Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

NLR Annual Report **2005**

www.nlr.nl

This photo was made by courtesy of Lelystad Airport and the Aviodrome

Chapter 3 features portraits of four NLR employees and their work. *"This is where the action is!"*

FOREWORD

During my first year as chairman, I came to know NLR as an organization full of enthusiastic people, who are passionate about their work and take great pride in the product they deliver. I also found an organization that had not yet fully succeeded in conveying this pride to the outside world. People are employed by NLR, but they work for our clients. We should be more outward oriented. This is of vital importance for an organization that I believe is one of the technological treasures of the Netherlands, an organization that is of immense value to society in general.

There is a growing awareness that our future is largely dependent on societal developments and political decisions. We must therefore give the public, government and political sector a clearer perspective on who we are and what we do. In 2005, NLR therefore began stepping out more actively, intensifying contacts with officials and decision makers, and seeking the media spotlight more frequently. That is excellent. I believe the development of our social antenna and our more proactive approach are elements of our cultural turnaround. We will pursue this process in the years ahead.

More than three quarters of our revenue is generated by concrete research projects commissioned by government institutions and industry. The remaining quarter comes from government funding intended for basic knowledge acquisition, which is a prerequisite for ensuring that we have the expertise and facilities to meet market demands. In 2004, the Wijffels Committee recommended more demand-driven spending of these funds. This is in line with the way NLR works. As our figures indicate, many of our assignments are demand-driven. Together with its fellow research institutes, NLR stresses that the debate surrounding the utilization of government funding should continue to focus on technology and content.

During the past year, we also pursued our efforts to intensify cooperation between authorities, industrial sectors and research institutions, both nationally and at the European level. NLR will, autonomously, also seek to initiate and strengthen cooperative ties. For instance, in the fields of knowledge development and research and testing facilities. When it comes to European cooperation, I sometimes see national interests outweighing European interests. However, European cooperation is vital in achieving a leading role in the global arena.

But let's get both feet back on the ground, returning to the NLR establishments in Amsterdam and Flevoland. In 2005, the Board, the board of directors, management, staff and works council joined hands to achieve greater flexibility and decisiveness within our organization. As a result, NLR can now face the foreseeable future with greater confidence, as an alert, conscientious, skilled and flexible organization. These efforts will be supported by a Supervisory Board, which advises and reviews where necessary. It is a privilege to be part of this process.

Amsterdam, June 2006

Arie Kraaijeveld
Chairman

Chapter 1:

INTRODUCTION

In 2005, NLR's activities closely reflected developments in the Netherlands. It was a year in which we participated in highly topical policy studies relating to Schiphol airport, provided technological expertise in preparing for military missions to Iraq and Afghanistan, and made headlines with the launch of our Sloshsat satellite. In addition, Dutch TV channel BNN used one of our wind tunnels to demonstrate the devastating power of a hurricane, after Katrina wreaked havoc in New Orleans in August 2005.

We are more than willing to play this role in the public eye, providing expertise on topical issues. As the national aerospace institute of the Netherlands, it is our duty to seek adequate answers to today's major (and sometimes minor) practical questions. Answers that must often be given without delay. On top of that, we have a duty to look ahead and develop appropriate expertise to answer the questions of tomorrow and beyond.

OVERVIEW

In 2005, NLR completed many assignments on behalf of the ministries of Transport, Public Works & Water Management, Defense, and Economic Affairs, the Dutch aerospace and airline industry, Air Traffic Control the Netherlands (LVNL), and numerous other domestic clients. We supported Dutch participation in international military operations, we studied safety and environmental factors relating to capacity growth at Schiphol airport, and we helped strengthening the competitive edge of Dutch industry.

We also served a great many clients from beyond our borders, including ESA, Eurocontrol, and the European Union. You will find an overview of these projects elsewhere in this report.

Fred Abbink — General Director

DUTY TO DUTCH SOCIETY

NLR is partly funded by the Dutch government. In 2005, this funding accounted for approximately a quarter of our total revenue, as was the case in previous years. We need this funding to develop the expertise and facilities that the Netherlands, government bodies and industrial partners require to play an independent role in the aerospace sector. Elsewhere in Europe and the United States, governments also contribute to the development of such expertise and facilities.

