maintained in Europe and far beyond. It was (and is) his firm belief that international cooperation is an absolute necessity for an institute like NLR.

Mr. J. van Houwelingen did a great deal to intensify cooperation between NLR and DLR — which dates back to the 1970s — in their utilization of the large German-Dutch wind tunnel located in the Noordoostpolder. NLR and DLR signed a partnership agreement in 1994, resulting in a single management body for practically all NLR and DLR wind tunnels, thus ensuring much greater efficiency.

Mr. J. van Houwelingen was also an advocate of the strategic alliance in air traffic management (AT-One) between NLR and DLR. He contributed to the establishment of the association of European Research Establishments in Aeronautics (EREA), which gives us a collective voice in Brussels.

His great commitment was also reflected in his contacts with NLR Works Council. Twice a year he briefed the council on the current state of affairs — not because this was required, but because he believed this was necessary and beneficial. The continuity of NLR was always his chief priority, knowing that this was in the best interests of his staff. This was especially apparent during the reorientation, which required some very difficult decisions.

Mr. J. van Houwelingen was closely involved in drafting the new Strategic Plan for 2005-2009. This contributed to unanimous approval of the plan by the Board, providing a firm foundation for implementation of the Wijffels Committee's recommendations.

Mr. J. van Houwelingen has left us with an organization that is internationally focused, well organized, and financially sound. His efforts were acknowledged by the State Secretary of Transport, Public Works & Water Management in her speech at his farewell reception, when she referred to NLR as “the leading center for aeronautical expertise in the Netherlands.”

NLR is deeply indebted to Mr. J. van Houwelingen for this achievement.

Chapter 1:

INTRODUCTION

MARKET-ORIENTED

The Netherlands government is adjusting its funding policy for major technological institutions such as NLR. It is assuming a more market-oriented and demand-driven approach. This is in line with recommendations outlined in the report of the Wijffels Committee, issued in the spring of 2004.

NLR has long been a market-oriented organization and endorses the government's approach. Certainly when compared to our counterparts abroad, NLR can be proud that 75% of its turnover comes from contracts awarded by government and industry. The remaining 25% comes from government funding, which is invested in knowledge acquisition and the development of research and testing facilities.

NLR is continually evolving in order to optimally meet the demand for expertise from government and industry. In 2004, NLR carried out a reorganization. Seven key departments were merged and regrouped into three divisions. NLR also reduced its workforce by 20%. This was mainly achieved through attrition, but unfortunately some staff also had to be laid off.

With this far-reaching operation, NLR has enhanced synergy and created a more decisive organization, further strengthening its demand-driven business culture. Within a single year, this has already produced quantifiable results. NLR earned a positive operating result in 2004, the year in which the reorganization and staff cutbacks took place.

KNOWLEDGE ACQUISITION AND INTERNATIONAL COOPERATION

One of NLR's tasks is to maintain its expertise in various fields, thus ensuring that it can meet the aerospace needs of the Dutch authorities and industry quickly, adequately, and efficiently.

The pooling of expertise within international cooperative ventures creates a climate for intensive knowledge exchange and promotes efficient knowledge acquisition and exploitation. Within its strategic alliances with European counterparts, NLR makes agreements about exchanging knowledge and personnel, thus using its own resources to gain access to the broadest possible pool of specialists and expertise.

In late 2004, NLR and its German counterpart DLR entered into a strategic air traffic management alliance called AT-One. With a staff of 260 experts, this alliance will be one of the world's largest centers of expertise in this field. NLR spends a substantial portion of its budget on participation in European programs, which involve a great deal of knowledge exchange and are financed, in part, by European funds.

It is of crucial importance to firmly embed NLR research in an international context through strategic cooperation, thus ensuring optimum support for aerospace ambitions within the Netherlands.

On the home front, NLR also maintains close ties with universities and centers of expertise. It provides lectures on air traffic management, offers posts and internships for post-graduate and doctoral study, and is involved in research at the Delft University of Technology, with which it shares one of its two research aircraft. NLR also cooperates closely with Marin, ECN, and the Netherlands Organization for Applied Scientific Research (TNO) in specific fields.

FACILITIES

Apart from expertise, aerospace research requires costly research facilities. Consequently, NLR has several wind tunnels (together with DLR in the DNW Foundation), as well as flight simulators and air traffic management simulators, research aircraft, and a wide range of laboratories (e.g. for the environmental qualification of electronic systems).

In 2004, NLR acquired a seal test rig for testing internal seals in gas turbine engines. NLR also decided to build a new testing facility on its grounds in the Northeast Polder and made preparations for an Automated Composite Manufacturing (ACM) Technology Center that will go into operation in 2005.

NLR's revenues from contracts do not fully cover the high cost of these research facilities. However, such facilities are of strategic importance to the Netherlands and its knowledge infrastructure. Thanks to NLR's broad base of knowledge and experience, Dutch industry has gained a solid position in the development of the NH90 helicopter, several Airbus aircraft, and the US-led Joint Strike Fighter program.

Thanks to NLR's flight simulators and air traffic management simulators, the Netherlands has acquired a leading international position in the research of new air traffic management models. This is why NLR wants to continue investing in high-quality research facilities, preferably in collaboration with its European counterparts.

For thirty years, the Dutch-German Wind Tunnel Foundation (DNW) has exemplified the benefits of pooling international expertise at shared facilities. At present, almost all wind tunnels belonging to NLR and its German counterpart DLR are grouped within this foundation. And now the French Aeronautics and Space Research Center, ONERA, has announced its intention to begin exploiting its wind tunnels in collaboration with the DNW.

OUTLOOK

At the end of 2004, NLR finalized its Strategic Plan for 2005-2009, outlining basic assumptions regarding the anticipated demand for research. Overall demand is expected to remain stable for the time being.

For the civil aviation sector, the anticipated focal points include air safety, air traffic management, and environmental and airport technology. For the aerospace sector, the anticipated focal points include support for satellite navigation systems, the utilization of earth observation data, and the development of innovative satellite subsystems.

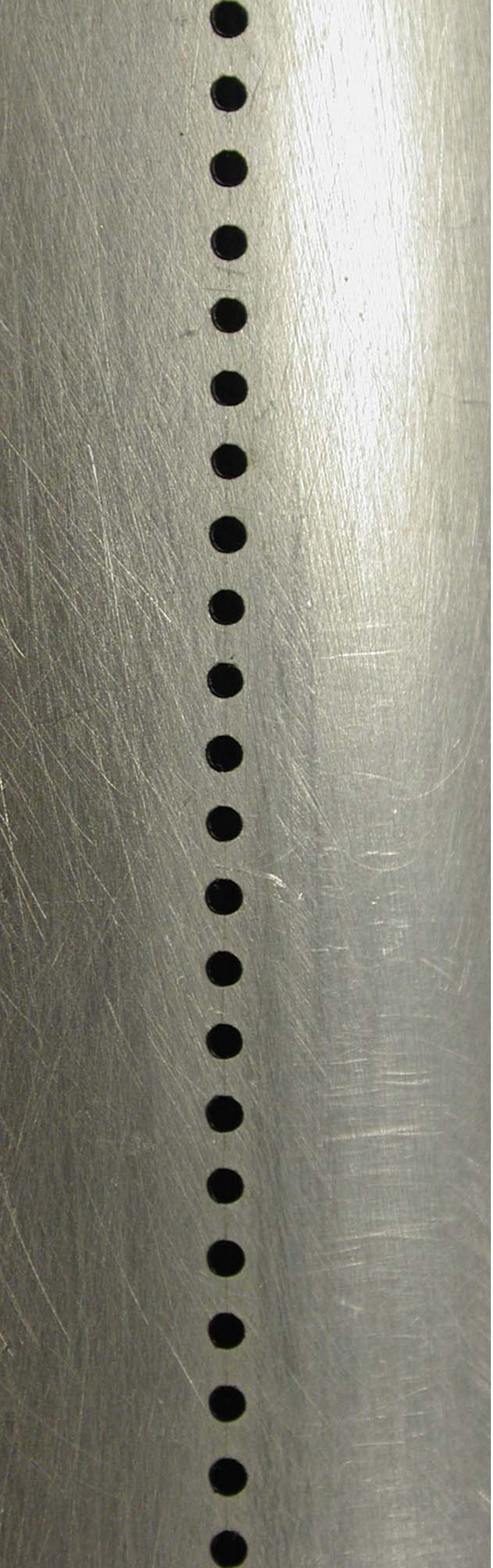
The military aviation sector is also setting new priorities. As the Royal Netherlands Air Force is frequently involved in worldwide peacekeeping missions, NLR must ensure that it can provide expert operational support. Focal points for the military aviation sector therefore include support of the Dutch armed forces in their acquisition, selection, and maintenance of aircraft and other defence equipment, and support in the operational deployment and maintenance of airworthiness of such materiel.

AN OVERVIEW OF NLR PROJECTS

When making strategic choices, NLR takes careful consideration of the interplay between various areas of expertise. For instance, research into the lifespan of military helicopters is only possible if one has access to broad operational experience and an extensive knowledge of materials. Similarly, research into air traffic management relies on insight into human behavior, flight simulation, flight tests, and avionics systems. And the study of flight procedures would be unthinkable without a knowledge of turbulence, risk analysis, noise, and avionics. In short, the interplay between these areas of expertise is essential for NLR.

The full spectrum of NLR research and the interplay between various fields is illustrated by the specific projects undertaken by our institute. A number of these projects are reviewed in Chapter 2 of this report, giving an overview of our activities in 2004. The projects have been grouped into six societal themes that are the focal point of NLR activities — job creation, mobility, safety, environment, defense & peacekeeping activities, and exploration & space technology.