In 2005, NLR spent part of this funding on various new facilities. We opened a new testing facility in Flevoland, and we teamed up with small and medium-sized businesses to establish an institute for advanced composite manufacturing (ACM). The latter institute also incorporates a tow-placement machine that produces advanced composite components using fibers and resins. In 2005, this institute produced its first composite landing gear for Stork. In Amsterdam, a valuable clustering of facilities was achieved in 2005. In March, the state secretary for Transport, Public Works & Water Management, Ms. Schultz-van Haegen, visited our Amsterdam facility to open the Narsim Tower for air traffic control simulations. In addition, the Grace flight simulator was equipped with an advanced motion system. This completed an integrated chain of state-of-the-art simulators. This combination of laboratory aircraft, flight simulators and air traffic control simulators enables NLR to conduct in-depth studies of all aspects of air traffic management.

As a result, NLR now leads the way in the research of quieter, safer and more efficient air transport. According to the EU report Vision 2020, one of the greatest challenges facing aviation in the coming years is the development of quieter, safer and more efficient air transport, as the demand for capacity increases. This demands in-depth studies of new technology and procedures, in the cockpit and on the ground. This also implies further research into safe and effective interaction between man and machine.

DEMAND-DRIVEN RESEARCH

2005 was also the year of "demand-driven research" for NLR, as recommended by the Wijffels Committee in 2004. The committee recommended better steering of government-funded research at TNO and the major technological institutes, such as NLR. These recommendations were adopted by the Dutch cabinet. It should be mentioned that NLR is well acquainted with demand-driven research, as 75% of our turnover is derived from contracts.

In 2005, NLR made every effort to implement the recommendations of the Wijffels Committee. We were one of the first centers of expertise to apply the new approach in drafting our research programs for the 2006-2009 period. These programs were mapped out in close consultation with four ministries closely allied to NLR, and were subsequently ratified by NLR's interdepartmental task force. This intensive consultation ensures that the expertise developed by NLR will, in the medium term, be well aligned with the government's expertise and policy requirements for the foreseeable future.

INTERNATIONAL COOPERATION

2005 was also a year of international ambitions for NLR. Cooperation with counterparts abroad and participation in EU projects greatly enhances the effectiviness and efficiency of our research. In 2005, NLR extended its international cooperation in various fields, including air traffic management (ATM). The most impressive result is AT-One, a joint venture with our German colleagues at DLR. In 2005, the foundation for the Aero Testing Alliance (ATA) was laid. The aim of this European partnership between NLR, DLR (Germany) and ONERA (France) is joint management of wind tunnel facilities. ATA was fully established in early 2006.

In 2005, we also invested in existing European partnerships, such as GARTEUR (involving seven European governments) and EREA (a cooperation of seven aerospace research establishments that will be chaired by NLR until 2007). In addition, we cooperated on composite structures with the Office National d'Etudes et de Recherches Aérospatiales (ONERA) in 2005.

Another key development for NLR is the memorandum of understanding that the Dutch aeronautics cluster signed with Airbus for the development of a joint strategic research program. As NLR was already involved in developing the successor to the F-16, this new agreement offers the Dutch aeronautics cluster a firm foundation for cooperation with the European and United States aviation industry in both the civil and military fields. This also means that Dutch industry can look forward to many spin-off contracts in the years ahead.

Leo Esselman — Financial Director

NEW DYNAMISM

2005 was a highly productive year for NLR. A lot of hard work was done. Some departments even had to work flat-out due to temporary staff shortages. The number of vacancies rose sharply in 2005, mainly due to the growing number of assignments. NLR took on a total of 50 new employees. Our 700 employees are the prime asset of our organization. It is vital to recruit excellent engineering and research personnel. We therefore did our utmost to bring NLR to the attention of job-seekers in 2005. Apart from personnel advertisements, we also launched special targeted campaigns, including presentations at trade fairs and a job interview training at the Delft University of Technology.

The new dynamism of our organization is also reflected by increasing internal mobility. Eleven of our employees moved to new posts within NLR in 2005. These colleagues were offered career guidance and additional training. We will also continue to hold our lunch meetings, which were introduced after the reorganization in 2004 and proved so successful. At these informal gatherings, staff and members of the board of directors discuss new opportunities for NLR, consultation with government bodies, new HRM policy and many other topics. In 2005, staff satisfaction, which is annually surveyed by the independent agency Effectory, rose so quickly that NLR received an award for the "fastest climber." With our newly-gained confidence, we opened our doors to the outside world more regularly in 2005. We welcomed TV crews and we met with numerous journalists. In 2005, we also began publishing a quarterly news bulletin, and we fully upgraded the NLR website. NLR also welcomed the Minister and State Secretary of Transport, Public Works & Water Management, the Minister of Education, Culture & Science, and the Minister of Defense, as well as other high-ranking officials from various departments, and members of parliament from various political parties.