Chapter 3 gives a rundown of NLR's facts and figures for 2004. The overview sketches a clear profile of a highly-skilled organization with a close-knit structure based on mutual cooperation.



Chapter 2:

AN OVERVIEW OF NLR PROJECTS IN 2004

JOB CREATION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Glare for the A380

High-Speed Propeller

Corrugated Ribs

Gas Turbine Seals

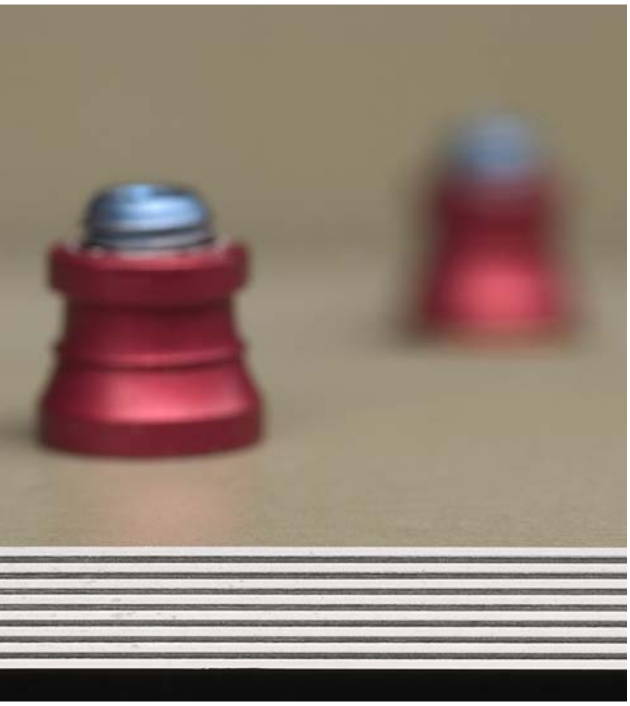
Center for Composites

JOB CREATION

The Netherlands is a prosperous country. To maintain the high standard of living, we need high-grade job opportunities. Dutch products must retain their distinctive quality in years to come.

GLARE UNDERGOES 2,500 TESTS

Thanks to Glare, the freighter version of the Airbus A380 will weigh less and be able to carry heavier loads. NLR subjected Glare to 2,500 separate tests to certify the new material for the manufacturer, Stork.



Glare is a durable, lightweight material designed for the world's largest passenger aircraft, the Airbus A380. Jointly developed by the Delft University of Technology and Stork, with the support of NLR and other parties, glare is a laminate composed of thin layers of aluminum and fiberglass, bonded with synthetic resin. An improved version of the material, called High Static Strength (HSS) Glare, allows the freighter version of the A380 to carry a heavier payload. HSS Glare is just as light as the standard version, but can endure even higher temperatures and humidity, and has greater static strength properties. Before the new material could be applied, it had to undergo a comprehensive test program assessing its strength and durability under extreme conditions for extended periods of time. At the behest of Stork and in close collaboration with Airbus, NLR carried out 2,500 tests during the course of 18 months. The program was completed in 2004.

NLR performed tests on 12 different types of HSS Glare, each with the glass fibers oriented in a different direction, or with varying numbers of aluminum layers, suitable for different parts of the aircraft. Samples of each type were exposed to tension, compression and shear, either with or without a rivet hole to weaken the material. During fatigue tests, sample panels were stressed up to 3 million times and continually monitored by microscope to assess the initiation and development of cracks. These tests were conducted at room temperature, but also at the extreme temperatures to which aircraft are exposed: -55° C (at 33,000 feet) and +90° C. (out on the apron in the tropical sun). NLR also examined the effects of material aging by simulating moisture absorption at tropical temperatures in climate chambers. To gather sufficient statistical data, the same test was sometimes performed on as many as 500 different samples.

Based on the data generated by NLR, Airbus was able to set maximum stress levels to which HSS Glare may be exposed. The test results were a key factor in the material's certification.

In the past, NLR performed similar certification tests on the original version of Glare, which was used in the passenger version of the A380. NLR also helped develop the original material and has amassed extensive knowledge about Glare, which will be of immense value as the material evolves in the years ahead.

PROPELLER AIRCRAFT IN THE WIND TUNNEL

Airbus is developing one of the largest propeller aircraft in the world. NLR was commissioned to create scale models of the propellers, and to test them in the DNW wind tunnels and elsewhere in Europe.

The Airbus A400M military transport aircraft, currently under development, will be equipped with high-speed, multi-blade propellers. NLR created various model propellers for wind tunnel tests. Tests of this kind, using scaled-down engines, were impossible in the past. However, all that changed with the advent of highly-compact, small-scale compressed air engines. Since then, the fatigue strength of the model propellers has been the weakest link. NLR is currently one of the few institutes in the world that can produce propeller models that hold up under extreme stress. NLR developed this technology for the European project SNAAP (Study of Noise and Aerodynamics of Advanced Propellers).

During wind tunnel tests at sea level, the propellers are subjected to forces that are much greater than those experienced by real aircraft flying at high altitude and high speed (Mach 0.72). On top of that, the propellers are put through maneuvers that no real pilot would willingly undertake – creating even more arduous conditions. NLR makes the model propellers from a single piece of material, reinforced with carbon fiber, that can withstand extreme and highly variable forces. This technology also allows propeller blade frequency to be adjusted, thus preventing resonance.

Ratier-Figeac and Dowty, the two competing bidders for the A400M propellers, both commissioned NLR to make their models. Most of the final wind tunnel tests were also conducted at NLR facilities. The reason being that our wind tunnels are equipped with a unique measuring system that can monitor the interplay of aerodynamic forces that affect a propeller aircraft. The system registers the subtle variation in forces that are exerted when the propellers are mounted on the model. The measurement of such forces is particularly difficult, as it is hampered by the ducts carrying compressed air to drive the propellers. NLR has developed special equipment to eliminate the disruptive forces emanating from these ducts.

Another unique instrument developed by NLR is the rotating balance, which is installed between the engine and the propeller. This is used to gauge how efficiently engine power is converted into propeller thrust, which is a key concern for propeller designers, engine manufacturers, and aircraft designers. And again, NLR is one of the few institutes in the world that has an instrument of this kind.

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CORRUGATION STRENGTHENS RIBS

There is a less labor-intensive means of reinforcing plating material.The only problem is the design principles haven't found their way into the manuals yet.

The old adage - unknown, unloved – apparently also applies when it comes to reinforcing structures. Traditionally, plating is made more rigid by gluing or riveting on angle sections. Years of experience have taught us exactly how this should be done, and exactly how many angle sections are needed to achieve a given strength. Simply open the manual and check the tables.

However, plating can also be reinforced by molding cigar-shaped creases in the material. This makes it stronger, as is the case with corrugated iron. The creases are molded with a press. This is a cheaper than traditional techniques, which makes it an interesting opion. However, the design principles are not yet outlined in the manuals. As a result, the industry has to keep experimenting with patterns, crease depth, and plate thickness. This is expensive and time-consuming. Consequently, corrugated ribs are seldom suggested as an option.

But all that is set to change, since the NLR laid down design principles for corrugated ribs in 2004. This took a few years of research, involving computer simulations of failure modes and the testing of various rib patterns.

Simulations were used to subject materials to forces matching those exerted on an aircraft wing, which is typically a place where reinforced plating is used. The results were surprising. A pattern of round indents ended up scoring far better than the cigar-shaped creases commonly used in corrugated ribs.

Many calculations were made to assess the full range of options, including variations in plate thickness and density, and indent depth. Stork Fokker AESP subsequently created a series of samples using various types of metal, as well as a composite material.

The samples were subjected to forces closely matching those applied in the calculation phase. NLR's predictions of the material's behavior proved to be so accurate, that a number of preliminary design principles could be laid down. However, these principles will only appear in the manuals once they have undergone further extensive validation.

Nevertheless, Dutch industry is already putting these design innovations to good use. Corrugated ribs have already been applied in the wings of two types of Airbus, and Stork Aerostructures has proposed to used similar reinforcements in the vertical stabilizer of the new Boeing 787.

NEW TEST RIG FOR GAS TURBINE SEALS

The seals used in gas turbine engines could be improved considerably. NLR now has its own rig for testing these seals.

In 2004, NLR opened a new facility for testing the internal seals in gas turbine engines. This seal test rig was designed and built in collaboration with turbine manufacturer Pratt & Whitney and Eldim, a Dutch supplier of turbine components. The new facility is used to assess seal performance under extreme variations in pressure, high temperatures, and high rotation speeds – a complex combination of conditions.

The industry needs a facility of this kind to analyze new seal materials and geometries. The industry is actively designing and applying new seals, because there is much to be gained with relatively limited investments. The better the seal between the rotating and stationary sections of the turbine rotor, the less air will be leaked, improving the engine's performance.

Until now, new seals were mostly developed on the basis of simple tests and practical experience. It also bears mentioning that there is no reliable method to calculate the quality of seals. NLR is, however, striving to improve the methods of calculation, with the aid of data from the new test rig. Such test data are needed to validate computer simulations. In the future, these simulations will be used to predict the complexities of air flows around seals in turbine engines. The test rig is also being used to hone empirical principles that are currently applied in seal design.

At the heart of the new rig is a pressure chamber with a 50-cm diameter, large enough to hold a model of a seal. These models consist of a disk mounted on an axle that rotates inside a seal ring made of metal honeycomb. The pressure chamber simulates the conditions within a turbine engine, including the extreme pressure variations to which the seal will be exposed. This demands sophisticated design, because pressure variations generate extreme forces in the test facility. High rotation speeds make it difficult to keep the rotor free of vibration. High temperatures, which lead to material expansion, make the design even more complex.