Following our challenging reorganization in 2003, NLR has fully regained its financial and organizational footing. The dynamism has returned and our operating result was positive in 2005. Consequently, former general director Fedde Holwerda, who retired for medical reasons, could step down with a sense of satisfaction on September 1, 2005. We are greatly indebted to him for the manner in which he steered NLR through this turbulent period. We can look to 2006 with confidence. We will see a lot of challenging work washing in on the wave of current developments.

The Board of Directors
Fred Abbink
Leo Esselman

NLR CONSULTS WITH OFFICIALS AND POLITICIANS

In 2005, NLR began actively strengthening its ties with officials and politicians. We consulted with representatives of numerous political parties (CDA, PvdA, VVD, D66, SP, CU and LPF) and welcomed ministers, members of parliament, city councilors, and EU parliamentarians.

Among the visitors were:

Ms. K.M.H. Peijs
Minister of Transport, Public Works & Water Management

Lt-Gen D. Starink
Commander-in-Chief of the Royal Netherlands Air Force

Ms. M. Schultz-van Haegen
State Secretary of Transport, Public Works & Water Management

Mr. M.C.E. Haverkamp and Mr. R. Kortenhorst
Members of parliament for the CDA (Christian Democrats)

Ms. E. van Egerschot, Mr. J.C. van Baalen and Mr. Z. Szabo
Members of parliament for the VVD (Liberal Party)

Lt-Gen H. de Jong
Commander of the Royal Netherlands Air Force

Ms. M. van der Hoeven
Minster of Education, Culture & Science

Ms. J. Tammenoms Bakker and Ms. G. Bekman
Directorate General of Transport & Civil Aviation
(Ministry of Transport, Public Works & Water Management)

Mr. C. Buijink
Directorate General for Enterprise & Innovation
(Ministry of Economic Affairs)

Mr. L. Blom, Mr. A. Wolfsen and Mr. D. Samson
Members of parliament for the PvdA (Labor Party)

Mr. H.G.J. Kamp
Minister of Defense

NLR meets with …

Mr. H.G.J. Kamp – Minister of Defense

NLR = meerwaarde voor
de b.v. Nederland
en
= waardevolle partner
voor Defensie

HGJ Kamp
MinDef
10 nov. 05

"NLR [means] added value for the Netherlands Inc. and [is a] valuable partner for the Ministry of Defense."

Recording for the TV program “Nieuwslicht” in the Grace flight simulator, with presenter Menno Bentvelt (left)

Live radio broadcast during the official opening of the Narsim Tower air traffic control simulator.

Interview with Ms. Schultz-van Haegen, State Secretary of Transport, Public Works & Water Management, after the official opening of the Narsim Tower.

Recording for Discovery Channel’s “Testcase” series, with presenters Fedor van Rossem and Peter Sterk

“Testcase” is broadcast in various countries. French, English, German, Italian and Polish versions of “Planes and Space” were recorded.

NLR in the media

MEDIA SPOTLIGHT

NLR attracted a great deal of media attention in 2005. We featured in a total of 18 television broadcasts, including nationwide news broadcasts on the two major Dutch news channels NOS and RTL-4 (launch of the Sloshsat satellite). NLR also featured in television programs broadcast by five other national channels.
NLR was also the topic of 11 radio broadcasts, and was mentioned in more than 300 newspaper and magazine articles.

A relatively large proportion of the media attention was devoted to NLR’s activities and facilities in the field of flight safety, and to issues such as airport capacity and aircraft noise. Other topics that attracted attention were wind tunnel tests, new aircraft materials, earth observation, and replacement of the F-16.

Chapter 2:

AN OVERVIEW OF NLR PROJECTS IN 2005

JOB CREATION

Dutch innovations aboard the A380

New testing facility

Composite landing gear for civil aircraft

Web access to aerial and satellite images

JOB CREATION

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

DUTCH INNOVATIONS ABOARD THE A380

The world's largest passenger aircraft completed its first test flight on April 27, 2005. NLR qualification tests and materials developed in the Netherlands played an essential part in achieving this milestone.

2005 marked a milestone for European aircraft manufacturers. The Airbus A380, which can carry up to 550 passengers, completed its first test flights. NLR plays an integral part in innovations developed by Dutch companies.

In 2005, NLR tested the fatigue life of Glare panels used in the aircraft's fuselage. The panels were produced by Stork NV in Papendrecht. In addition, NLR conducted qualification tests for the so-called J-Nose, which is part of the fixed wing leading edge. These were tested to see whether they gave the wing sufficient strength and stiffness. The J-Nose components are made of a thermoplastic composite manufactured by Stork in Hoogeveen.

NLR also conducted qualification tests on another thermoplastic component used in the A380; the corrugated section of the vertical stabilizer. These corrugations, developed by Stork, make the vertical stabilizer more rigid. NLR subjected these corrugations to tests and analyses.

The A380's aerodynamics at takeoff and landing were previously tested at the DNW-LLF wind tunnel in Flevoland. These tests demonstrated that the aircraft's takeoff and landing speeds could be kept low enough to allow it to operate safely. Tests also proved that the aircraft can continue to climb after takeoff, even with one engine out. NLR also supplied Airbus Germany with calculation models for analysis of the aircraft's fatigue life, particularly the fuselage. Fokker Elmo also contracted NLR to qualify the electrical wiring in the pylons, from which the engines are suspended, and in the horizontal tail of the A380.

In addition to NLR and Stork, several other Dutch companies participated in A380 development. Driessen of Wieringerwerf developes trolleys and galleys for inflight catering. NLR tested the strength and durability of various components of this equipment in 2005. Ten Cate Advanced Composites of Nijverdal is supplying fiber-reinforced composites to Stork and directly to Airbus. And Akzo Nobel Aerospace Coatings developed a special selectively removable coating for the A380.

A second highlight in 2005 was the signing of an agreement between Airbus and the Dutch aeronautics sector. Minister Brinkhorst of Economic Affairs attended this ceremony. The aim of this agreement is to develop strategic partnership in five different areas of research and technological development. A small step for Airbus, but a major step for the Dutch aeronautics sector, and for NLR. This ensures that the Netherlands will continue to contribute to the development of Airbus products, thus generating more job opportunities.

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NEW TESTING FACILITY FOR AIRCRAFT COMPONENTS

NLR's new testing facility for aircraft components in Flevoland was taken into operation. Sections of the NH90 transport helicopter and five other aircraft types are lined up for strength and fatigue life tests. The facility allows a wide variety of structural tests to be conducted under one roof.

Among the first in line for testing is the tail of the NH90. It will be subjected to the same interplay of forces exerted during takeoff, flight, and landing. We will also test the effect of variations in air pressure and the movement of a flight deck of naval vessels.

These tests are conducted with a wide array of hydraulic and other equipment that simulate the desired interplay of forces on the tail-structure. Ultrasonic inspection techniques will subsequently be used to check for cracks resulting from structural fatigue.

A great deal of materials research is done in Flevoland. If cracks occur in test components during simulated flight tests, NLR always has experts on hand for an assessment. They have on-site access to specialized equipment, such as electron microscopes.

The new testing facility is large enough to accommodate an entire Joint Strike Fighter, but in most instances various components are tested side by side. Many of the installations are duplicated, so that time-consuming tests can be run in parallel.

The facility is open to clients such as Stork, Airbus, and Dassault. Tests are required during various stages of aircraft development, for instance when new materials are used. One such material is Glare, which was developed in the Netherlands and is used extensively in the Airbus A380. New tests have been developed to gain insight into bonding between Glare and standard aluminium. Tests will also be conducted on the wing movables of a new business jet built by Dassault. These tests demand a complex test rig, because the position of the flaps changes continually during flight, and thus the interplay of forces exerted by airflow.

NLR also conducts certification tests to assess the airworthiness of new aircraft. The new testing facility enables Dutch industry to prove that their aircraft components are of the highest technological standard and safety. In short, this facility supports innovation in Dutch industry.

COMPOSITE LANDING GEAR FOR CIVIL AIRCRAFT

The prototype of a composite landing gear component for a new civil aircraft was delivered to Stork SP Aerospace in 2005.

Until now, steel was the preferred material for the landing gear of helicopters and airplanes. Steel is durable and can be easily molded into shape, but the machining process is costly and time-consuming. The production of a steel landing gear component can take up to nine months, from order to delivery.

There are several good reasons for studying the suitability of composites in landing gear. Components made of composite materials can be manufactured far more quickly. This cuts costs. Furthermore, composite materials are lighter than steel and they are not subject to corrosion.
In 2005, NLR teamed up with industry partners to develop an automated composite production process for landing gear components that must withstand the most extreme forces. Braided carbon fibers ensure the durability and rigidity of the composite. Using a special braiding machine, Eurocarbon of Sittard creates the desired shape out of the carbon fibers. This company is also applying this newly gained expertise in the production of crumple zones in car bumpers for the automobile industry.