It took four years to incorporate these seemingly conflicting conditions into a single facility. Following a series of experiments, the rig was equipped with a dynamic regulation system, which adjusts pressure balance in the chamber. The bearing system was also optimized in a series of design phases, so that it can be pushed to the limit. The rig can now handle temperatures of up to 800° C, and pressure variations of up to 2.4 MPa. Seals can be tested at speeds of up to 450 revolutions per second. Since the opening of the new rig on October 15, 2004, various seals have been successfully tested. Manufacturers are currently using the facility to develop and validate new seal designs. In addition, efforts are underway to upgrade the rig, so that it can handle even more extreme conditions.

CENTER FOR COMPOSITES BRINGS BUSINESSES TOGETHER

NLR has teamed up with businesses and universities to established a technology center for the development of innovative manufacturing techniques using composites. Innovation improves the competitive edge of all involved.

The aviation industry is constantly seeking materials that are stronger, lighter, and more corrosion-resistant. For many years, NLR has therefore been developing aircraft components made of composite materials. More recently, quite a number of Dutch companies, large and small, have begun specializing in the manufacture of composite components, composite materials, and molds. In 2004, NLR was involved in the development of composite landing gear for the NH90 helicopter, working in close collaboration with the manufacturer, Stork SP Aerospace of Geldrop, and with Eurocarbon of Sittard, which weaves carbon fibers into tubular structures. Meanwhile, the universities of Delft and Twente were also working on composites.

All of these parties stand to benefit from joining forces. NLR therefore paved the way for the Automated Composite Manufacturing (ACM) Technology Center in 2004, to gain further insight into composites and to improve innovation. With funding from the Province of Flevoland, NLR acquired an Advanced Fiber Placement robot, which will be used to conduct applied research into automated composite manufacture. With this robot, NLR can create structures that would otherwise have been difficult, if not impossible to realize. This will allow composites to be more broadly applied, at lower cost.

Composite components for the aircraft industry are generally made of carbon fibers and synthetic resin. The fibers give the composite material its strength, while the resin bonds the fibers. The robot is capable of placing narrow strips of composite material on just about any form. And because it can bond the composite on application, only one production step is required.

This facility, the only one of its kind in the Netherlands, opened in 2005. It will give the Netherlands a significant head start over low-wage nations, which are set to become key competitors in the labor-intensive composite manufacturing market.

In 2004, all parties involved in the establishment of the ACM Technology Center got together on several occasions. This included representatives from Stork (aircraft), Dutch Space (aerospace) and Donkervoort (automotive), as well as aeronautical experts from the universities of Delft and Twente, and even a company that specializes in pre-formed racing sails. The new center will play a leading role in education, offering workshops and training, and in the facilitation of research and innovation.

MOBILITY

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More Takeoffs and Landings

Capacity at Schiphol

Flying Without Air Traffic Control

MOBILITY

An endless stream of goods and passengers moves to and from and through the Netherlands – and that certainly applies at airports. Ours is an accessible country. But this accessibility is easily endangered when bottlenecks arise, hampering the flow.

MORE TAKEOFFS AND LANDINGS PER HOUR

Aircraft always give each other a wide berth to avoid each another's wake turbulence. With the aid of smart planning techniques, however, these distances can be safely reduced, significantly increasing airport capacity.

Aircraft create wake vortices when taking off and landing, restricting runway capacity. These vortices usually dissipate quickly, but most airports opt for the safest scenario, which means the interval between aircraft taking off or landing often amounts to several minutes.
However, with the aid of accurate meteorological data and precise measurements of wake turbulence, more efficient intervals can be set, particularly when weather conditions are stable. Depending on traffic volume, these adjustments can generate capacity gains of up to 10%, which has major commercial benefits.

© VASCO GARCIA

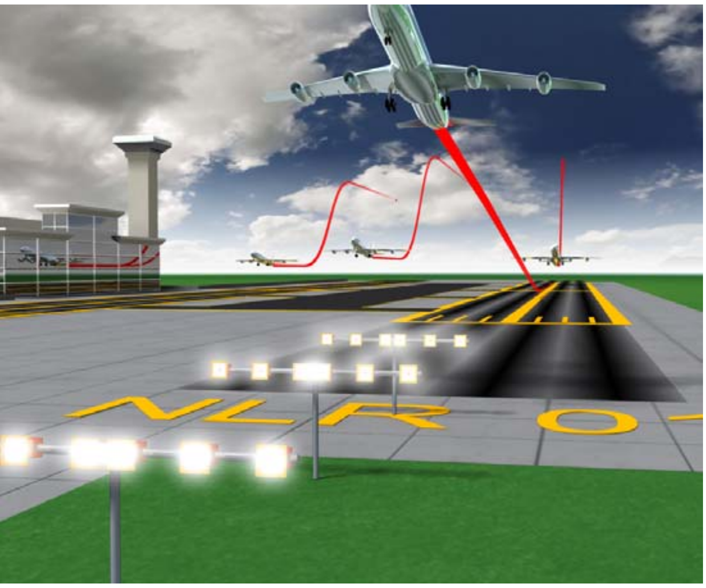
In 2004, NLR successfully studied various aspects of the manner in which wake vortices affect air safety. One study focused on safe utilities that can be used by air traffic control. The ATC Wake research program, commissioned by the European Commission, was jointly conducted by NLR, Eurocontrol, European industry (Thales), and our German counterpart DLR. Under NLR's direction, these parties jointly developed procedures that help air traffic controllers decide how long the intervals should be.

These procedures are based on laser technology called Lidar, that monitors the movement of dust particles through the air. This system is used to continually monitor wake turbulence on runways. This turbulence data is combined with meteorological data to generate recommendations for intervals, which are displayed on the air traffic controller's screen. The recommendations are also used in planning systems at air traffic management.
In 2004, prototypes of the ATC Wake system were tested in NLR's research simulators for air traffic control (NARSIM Radar and NARSIM Tower). The tests were so successful, that Eurocontrol has decided to prepare the system for rollout, so that airports can begin conducting preliminary tests that will lead to full implementation around 2010.

Another NLR study focused on pilots, who would find it easier to avoid dangerous situations if they could detect vortices from the cockpit. This I-Wake study was also commissioned by the European Union. NLR is responsible for the test flights and cockpit display design. One of NLR's research aircraft, the Cessna Citation II, was equipped with a Lidar installation. To get a good view of conditions ahead, the laser mirror had to be mounted on the outside of the aircraft. This major modification had substantial impact on the aerodynamics of the aircraft, which subsequently had to be recertified. In 2004, this modified research aircraft conducted several tests flying in the wake vortices of an Airbus A340-600, a large commercial aircraft. These tests revealed that wake vortices can be effectively monitored in this manner.

HOW MUCH CAN SCHIPHOL TAKE?

What are the limits to Schiphol's capacity in its current configuration? Detailed simulations provide a solid starting point for political deliberation as well as technical and organizational measures.



Air traffic at Schiphol is growing annually. But growth is bound by environmental regulations and limitations in airport and airspace capacity. However, no one knows exactly where the absolute limit lies. This is simply too difficult to predict, owing to the complexities of flight paths, approach and take-off procedures, and shifting timetables. At the request of the Ministry of Transport, Public Works & Water Management, NLR conducted detailed simulations to assess when the limits of capacity would be reached within the existing framework of technology, procedures, and regulations. The simulations brought together the expertise of KLM Royal Dutch Airlines, Amsterdam Airport Schiphol, the Royal Netherlands Air Force, the Netherlands Civil Aviation Authority, Air Traffic Control the Netherlands (LVNL), and NLR.

NLR managed to convince the other parties that the complexities of the real world could be accurately modeled. Using NLR's fast-time simulation, the movements of a large number of aircraft and air traffic control activities can be simulated faster than real-life. During the simulation (using the TAAM system), researchers see everything in fast motion — aircraft approaching and climbing out, taking off and landing, taxiing and being handled at the gate. Prior to the simulation, NLR also compiled an inventory of real-world restrictions, and incorporated these into the simulation.

Under normal weather conditions, Schiphol makes use of three runways at a time — either two for takeoffs and one for landings, or vice versa. During the day, runway use is varied on the basis of set schedules. Furthermore, airport capacity is affected by changes in fleet makeup. KLM provided the necessary prognoses to incorporate this factor. Parallel to the simulations, NLR also calculates the associated noise contours.

One of the key factors is the maximum workload that air traffic controllers can handle in the six sectors into which Schiphol's flight paths are subdivided. Based on extensive consultation with air traffic controllers and on comparisons of fast-time simulations with real-life circumstances, NLR has not only established how much time an air traffic controller needs for each action, but also that controllers may only be taxed to 70% of their full capacity if they are to remain fully focused. During the simulations, NLR gradually stepped up the intensity of air traffic, to determine when the efficiency of air traffic handling at Schiphol would go into decline. NLR evaluated these borderline cases by presenting them to experienced air traffic controllers. The results of this study are currently being assessed.

This capacity study will be followed up in the years ahead, with studies examining what technical and organizational adjustments could help Schiphol raise its capacity. Apart from its expertise in developing simulations, NLR could also conduct independent evaluations of the environmental and safety aspects involved.

FREE FLIGHT OVER THE MEDITERRANEAN

Imagine aircraft crisscrossing the Mediterranean without the assistance of air traffic control. This test ushered in a new way of utilizing airspace.

© NICK ABBOTT

There is enough airspace for pilots to deviate from their prescribed flight routes — that is the basic idea behind Free Flight, a new model for airspace usage, initiated by NLR. Free Flight reverses the traditional roles — not air traffic control, but pilots determine how they will respond to surrounding air traffic. In the Free Flight model, pilots use their avionic equipment to assess the situation and decide how to respond if another aircraft gets too close.