NLR developed a unique automated machine that injects resin into the braided carbon fiber reinforcements under carefully controlled conditions. The resin ensures that the component retains its shape. Because aircraft manufacturers seek to exclude all safety risks, they want proof that the production process for the composite components could be qualified. This implies that the automated injection machine had to produce exactly the same composite component each time. But this is no simple task, because the composite consists of two materials. The resin must impregnate the fibers completely, for instance, so that no air is trapped.

NLR supplies a CD ROM with each component, containing information about the conditions under which the component was manufactured. This is much like a fingerprint, proving reproducibility. In addition, a program was launched, together with the University of Twente, to simulate the braiding process for carbon fibers. This will allow production to be fully automated, ensuring precise stiffness and sufficient strength.

The first composite landing gear component for a new type of civilian aircraft was delivered to Stork in 2005. This 1.5-meter-long component, known as the Generic Composite Brace, is four times larger than the composite component produced for the F-16 jet fighter several years ago. The new component can also withstand much greater forces than the F-16 component. Stork SP Aerospace will subject the Generic Composite Brace to rigorous tests in 2006.

Various companies have already expressed an interest in the automated injection machine. One company in Flevoland even wants to take the machine into production – an unexpected spin-off.

Stork intends to market the composite landing gear in due course. This development offers excellent contract opportunities for Dutch industry.

GEOPORTAL FOR AERIAL AND SATELLITE IMAGES

NLR has teamed up with two specialist companies to establish professional web services offering access to aerial photos and satellite images.

In 2005, NLR teamed up with Imagem of the Geomatics Business Park (Flevoland) to launch a web service called Beeldportal (Image Portal) that offers access to digital aerial photos covering the entire surface area of the Netherlands. NLR also partnered with the specialist company Neo to established a website called Sat1, that offers access to high-resolution satellite images. In both instances, NLR developed the underlying data service systems and web interface, meeting the high standards for geo-information. Imagem and Neo sell these images to professional as well as private users. The available images currently date back as far as 2001.

In the past, it was difficult to access detailed aerial photos and satellite images of the Netherlands. However, such images were in great demand among a wide array of users. This includes agencies that compile environmental reports and need to establish what sort activity has taken place on particular tract of land, as well as government institutions that need to monitor how building density has changed over time.

The best satellite images have a surface resolution of 50 cm, while aerial photos offer surface resolution as detailed as 10 cm. Satellite images offer a flat, two-dimensional image, while aerial photos give a more three-dimensional impression of the earth's surface.

NLR sees the Beeldportal website as the starting point of a future Geospatial Data Center, a nationwide archive of aerial and satellite images. New images would be continually added to this archive, ultimately providing a national geodata infrastructure. The Geospatial Data Center will offer clients online access to advice, data, products and services relating to earth observation and navigation.

www.beeldportal.nl / www.sat1.nl

MOBILITY

SPADE helps prevent delays

Snow exercise

Olympic rush

Up and away on time

MOBILITY

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

SPADE HELPS PREVENT DELAYS

A new system platform is helping airports monitor complex flows of aircraft, freight, baggage and passengers, enabling them to take whatever measures are required.

Airports are complex systems handling multiple flows of passengers, baggage, freight, and aircraft. Minor shifts in day-to-day patterns can result in bottlenecks that easily lead to major operational disruptions. Examples of such shifts include the annual flood of holiday charter flights, maintenance activity on a taxiway, the introduction of a large, new aircraft like the A380, and tighter security measures.

The chain of operations is only as strong as the weakest link. An aircraft may arrive at the gate on time, and passengers may be checked in and boarded punctually, but if baggage handling backs up, the aircraft will not depart on time. That means the gate will not be available for the next aircraft.

NLR is heading the European consortium SPADE, the Supporting Platform for Airport Decision-Making and Efficiency Analysis. An experimental version of this decision-support system, which allows airports to analyze and resolve bottlenecks in logistics and planning, was delivered in early 2006. The project combines specialist expertise on airports, simulation techniques and (analysis) software. Collaborating partners include the Delft University of Technology, Incontrol Management Consultants, our German counterpart DLR, the International Air Transport Association (IATA), and the airports of Athens and Toulouse.