The model was first tested over the Mediterranean in 2004. The test was commissioned by the European Union and coordinated by the Italian air traffic control authority, ENAV. The participating aircraft were equipped with prototypes of the Airborne Separation Assurance System (ASAS), an onboard system that NLR had previously developed for Free Flight. ASAS visualizes all nearby aircraft on a screen in the cockpit, and also offers pilots recommendations on how to proceed. The system enables pilots to follow another aircraft at a safe distance and to react to its movements autonomously, without directions from air traffic control. This makes it easier for aircraft to fly in single file, without air traffic control having to give directions constantly. ASAS could also be used to take this model one step further – allowing aircraft to cross each other's flight paths. The system can even be used to plot an entire flight, without having to rely on preset routes.

The tests over the Mediterranean were conducted using equipment that incorporated existing right-of-way regulations. The tests ran smoothly, with pilots carrying out various maneuvers, such as tailing another aircraft or crossing its flight path. In the next phase, pilots will be freed of all intervention by air traffic control.

Eurocontrol expects that ASAS will be officially introduced in 2010, but only for limited maneuvers, such as flying in single file. Fully autonomous free flight is expected to be introduced by 2015. Ultimately, this will lead to more efficient use of airspace, reducing the burden on air traffic control and enhancing their ability to absorb anticipated air traffic growth.

Free Flight will also help save a lot of fuel. If pilots are permitted to plot their own courses, routes across Europe would be 3% shorter, on average, compared to the existing, angular network of preset routes.

SAFETY

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Seeing Further from the Cockpit

Smoldering Insulation

Modifying Norwegian ATC

The Risk of Vibrations

SAFETY

The aviation industry has more safety regulations than any other. You could fill an entire library with the international codes for aircraft. And so it should be – passengers have a right to safety.

SEEING FURTHER FROM THE COCKPIT

Photo-realistic images in the cockpit make pilots more aware of the circumstances in which they find themselves.This means they are better prepared to respond to problems, should they arise.

A pilot's horizon is limited. Few of the onboard instruments are able to detect anything more than a few minutes away. That's enough to ensure flight safety, but not very helpful if you have to analyze a difficult situation. Existing data communication technology makes it possible to look further ahead, gathering data for the entire route, and revealing potential difficulties along the way. If a pilot flying over Brussels can see a storm brewing over the Pyrenees, he will have plenty of time to take appropriate action. In short, he has more time to make decisions, thus reducing the risk of accidents.

Over the past three years, NLR has made an significant contribution to ISAWARE II (Increasing Safety by Enhancing Crew Situation Awareness), a major European research project to study new safety technology. Other major players, such as Thales and Airbus, are also involved in this project.

During the tests, both the horizontal navigation display and the primary flight display were enhanced to feature near-photo-realistic images of the surroundings. One particularly important upgrade is the information about terrain altitude. The new vertical navigation display maps out the terrain profile for the entire route. The terrain profile also features pictograms with warnings of obstacles or bad weather along the route. There is also a taxi display, showing the situation on the ground at the destination, including the presence of other aircraft. This makes it easier to taxi in poor visibility and reduces the chance of unexpected encounters.

In addition, a presentation has been developed with a schematic display of the minimum flight altitude that pilots must adhere to. At present, pilots use air charts to interpolate permissible altitudes, which can get pretty uncomfortable if you have to descend quickly to evade an oncoming aircraft.

NLR is developing a series of cockpit simulations within this project, assessing how pilots utilize the extra information. In 2004, test pilots used the stationary simulator at Darmstadt University of Technology to make several test flights over Switzerland, taking off from Sion Airport, deep in the Rhone Valley. In experiments of this kind, pilots are routinely surprised with potentially dangerous situations. Only under the pressure of a realistic flight, can researchers assess whether the new information will help pilots to respond adequately to the situation at hand.

Based on these first simulator tests, the information display was improved. In 2005, airline pilots will test the final version in GRACE, NLR's full-motion research simulator for commercial aircraft. Similar tests will also have to be conducted to certify the system in due course. These tests will demonstrate that the systems meet requirements and do not jeopardize air safety. Experimental data are vital for ensuring the latter. The project has generated a great deal of new insight, which is already being put to good use in the aircraft industry. For instance, in the design of the Airbus A380 cockpit.

THE FORGOTTEN COMPONENT

Electrical wiring is often buried deep in the aircraft, well out of sight. Damaged wiring can lead to smoldering insulation material — and that can be dangerous.

Aging wiring in aircraft is a growing problem. The synthetic insulation covering electrical wiring gets brittle with time. Hairline cracks develop, causing current leakage, and further degeneration can eventually lead to fire. This phenomenon is known as arc tracking.

In the late 1990s, there were a number of aircraft accidents in which aging wiring was probably to blame. Researchers worldwide are seeking technology that will detect this problem at an early stage. NLR conducted a series of experiments in 2004, to gain greater insight into the aging process and to develop a means of detecting problems in aircraft wiring.

In the 1970s, Kapton was a popular insulation material. We now know that this material is highly susceptible to arc tracking. Around this time, there was also a sharp increase in the amount of electronics aboard aircraft. And that meant more wiring. To save weight, insulation was made as thin as possible. Today, this is making the problem all the more pressing. Vibration, heat, and the absorption of oil and other contamination have made the insulation more and more brittle over the years. Hairline cracks and contamination combine to cause current leakage. This, in turn, generates heat and causes further degeneration, which may eventually trigger a small spark that sets the insulation smoldering or on fire.

This is a gradual process over a long period of time. Current leakage increases over time, but can be of such short duration that the fuses cannot detect it. In addition, this process often results in the formation of carbon, which is also a conductor, creating an even greater flame arc. Ultimately, entire sections of cable loom can burst into flames — only then do the fuses blow.

The trick is to detect the problem at an early stage, and to pick the right moment to shut down the current passing through the wiring. A series of tests were conducted using different types of wiring, which were subjected to simulated aging and then charged with electrical loads matching those of normal flight conditions.

The tests revealed that rapid fluctuations in current are an indication of leakage. A statistical criterion was derived from the results. This criterion may be used to assess whether arc tracking is taking place. This fundamental insight can now be used to develop equipment that helps detect problems in the wiring before dangerous situations arise.

MODIFYING AIR TRAFFIC CONTROL

New European guidelines stipulate that modifications of air traffic control should be subjected to risk analysis. NLR has developed various methods for doing so.

Modifications of air traffic control can have unexpected consequences. That is why new European regulations require that all changes are subjected to risk analysis. NLR has developed methods to conduct reliable analyses of any situation. This makes NLR one of the few institutes in Europe capable of carrying out risk analyses of this kind, using a wide range of analytical techniques. NLR regularly carries out assessments of this kind for Air Traffic Control the Netherlands (LVNL) and other aviation authorities. In 2004, NLR started an analysis of proposed modifications of Norwegian air traffic control, which were also subject to European regulations. In the years ahead, ATC assistants will be withdrawn from towers at around 20 different airports, leaving three people in each tower, instead of four. The authorities believe this is possible because new equipment will be capable of taking on some of the tasks in the tower.

NLR started by analyzing the airport at Tromsø, a town located just within the Arctic Circle. The analysis was conducted in collaboration with Acona, an Anglo-Norwegian safety consultancy. An analysis of this kind begins with a series of coordinated brainstorming sessions, where participants think up as many and as varied forms of danger as they can. The success of this process hinges on the ability of all participants to take an open view of the situation. This was especially difficult in this case, because the proposed changes had already triggered fiery debate in the Norwegian press. This was a sensitive issue. However, the techniques that NLR consultants deploy in such analyses always reveal relevant risks, even under such difficult circumstances.

The identified dangers are tested by NLR safety experts, who usually rely on the operational expertise of people at the airport, in combination with information derived from a database of known risks. In this way, they can assess what kind of safety risks may arise from the identified dangers. To do so, NLR has developed methods to classify the consequences and risks of each danger. Separate analyses have to be made for each airport. Tromsø is cloaked in darkness for much of the winter, and snow regularly disrupts operations. And in the summer, the airport is used by many small aircraft that fly tourists to the north of Norway to see the midnight sun. These are all important factors in analyses of this kind.

Ultimately, the analysis reveals the key risks of the new situation — and whether these are acceptable. Once the plans for Tromsø have been fully analyzed, NLR will begin conducting its safety analyses at other Norwegian airports.

TIGHT SCHEDULE FOR OSCILLATION ANALYSIS

Only when the tailpiece of the NH90 helicopter was in the final phase of development could the risk of 'flutter' be definitively assessed. At that stage, time was of the essence.

Oscillation is a major risk for helicopters and fixed-wing aircraft. This may arise when air flows set parts of the structure in motion. Under certain circumstances, this motion becomes self-amplifying. This phenomenon is known as flutter, and it can have sudden and dramatic consequences, especially if a wing or tailpiece breaks off. In the past, aircraft have crashed on their first test flight, due to unexpected flutter.

Because this is such a dramatic and hazardous phenomenon, companies regularly approach NLR for an independent evaluation of an aircraft design. NLR assesses susceptibility to flutter with the aid of computer simulations. Calculations of this kind are indispensable when designing and certifying fixed-wing aircraft and helicopters

In 2004, Stork Aerostructures commissioned NLR to conduct a flutter analysis on the tailpiece of the NH90 military helicopter it is designing and manufacturing. Using its trend-setting analytical system AESIM-BASIC, which was developed over the past 15 years, NLR swiftly and accurately calculated flutter risk under a wide range of circumstances.

There is often a tight schedule for flutter certification analyses. The reason being that flutter can only be calculated once the design — both internal and external — has been finalized, and only after the prototype has been subjected to oscillation analysis on the ground. The actual external form determines the interplay between the structure and external air flows. And the internal features determine the structure's mass, rigidity, and vibration damping characteristics, which are essential for predicting resonance. In short, NLR needed the entire helicopter to check for flutter in tailpiece, and this included all components supplied by other parties.

Once these details were available, NLR had to make every day count. Fortunately, AESIM-BASIC can work very quickly. The system is capable of automatically incorporating most of the form properties into the analysis. That means a new shape can be swiftly evaluated, and the same goes for any design modifications that are subsequently made.

AESIM-BASIC can assess the impact of a wide range of aerodynamic phenomena. For instance, by simulating shock waves and other non-linear aerodynamic conditions. It can also provide simple modeling. Both of these features are essential when evaluating flutter at trans-sonic speeds — the cruising speed of many commercial aircraft.

Owing to its extensive experience in this field, NLR managed to complete the analysis of the NH90's tailpiece within a few weeks. The structure proved to be flutter-free, and the tail designers can now rest easy as they await the first test flights.

ENVIRONMENT

Inspecting Pipelines from Space

Reducing Aircraft Noise Impact

Analyzing Noise and Complaints

ENVIRONMENT

With 16 million people inhabiting an area of just 35,000 square kilometers, the Netherlands is one of the most densely-populated countries in the world. It is therefore hardly surprising that our country is among the global frontrunners in the development of environmental policy. One example is the use of noise and odor contours around airports, intended to protect local inhabitants.

INSPECTING GAS PIPELINES FROM SPACE

Can satellites be used to monitor Europe's gas pipelines? NLR played an key role in the EU program PRESENSE.

Europe is crisscrossed by about 200,000 kilometers of high-pressure gas pipelines. The people in charge of this immense network have to monitor it day in, day out. Damage to the network can present the threat of explosion and environmental damage. The pipeline wardens usually conduct a helicopter patrol every two weeks, so that they can take action wherever damage may be imminent (e.g. as a result of construction activity). There is, however, an interesting alternative to these time-consuming, expensive, and eco-unfriendly patrols: observation from space.

NLR played a key role in the EU program Pipeline Remote Sensing for Safety and the Environment (PRESENSE), which explored the possibility of an observation system that automatically identifies suspect locations and reports them to the pipeline wardens for assessment. The program, completed in 2004, also involved the Netherlands Organization for Applied Scientific Research (TNO), the Dutch gas supplier Gasunie, and a number of foreign partners.

NLR mapped out the component assembly and assessed the feasibility of the observation system. To make adequate observations, highly-detailed satellite photos are required, with a resolution of around 1 meter. Photos of this kind capture an area no more than 10 km wide. To get a complete overview of the pipeline network, a great number of satellite passes would be required, particularly because darkness and cloud cover would also hinder the process.

NLR computer simulations revealed that four satellites (in polar orbits) could cover 70% of the European gas pipeline network every two weeks, and that six satellites could cover 80%. The database with up-to-date satellite photos will cover more than 50% of European soil. It would therefore also be interesting reference for countless other users of geo-information, for instance, for agriculture, town and country planning, and environmental and coastal management.

Aircraft belonging to our European counterparts performed test flights above gas pipelines in the Netherlands, Germany, and France. The images were semi-automatically processed. NLR built a system that stores the results and distributes them in the correct configuration. This proved that high-risk locations could be identified using image recognition, after which reports could easily be made available to gas pipeline wardens.

In July, NLR team up with the Geomatica Business Park (GBP) in the Netherlands' Noordoostpolder, and presented itself as a strong contender for the further development and handling of image analysis. The Business Park itself has a great deal of practical experience in satellite image storage, processing, and analysis. The GBP is developing itself in close collaboration with, and in close proximity to the NLR's facility in the Noordoostpolder. In short, this is a healthy cross-pollination of science with practical business experience.

QUIETER TAKEOFFS AND LANDINGS

Alternative procedures for takeoffs and landings can substantially reduce noise impact on the ground. NLR is heading the Sourdine II project, an international study of environmental impact, safety, and acceptability of the new procedures.

More and more airports are taking measures to limit noise impact on their surroundings. Public acceptance of noise is decreasing all over the world, while the number of aircraft movements is increasing. This discrepancy can be resolved by developing new takeoff and landing procedures.

NLR is a key center of expertise in the study of flight procedures, both in the Netherlands and abroad. NLR is heading the EU's Sourdine II project, which develops and validates low-noise flight procedures. The project is being conducted within a consortium including Airbus France and the Eurocontrol Experimental Center. The project also consults with a panel of European and American experts from aviation institutes, airports, and industry.

Noise impact is not only determined by flight altitude, but also by an aircraft's speed, engine capacity, and operational configuration (the use of flaps and landing gear). In 2003, the Sourdine II project analyzed the noise impact of a wide variety of alternative flight procedures, using two different aircraft types, the Airbus A320 and A340. In 2004, four approach procedures and two climb-out procedures were selected and extensively assessed for safety, their acceptability to air traffic controllers and pilots, and their consequences for airport capacity.

Safety is a key factor in existing procedures. Air traffic controllers are used to separating aircraft, by having them fly at different altitudes, for instance. Approaching aircraft are therefore guided down step by step. However, if an aircraft makes a continuous descent, it will pass a specific point on the ground at a higher altitude, using less engine power. That means less noise impact on the ground. Furthermore, if aircraft climb out and approach along curved routes, they can be steered around more densely populated areas.

But can air traffic controllers and pilots cope with such modified procedures? This was the key question during exercises in the NLR simulators for pilots (GRACE) and air traffic controllers (NARSIM Radar and NARSIM Tower). Test pilots and experienced air traffic controllers carried out the new procedures, during which workload and acceptability levels were assessed.

Another key question is: Are the procedures safe? To find out, NLR's Traffic Organization and Perturbation AnalyZer (TOPAZ) was used to calculate the risk of two aircraft coming too close together when using the new landing procedure.

And how will these new flight procedures affect airport capacity? The partners in the Sourdine consortium conducted analyses at their own airports — in Amsterdam, Paris (CdG), Naples, and Madrid. There is a great deal of international interest in the results of Sourdine II, which will be announced during the course of 2005. NLR will be giving presentations in Europe and the US.

THE SIMPLE LINK BETWEEN NOISE AND COMPLAINTS

The link between aircraft noise and public complaints was always vague, until NLR put an existing noise indicator to work at Schiphol Airport.

There is a yawning gap between regulation noise standards and noise perception among the general public. Standards take account of total noise impact and consist of formulas to calculate the cumulative effect of all aircraft movements. Other assessment factors are also taken into account, including the time of day, altitude, and aircraft type. Ultimately, noise standards are therefore reduced to a single figure, reflecting all effects over the course of the full year.

Public perception of noise works quite differently, however. A single noisy flight can spark a flood of complaints. Because standards apply a completely different system to assess noise impact, they are very difficult to link with public complaints. In fact, most complaints do not come from areas with the highest cumulative noise impact.

In 2004, NLR managed to bridge the gap between objective data and subjective perception. During a study commissioned by Amsterdam Airport Schiphol, NLR researchers assessed how different noise indicators tallied with complaint patterns. Contact with Australian colleagues revealed that they are getting good results using an indicator that counts aircraft with a noise level above a set threshold value. The NLR researchers opted to count the number of aircraft passing overhead each day registering louder than 60 decibels on the ground. Data for this "Na60" indicator are readily available via the existing noise monitoring system, Fanomos, which NLR developed and now forms the basis for noise regulation around Schiphol and many other airports worldwide.

Using the Na60 noise indicator, shifting complaint patterns were analyzed around the town of Castricum, northwest of Schiphol. As operations were stepped up on the new Polder Runway, the number of complaints rose steadily. The shift in complaints corresponded closely with changes in Na60 values. In short, increases in Na60 values matched increases in complaints.

The results of this study sparked a heated response in Castricum, where local residents felt vindicated about the complaints they had made. Finally, their subjective perception had been quantified using a single noise indicator. Amsterdam Airport Schiphol, which had commissioned the study, was also pleased with the results. It is now easier for them to understand and analyze complaint patterns. However, further study will be required to validate this noise indicator for other areas and times of day.

Meanwhile, the Na60 indicator is being used in a number of noise studies. The Expert Committee for Aircraft Noise used the Na60 indicator in its third progress report to the government. And the Na60 indicator will also be used to evaluate the new enforcement system, which the government plans to implement shortly.

DEFENSE & PEACEKEEPING MISSIONS

Flares Mislead Missiles

Virtual Airborne Enemies

Assessing Wear in Planes and Helicopters

NATO Simulation Exercise

DEFENSE & PEACEKEEPING MISSIONS

Times are changing – and this certainly applies to the Dutch armed forces. More often than not, Dutch troops operate far beyond NATO territory, in Bosnia, Eritrea, Ethiopia, Afghanistan, and Iraq. These peacekeeping missions impose new demands on personnel, but also on their equipment.

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SPECTRAL FLARES PROTECT DUTCH AIR FORCE

Dutch military planes and helicopters on peacekeeping missions are being equipped with spectral flares to divert advanced infra-red guided missiles.

Infra-red guided missiles track the hot exhaust fumes emitted by planes and helicopters. To evade these missiles, the aircraft release flares; high-quality “fireworks” that emit a great deal of heat, diverting the missile. However, modern guided missiles are not so easily fooled. They can often detect the difference in temperature between exhaust fumes and the much hotter flares. That means existing flare types are not always effective.