Specific systems are already available for the analysis of various sub-processes at airports. Aircraft movements and passenger flows at airports can be simulated with TAAM; passenger flows are analyzed using Incontrol Enterprise Dynamics Airport Suite; while NLR previously developed TRIPAC to assess risks in areas surrounding airports.

SPADE provides a user-friendly platform for all these systems, offering insight into the potential consequences of changes in fleet composition, flight schedules, and runway layout. Users require no knowledge of or experience with the underlying systems. That means, when the A380 becomes operational, a coordinated overview can be compiled of the consequences in terms of runway capacity, taxiing and gate times, environmental factors, and external safety.

SPADE chooses the appropriate calculation scenario based on the proposed adjustment to the standard scenario at the airport. Depending on the chosen adjustment, the system poses additional questions. If passenger flows in the terminal are also a factor, for instance, SPADE will ask the user to specify the number of seats aboard a new aircraft type. SPADE then prompts the sub-systems to execute simulations and relays information back and forth between the sub-systems.

SPADE ensures that such simulations are less time-consuming and makes them more accessible to planners and managers. SPADE attracted a great deal of attention during a series of presentations at airports in late 2005 and early 2006. During the next phase of the project, SPADE will be further developed and a number of operational tests will be conducted with the platform, at which time Amsterdam Airport Schiphol will join the project.

SNOW EXERCISE

Heavy snowfall can seriously disrupt airport operations. NLR organized a special snow exercise last fall to prepare Schiphol for the coming winter.

Heavy snowfall hampered operations at Schiphol on March 2 and 3, 2005. Flights were cancelled and many passengers spent the night in the terminal. A subsequent evaluation revealed that the consequences could have been contained through better preparation and coordination of operational departments at KLM, Schiphol, and Air Traffic Control the Netherlands.

NLR was therefore asked to organize a scenario exercise in the early fall, to ensure that Schiphol was well prepared for the coming winter. Four sessions were held, each involving 40 air traffic controllers, planners, and de-icing and handling coordinators, who worked to improve coordination and procedures. The exercise was held in NLR's NARSIM tower simulator (which offered a panoramic view of Schiphol in the snow) as well as various other simulation facilities, interconnected by a computer network and numerous phone lines.

The magnitude of the exercise gives some indication of the complex impact that snowfall has on airport operations. Heavy snowfall not only restricts the use of runways and taxiways, but also hampers handling on the ramp and puts immense pressure on aircraft de-icing facilities. That is why personnel from a wide range of disciplines took part in the exercise.

NLR analyzed how the different parties cooperated to maintain control of the situation during heavy snowfall. Our training experts subsequently developed an exercise scenario, which not only gave a realistic impression of the many problems and complications, but also offered a good balance in work pressure – high enough to confront air traffic controllers and coordinators with their own mental limitations, but not so high as to disrupt the learning process.

© GARY WATT

We devoted a great deal of attention to the simulation environment, which had to be so realistic that the participants would become fully engrossed. We therefore ensured that the tower simulator not only featured falling snow and iced-up aircraft, but also snow ploughs working on the runways. The layout of the data screens closely matched those used in reality, including weather forecasts and radar images. We linked NARSIM Tower to the Central Information System Schiphol (CISS), enabling participants to work with flight information systems they were familiar with. Pseudo-pilots simulated communication from the 100 aircraft involved in the simulation.

These efforts paid off. The scenario was so realistic that many of the participants felt the pressure. The exercise was later extensively evaluated with the participants, offering them insight into their own role, but also into the roles of other parties involved.

We will be organizing another snow exercise for Schiphol in the fall of 2006.

OLYMPIC RUSH

Architect Norman Foster, renowned for the dome on the Reichstag in Berlin, designed a new terminal building for Beijing Airport.

The new Beijing terminal is as big as all of the Schiphol terminals combined. The airport will also add a third runway and a new air traffic control tower. In short, preparations are underway for the anticipated rush surrounding the 2008 Olympic Games in the Chinese capital. With air traffic growing at 15-20% a year, Beijing Airport has every reason to expand. This heightened activity is also making coordination of takeoffs and landings increasingly complex, particularly because the airport is frequently shrouded in low-level clouds that form around the nearby mountains. Once the third runway is taken into operation, ground traffic crossing the center runway will further complicate matters.