With the support of NLR, the Royal Netherlands Air Force equipped its F-16 fighters, Apache attack helicopters, and Fokker 60 transport planes with spectral flares, before dispatching them to Afghanistan and Iraq in 2004. The same was done with Chinook helicopters and Hercules transport planes back in 2003. In many instances, there were only a few days to develop these flare programs. Fortunately, NLR’s extensive involvement in NATO research programs provided crucial background knowledge.

NLR developed flare programs for each aircraft type. These programs determine what types of flare need to be released in which direction to offer maximum protection against guided missiles. To ensure protection against both older and newer types of missile, the aircraft release both standard and spectral flares, the latter having the same radiation spectrum as the aircraft itself. The flares must attract the full “attention” of the missile and divert it. The flare programs were based on computer simulations, which show the paths of the flares from all angles around the aircraft. It is of crucial importance to validate these computer simulations. This is done by means of test flights, during which aircraft release their flares near NLR’s Seeker Test Facility, a transport container with measuring equipment and a battery of heat-seeking missiles that track maneuvers from the ground. The measuring equipment accurately registers how the missiles react to the burning flares – do they continue to track the aircraft, or do they target one of the flares?

Because of their lower combustion temperature, spectral flares must meet stringent demands. NLR has tested spectral flares for various manufacturers since the late 1990s. These tests assessed whether the flares ignited quickly and reliably, and whether combustion was stable. NLR teamed up with the Royal Netherlands Air Force and took part in intensive NATO flight tests, during which thousands of spectral flares were released.

VIRTUAL COMBAT MANEUVERS IN AN AIRBORNE F-16

Flight training with fighter aircraft is much more effective when pilots are confronted with virtual adversaries. NLR and Dutch Space developed the Embedded Combat Aircraft Training System (E-CATS) to demonstrate the possibilities.

A fighter pilot's training hours are not all equally effective. Pilots must sometimes play the role of adversary to help train other pilots. These "Red Air" flights are no longer necessary if onboard electronic equipment can simulate enemy aircraft. This "embedded training" cuts costs, is highly realistic, and provides a flexible training program. Embedded training is also safer, because aircraft no longer have to engage in mock combat with each other. In addition, it also allows virtual launch sites for heat-seeking missiles to be programmed at any designated point on the ground. The Netherlands is in favor of equipping the Joint Strike Fighter with embedded training functionality.

NLR teamed up with Dutch Space to develop the embedded training concept. After conducting a feasibility study, NLR built a demo system in 2003/04 called E-CATS, for embedded training aboard an F-16. The Netherlands Ministry of Defense commissioned the project, giving test pilots from the JSF Program Office and Lockheed Martin the opportunity to spend a week getting acquainted with the system in April 2004. The test pilots were enthusiastic about the system. One of them even reported that he had found the combat simulation so realistic that he involuntarily looked outside to catch a glimpse of his "adversary."

NLR has developed electronics that add data about the virtual adversary to the F-16's existing onboard systems. Apart from hostile threats, the system also simulates friendly aircraft that have to be taken into account during an exercise. The fighter's Electronic Warfare Management System is supplied with simulated data about this kind of aircraft. E-CATS also simulates communications with Ground Control Intercept during the exercise – a voice reviews the situation every minute and reports whether aircraft in the vicinity are hostile or friendly.

Because there is little room to spare aboard an F-16, one of the two system computers was installed in the hollow tip of the pylon under the aircraft, while the other was placed in the aft avionics bay. NLR tested the electronics for their ability to withstand vibration, temperature and pressure fluctuations, and electromagnetic interference. The computers were developed in such a way that the pilot can disengage them in the event of malfunction.

Dutch Space developed part of the software that simulates the chosen training scenario. NLR supplied software that makes it easier for trainers to compile scenarios. With a simple click of the mouse, they can designate missile launch bases and set virtual flight movements, which are then loaded into the onboard electronics of the training aircraft. The onboard electronics also record the entire training, so that pilots can review their own maneuvers and combat actions, as well as those of their virtual adversaries, during debriefing.

P3 SLAP
Commissioned by
the Royal Netherlands Navy

CHECKING WEAR AND TEAR ON CHINOOKS AND ORIONS

The Dutch Ministry of Defense has invested heavily in Chinooks and Orions.Their lifespan can be extended by carefully checking for wear and tear.

The Chinook is the largest helicopter of the Royal Netherlands Air Force. It is used for transporting troops and materiel. The Netherlands has had 13 of these workhorses since 1995. In recent years, NLR developed a program allowing the air force to effectively manage its Chinooks and to keep operating costs as low as possible. All helicopters were equipped with a flight data recorder that registers flight information. Three helicopters were also equipped with a system that measures loads with the aid of strain gauges. NLR staff spent several days aboard the helicopters in 2004, to record the types of maneuvers — turning, descending, hovering, landing they performed. This enabled them to accurately interpret the recorded flight data. NLR subsequently charted the operational range, based on 1,000 flight hours, recording how often the helicopters executed certain maneuvers, and what forces they had to withstand. Using the collected data, NLR developed software linking helicopter use with wear to the fuselage, rotating parts, and engine components. NLR also developed an application allowing the air force to predict wear during operational use. This means they can assess operational costs in terms of lifespan, maintenance, and spare parts, irrespective of where the helicopters operate. NLR is a trendsetter in this regard, because similar research programs are currently a hot item at in the US Army and British RAF, which also operate Chinooks.

NLR is conducting similar studies on various other aircraft and helicopters (the F-16, Hercules, Cougar, Apache and Lynx) for numerous clients at home and abroad, including the Belgian, Portuguese, Spanish, and Norwegian defense forces.
Monitoring operational use and potential lifespan are key aspects of modern flight management, whether it be in helicopters, fighters, transport planes, or maritime patrol aircraft. This can take various forms. For example, from 2000 through 2004, NLR analyzed material fatigue in the Lockheed P-3 Orion maritime patrol aircraft, as part of the Service Life Assessment Program (SLAP), which was conducted in a consortium with America, Canada, Australia, and Norway. This program was commissioned by the Royal Netherlands Navy.
The “tear down” was performed on a decommissioned aircraft, which was subjected to additional stress under laboratory conditions. NLR studied the left wing. The part was sawed into pieces at Schiphol, after which our test laboratory in the Noordoostpolder scrutinized 5,600 coupons for cracks. The collected data will be used to develop computer programs that will forecast which parts need to be replaced to extend the Orion’s lifespan. This study is also of interest to Germany, which purchased the Dutch Orions.

NLR SIMULATOR JOINS NATO AIRBORNE EXERCISE

Pilots can undergo only limited training for international operations. However, a recent transatlantic experiment revealed that, by linking simulators, many more pilots can be prepared for NATO tasks.

Sixteen combat pilots took off in rapid succession from various airfields in southern Italy. They grouped over the Adriatic before setting course for Split in Croatia. From there they flew different routes to targets in Kosovo. But all is not as it appears. In reality, the pilots were sitting in linked simulators located in Canada, France, the Netherlands, Italy, and Germany. A total of twelve cockpit simulators were linked for the exercise. Even though they were hundreds of kilometers apart, the pilots could see each other through their cockpit windows. Radio contact was also completely realistic. In addition, the exercise involved more than 20 less complex simulations, which took the form of airborne tankers, ground positions, and other support units. Several hours before takeoff, the pilots had prepared for the mission via video conferences — a close simulation of the eye-to-eye contact they have prior to combat missions.

The aim of First WAVE, as the virtual exercise was called, was to investigate whether a link-up of this kind could provide new opportunities for NATO to train for international operations. Until now, training for such missions was limited to joint NATO exercises — costly operations in which only a limited number of pilots can participate. By linking up simulators, many more pilots can train for international operations. Moreover, a simulator closely monitors the pilots' behavior. And when the exercise is over, the film can be rerun so that the pilot can evaluate each action.

NLR assessed the instructional value of a network simulation of this kind. The researchers mapped out the competencies of the mission commander, based on the "Mission Essential Competency" (MEC), which focuses on a mix of crucial abilities. This generates more relevant information than the traditional analysis of separate abilities.

For this exercise, NLR linked four Dutch flight simulators to the NATO network. That meant four Dutch F-16s were "airborne," with three pilots sitting in Volkel and the fourth in NLR's GFORCE simulator, the only F-16 simulator with a 360-degree surround screen. For the purposes of the exercise, all the participating pilots have to fly over the same landscape. Detailed geographic information therefore had to be converted for the specific data formats used by the different simulators.

Data generated by this link-up can be used in establishing a more permanent simulator setup for international operations. The pilots clearly felt the adrenaline pumping. For many of them, this was the first time that they had been able to participate in an international operation.

EXPLORATION & SPACE TECHNOLOGY

Modern Aviation Electronics

Testing Satellite Navigation

Fluid Motion in Space

André Kuipers' Physics Experiments

Ariane 5 in the Wind Tunnel

EXPLORATION &
SPACE TECHNOLOGY

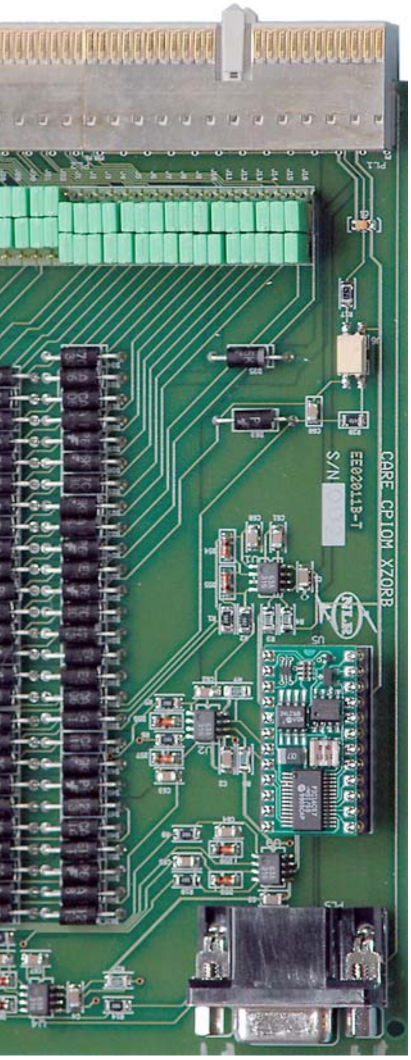
Fundamental research is the basic substrate for technological development. The more we know, the better the technology we develop – more economical, lighter, safer, and more eco-friendly.

TESTING A NEW GENERATION OF AVIONICS

New avionics architecture is set to spark a revolution in the aviation industry. The EU project VICTORIA revealed the possibilities and offered ample opportunity to gain expertise and experience.

Avionics must conform to high functional and safety criteria. Electronic systems and software are therefore subjected to comprehensive tests; for instance, to assess their reliability under hostile conditions, such as high and low temperatures, vibration, and electromagnetic radiation. That makes certification a mammoth task. Although the system's function (its software) generally goes unchanged for decades, the chips in the underlying system may be hard to obtain or no longer available after a few years, which means they must be replaced with alternatives, after which the system must be recertified.

During the coming decade, the aviation industry will switch to a modern, modular system architecture, in which applications will run on an independent hardware platform, as is the case on any personal computer. If the hardware platform is replaced, the same tried and tested applications can still be run. This will ensure greater continuity in the development of avionics, and will make it easier for various manufacturers to contribute to a single system. This modern avionics concept will be a feature of all new commercial and military aircraft around the world.



The EU project VICTORIA, completed in 2004, offered excellent opportunities to gain experience with all the new technologies and concepts. The VICTORIA consortium - which included Thales Avionics, Airbus, NLR, and Fokker Elmo - integrated the new technology into a functioning system prototype that simulated an entire flight during its final presentation in Toulouse. NLR coordinated the certification of all VICTORIA systems. Certification is crucial if the new avionics are to be installed in real aircraft in future. Traditionally, each instrument must be certified separately, with each individual manufacturer bearing full responsibility for ensuring that it functions flawlessly. However, in the case of modular avionics, more than one party may be involved in developing a specific function. NLR has therefore developed a new approach, in consultation with the certifying authorities, whereby systems are tested layer by layer — starting with the basic electronics and then each time new applications are added.

NLR also contributed to system development, supplying VICTORIA with the I/O Module, which converts the signal from classical hardware in the aircraft, such as switches, into reports that are relayed via a 'packet switched' data communications network (AFDX) to all other applications running in the aircraft. NLR opted to develop the I/O Module using commercially available components only.
And finally, NLR assisted Fokker Elmo in developing a Remote Power Distribution Unit (RPDU), which allows the crew to remotely secure and switch off the power supply anywhere in the aircraft. This is currently done from a central point, usually in the front of the aircraft, which requires a lot of extra wiring. In the system prototype in Toulouse, this RPDU is linked to the heart of the aircraft via the I/O Module.

SAFETY TESTS FOR SATELLITE NAVIGATION

Satellite navigation is really taking off — on the ground and in the air. But how accurate and reliable are the location and altitude indicators supplied by satellites? NLR tested the European EGNOS system.

Satellites are showing us the way with increasing accuracy. Aviation can benefit from satellite navigation, provided the systems are accurate as well as reliable. The latter is especially problematic. American GPS satellites can accurately pinpoint positions, but the GPS does not indicate how reliable this is. Atmospheric conditions can disrupt GPS signals, affecting the accuracy of positioning. To prevent this, the European Space Agency (ESA) transmits a correction signal via EGNOS (European Geostationary Navigation Overlay Service). EGNOS also issues a warning within seconds if one of the GPS satellites malfunctions, ensuring that the navigation equipment omits its data from calculations. EGNOS consists of three geostationary satellites and an extended network of reference receivers on the ground.

NLR conducted a series of test flights in 2004 to assess the combined reliability of GPS and EGNOS. An NLR research aircraft was equipped with instruments to register ground position and altitude data from the satellites. This data was then compared with the data supplied by traditional terrestrial navigation systems. Previously, a test version of EGNOS was used for a series of landings at Nice airport, approaching along both straight and curved paths. The latter option is particularly interesting, as it offers airports greater freedom to spread noise impact. In 2004, NLR conducted test flights around Lugano Airport in Switzerland. EGNOS is of particular interest here, as standard terrestrial navigation systems are unfeasible due to the proximity of the mountains. As a result, only a handful of aircraft types can land at Lugano. EGNOS would make the airport accessible to a lot more aircraft types.

NLR developed CELESTE (www.valileo.nl and celeste.nlr.nl), a computer system that uses navigational data from test flights to calculate accuracy and reliability indicators. The system is fed with positioning coordinates from a satellite receiver, along with those from a second navigation system, which serve as reference. The recorded data are currently being processed and analyzed together with the customers, Thales and Alcatel.

In the years ahead, NLR aims to develop its reputation as a knowledge center for safety and reliability in satellite navigation. Errors in satellite navigation can occur at various levels — in the signal received from space, in the reception of that signal, and in the processing and interpretation of that signal. NLR has therefore teamed up with LogicaCMG, TNO, and Dutch Space, coordinating activities and seeking ways to complement each other's efforts. In 2005, the consortium will bid for a series of projects for Galileo, the independent European satellite navigation system developed under commission from the EU and ESA.

SLOSHSAT FLEVO DELIVERS DUTCH EXPERTISE AND EXPERIENCE

NLR's development of the Dutch research satellite Sloshsat FLEVO generated further insight into the complexities of fluid motion in space and a wealth of experience in building and operating mini-satellites.

On February 12, 2005, the Dutch mini-satellite Sloshsat FLEVO carried a synthetic research tank containing 33.5 liters of water into space. Maneuvers with Sloshsat provided researchers from the universities of Groningen and Delft, ESA, NLR, and NASA with a wealth of information on fluid slosh in a weightless environment, and how this affects satellites. One interesting discovery was that fluids come to rest differently than expected.

Sloshing characteristics are important when a satellite carries out maneuvers with partially filled fuel tanks. Insight into this phenomenon can contribute to lighter satellite design and more efficient maneuvers, extending the lifespan of satellites. This insight can also be applied on earth, in tanker ships and trucks. One disappointment was that the data on the state of the water in the Sloshsat tank were not received. As a result, some of the experiments will provide only limited insight.

NLR initiated, developed, and constructed Sloshsat for ESA, working with subcontractors in the Netherlands (Dutch Space), Belgium (Verhaert and Newtec), and Israel (Rafael). The project took just over seven years to complete. The year before Sloshsat's launch was an intensive one, during which the satellite was adapted for launch aboard the Ariane 5 rocket. Originally, Sloshsat had a ticket to ride the Space Shuttle. The switch to Ariane Space meant the satellite had to be reinforced and recertified. It also meant NLR had to take charge of communications and operations. Originally, communications with Sloshsat were to be relayed via the Space Shuttle, and NLR was to make use of NASA's operations center in Washington. Instead, NLR set up an operations center at the ESOC ground station Diane in Kourou in August. The dish antenna at the ground station had to be trained very accurately on Sloshsat.

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The project, largely funded by the Ministry of Economic Affairs, proved that the Netherlands is capable of building mini-satellites. Owing to their relatively low cost, satellites of this kind are ideal for conducting scientific research and service in space. NLR is also involved in developing ConeXpress, a satellite project run by Dutch Space. ConeXpress is designed to tow large telecommunications satellites, extending their lifespan when they run out of fuel.

KUIPERS' MISSION AN EXERCISE FOR COLUMBUS OPERATIONS

NLR supported Dutch astronaut André Kuipers in performing physics experiments that were a preparatory exercise for the Dutch-Belgian mission control center that will coordinate operations aboard the European Columbus module of the International Space Station (ISS).


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Space research is a costly business. That means nothing is left to chance during the flight. In April 2004, about a hundred ground staff took part in the DELTA (Dutch Expedition for Life Science, Technology and Atmospheric research) mission. A three-strong NLR team assisted Dutch astronaut André Kuipers in carrying out various physics experiments. The team worked from 6:00 in the morning until 10:00 at night to set up communications and operations, to read out measurement data for the astronaut, and to discuss program adjustments with the research team.

The DELTA mission was a useful exercise for NLR in preparing the Erasmus User Support & Operation Center (USOC), which NLR and the Belgian company SAS are jointly setting up in Noordwijk for operations aboard the Columbus. This is the European module for the International Space Station, which is scheduled for launch in 2007. The Netherlands, Belgium, and ESA are jointly responsible for operations involving the European Drawer Rack aboard the Columbus. This rack can hold a maximum of seven instruments. In addition, these parties are providing support for an external facility, the European Technology Exposure Facility.

During the flights, all amenities for these facilities — power supply, air and water cooling, ventilation, water supply, and video — were controlled from Noordwijk. USOC has two mission control rooms, as well as training and office facilities. In addition, the center houses models of the facilities aboard the ISS Columbus module that are technically identical to the real thing. These engineering models are being used for training and validation of operations in the run-up to the launch. During the flight itself, the models can be used to seek solutions to any technical problems that may arise.

Almost all ESA-affiliated countries have their own USOC from which they can control instrument racks or smaller Columbus facilities. The Erasmus USOC is being constructed step by step by NLR and SAS, and all techniques and procedures are being thoroughly tested and validated. Although Columbus has not yet gone into space, a link was established in 2004 with the flight module that is still at EADS Space in Bremen. This link was relayed via the Columbus earth station in Oberpfaffenhofen in Germany, which will coordinate communications once Columbus is launched. The Erasmus USOC is part of a broader program that has, since the 1980s, seen NLR assisting companies and scientists with space operations, satellites, sounding rockets, and SpaceLab.