NLR simulated ground traffic to assess the future setup at Beijing Airport. This study revealed that, with the current approach to air traffic control, the airport will become severely congested during the Olympic Games. Aircraft queues at runways will become dangerously long once expansion is completed. However, our "Fast-Time" model showed that considerable improvements could be achieved with a system of departure management. This would allow aircraft to remain at their gate until departure time. The order of takeoff could then be optimized, allowing better control of the situation on the ground.

NLR conducted these simulations on behalf of LINFAIR, a Hong Kong-based company.

Beijing 2008

PUNCTUAL TAKEOFF PLANNING

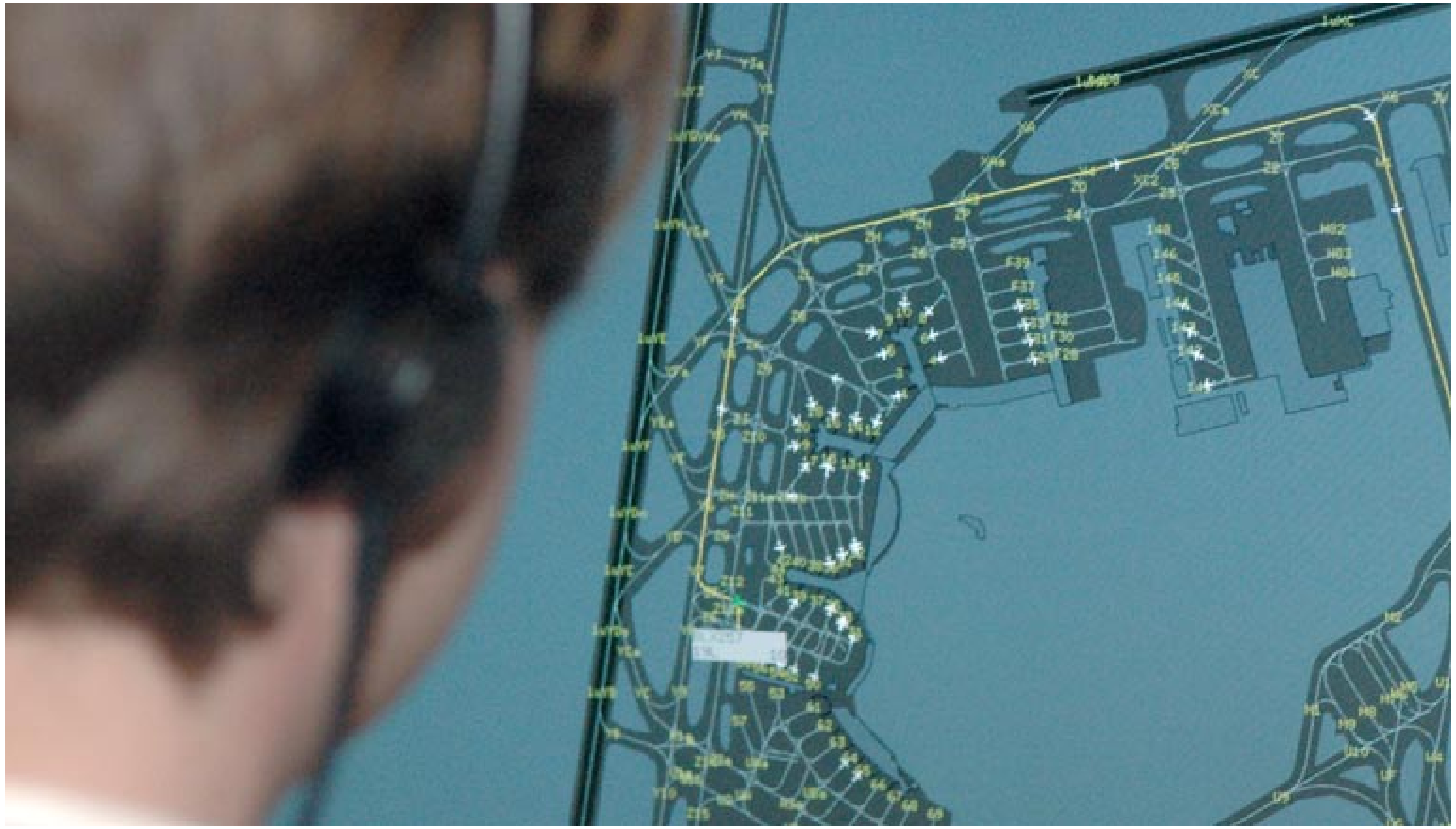
A passenger fails to show up. Tension mounts at the gate. Planning at an airport can change at the very last minute.