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ARIANE 5 IN THE WIND TUNNEL

Wind tunnel tests on a model of the Ariane 5 rocket helped provide assurances that the design of the Vulcan 2 engine is safe. NLR built the highly advanced model and conducted the wind tunnel tests.

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The Vulcan 2 engine was developed in the late 1990s to give the Ariane 5 rocket extra thrust, allowing it to carry a bigger payload into space. Wind tunnel tests previously conducted by NLR with a scale model of the original rocket, revealed that the force exerted on the engine's conical exhaust nozzle was too great. Rocket manufacturer EADS Space subsequently went in search of a solution, conducting a series of advanced tests in the high-speed tunnel (HST) of German-Dutch Wind Tunnels (DNW). The designers tried to alter air flow around the rocket in various ways. For instance, by streamlining the steel supports between the fuselage and the side rockets, by placing serrations on the booster rockets, and by adding fins to the boosters. However, the results of these adjustments were insufficient. The solution was eventually found in 2004, by shortening the exhaust nozzle.

NLR manufactured the scale model and carried out the tests in cooperation with the DNW-HST. Owing to NLR's broad base of expertise, EADS was able to commission a single institute to develop the model and carry out the tests. The 86-centimeter-long scale model (1:60) of the Ariane 5 was made to a tolerance of less than 0.8 micrometer. To measure the forces generated by shock waves and turbulence, the 9-centimeter nozzle was equipped with 128 minuscule pressure sensors, each fed by hair-thin electrical wires and a thin tube to provide counter pressure. All of these connections led, over a distance of 5 meters, from the exhaust nozzle through the wind tunnel to connection points outside, via the mooring that holds the model in the wind tunnel. The pressures measured during the tests were recalculated as forces, so that EADS experts and NLR were able to make immediate adjustments.

The Ariane 5 turns on its axis during ascent and changes course. As a result, the airflow around the rocket changes continually. A wide range of airflow orientations were therefore tested in the wind tunnel. The forces exerted on the shortened exhaust nozzle of the Vulcan 2 engine always remained within acceptable limits. In November 2004, measurements taken during the first launch of an Ariane 5, which still had the longer exhaust nozzle, closely coincided with measurements obtained during NLR's earlier wind tunnel tests. This convinced the client to commission NLR and DNW to also conduct the tests on the shortened Vulcan 2 exhaust nozzles. Since then, the first Ariane 5 ECA rocket (Évolution Cryotechnique version A) with a shortened Vulcan 2 engine has been launched successfully.

Chapter 3:

FACTS & FIGURES

This chapter gives an overview of NLR's facts & figures for 2004. This includes financial data, information regarding organizational structure, and the composition of the NLR Board.

I) ORGANIZATIONAL STRUCTURE

General Director
Fedde Holwerda

Financial Director
Leo Esselman

Technical Director
Fred Abbink

General Secretary
Ernst Folkers

Marketing

- Aircraft Development
- Defense / Industry
- Air Transport
- Defense / Government
- Space

- Internal Communication
- External Communication

- Strategy & Alliances
- Government Relations
- Knowledge & Technology
- Quality Management

Supporting Services

- ICT
- Documentation & Information
- Housing & Facility Services

Finance & Accounting

Planning & Control

Personnel & Organization

Legal

Aerospace Systems & Applications

- Avionics Development & Qualification
- Flight Test Systems & Applications
- Avionics Systems
- Military Operations Research
- Space

Air Transport

- Safety & Flight Operations
- Air Traffic Management & Airports
- Air Transport Systems Technology
- Training, Human Factors & Cockpit Operations
- Environment & Policy Support

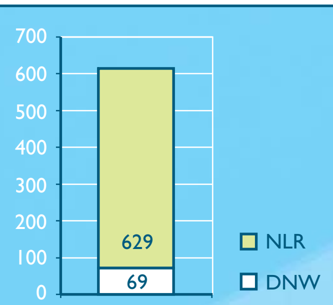
AerospaceVehicles

- Gas Turbines & Structural Integrity
- Flight Physics & Loads
- Helicopters & Aeroacoustics
- Collaborative Engineering Systems
- Structures Technology
- Engineering & Technical Services
- Structures Testing & Evaluation

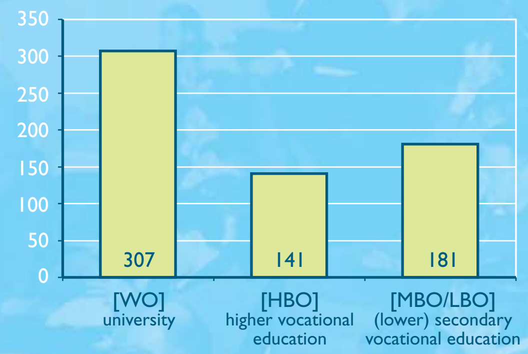
German-Dutch Wind Tunnels

II) NLR STAFF ON DECEMBER 31, 2004

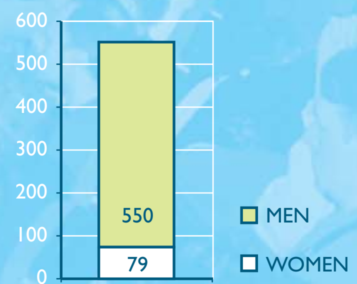
Number of staff:
(total = 698)



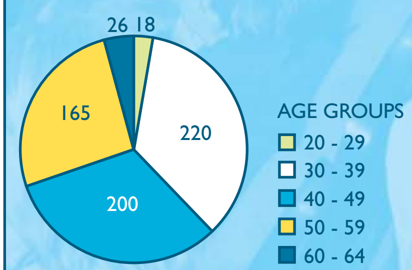
Academic level of staff
(excluding DNW)



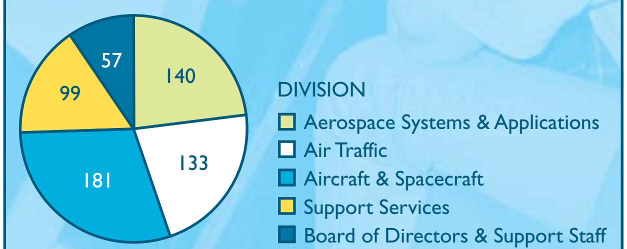
Gender division
(excluding DNW)



Age breakdown
(excluding DNW)



FTEs per division
(excluding DNW)

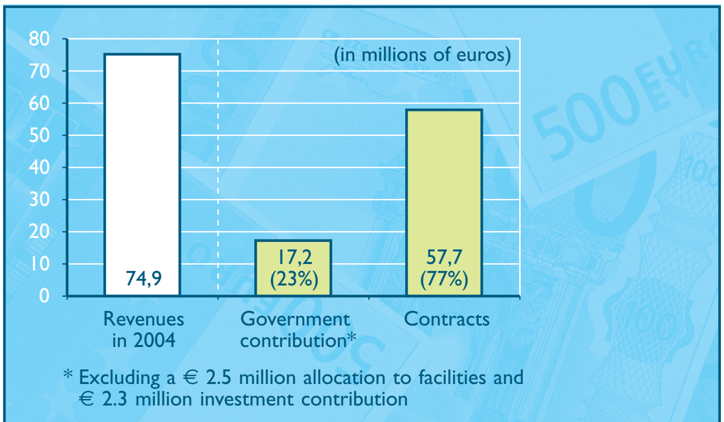


III) NLR ON DECEMBER 31, 2004

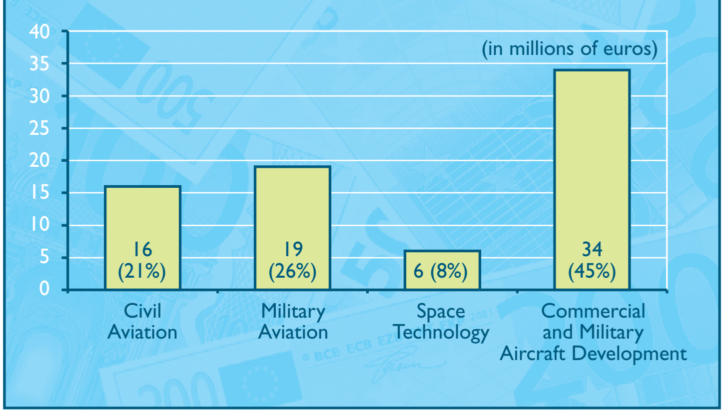
J. van Houwelingen	• Chairman
Drs. A. de Ruiter	• Ministry of Transport. Public Works and Water Management
Ir. P.J. Keuning	• Ministry of Defense
Gen.maj. E.H. Evers	• Ministry of Defense (RNLAF)
Drs. A.A.H. Teunissen	• Ministry of Economic Affairs
Drs. L. le Duc	• Ministry of Education, Culture and Science
Prof. B.A.C. Droste	• Netherlands Agency for Aerospace Programs (NIVR)
Ir. C.A.M. de Koning	• Stork
Drs.ing. P. Hartman	• KLM
K. Dosker	• Amsterdam Airport Schiphol
G.H. Kroese	• Air Traffic Control the Netherlands
C. van Duyvendijk	• TNO
Jhr. J.W.E. Storm van 's Gravesande	
Prof.dr.ir. M.P.C. Weijnen	
Prof.dr.ir. P.J. Zandbergen	• NLR/NIVR Scientific Commission

IV) NLR FINANCIAL DATA

Revenues in 2004:



Breakdown across sectors:



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National Aerospace Laboratory NLR

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