A few minutes' delay at the gate immediately affects all runway operations and often leads to long waiting times. Aircraft get in each other's way and the takeoff pattern is no longer optimal. More flexible departure planning can produce substantial efficiency gains.

NLR took part in the European Gate-to-Gate research project, which aimed to develop a departure management system ensuring better takeoff handling.

Until now, departure management was a last-minute business. Pilots only called in once they were fully prepared for takeoff. And then the waiting starts. Often there is very little room to adjust planning.

The new departure management system urges pilots to call in earlier and indicate when they expect to depart. This is possible because they know how many passengers still have to board and how baggage loading is progressing.



NLR has developed planning software that uses these prognoses to set a preliminary order of departure. This is a complex puzzle, involving numerous factors such as the wishes of the airline, activity on taxiways, airborne traffic, and the difference in wake turbulence left by larger and smaller aircraft. The planning software therefore also includes a model for taxiing times at the airport. These can vary greatly, especially at larger airports, depending on the aircraft type, the taxiways in use, and the volume of traffic.

The software also takes arrival planning into account, because many airports alternately use their runways for takeoffs and landings. The software ensures that the intervals between landing aircraft are large enough to allow takeoffs in between.

Early planning allows for easier adjustment, without affecting punctuality and capacity at the airport. Because pilots call in early, airlines gain online access to preliminary planning. This enables them to suggest adjustments ensuring better connections and deployment of ground material, among other things.

The new system was tested at Stockholm's Arlanda Airport in Sweden. The situation at the airport was simulated in NLR's NARSIM Tower. Seven air traffic controllers and ten pilots participated in the study. A variety of scenarios were simulated, involving 100 flights per hour distributed over two runways, which were used for both takeoffs and landings. This is in line with projected traffic in 2010.

NLR has partnered with LINFAIR, a Hong Kong-based company, that is adapting the software for commercial purposes. Arlanda airport is expected to test the new system in its air traffic control tower in 2007.

Anticipating human errors

Reassessing risks at Schiphol

Color-coded warning system

Smaller aircraft separation distances

How safe is European airspace?

SAFETY

The aviation industry has more safety regulations than any other. You could fill an entire library with the international codes for aircraft.

ANTICIPATING HUMAN ERRORS

At the request of the US Federal Aviation Administration, NLR analyzed more than 400 accidents in an effort to improve cockpit design requirements. The key question was: how can pilot errors be prevented?

Little or nothing is left to chance when it comes to the certification of aircraft. The risk of an accident must be smaller than one in a million flights. The pilot's role is crucial in this regard, because it is up to him to respond appropriately or to take anticipatory action when systems fail. If an engine malfunctions, an alarm goes off in the cockpit. Warning lights usually indicate which engine is affected. During certification, it is assumed that the pilot will take appropriate action and cut the engine in question. Pilots are intensively trained to do so. However, there have been instances when the pilot cut the wrong engine.

The US Federal Aviation Administration (FAA) commissioned NLR to reconstruct hundreds of accidents and to issue recommendations on how such pilot errors could be prevented. NLR has gained international renown for its studies of safety and human behavior. The FAA has therefore commissioned us to conduct various studies in recent years. A three-strong NLR team, including a test pilot, analyzed more than 400 accidents, seeking patterns in pilots' responses to unexpected situations.

We discovered that the certification of onboard systems should take better account of the circumstances under which pilots are expected to respond. For instance, pilots sometimes make the wrong decision when a tire blows out during takeoff. Pilots are trained to proceed with their takeoff under such circumstances, particularly if the aircraft is already moving at high speed. However, because a blowout usually causes a lot of noise and vibrations, pilots sometimes conclude that the problem is more serious, and therefore abort their takeoff. A flashing indicator on the instrument panel, which would otherwise immediately attract the pilot's attention, is not adequate at such times.

We discovered that pilots find it hard to ignore crucial instruments, such as the artificial horizon, airspeed indicator and altimeter, when circumstances demand otherwise. Their attention for these instruments is so much part of their routine that they continue to monitor them, even if they know the readings are incorrect because the instrument is faulty. It would therefore be better if incorrect data were made invisible.

On behalf of the FAA, NLR designed a scoring system to assess whether a cockpit design takes sufficient account of such risks. Within the EU's SAFE SOUND project, NLR is studying a system that may help pilots in emergency situations. This system uses "3D" sound to give pilots spatial information. If an engine fails, for instance, the acoustic warning is directed at the pilot from that engine's specific location.

REASSESSING RISKS AT SCHIPHOL

The reassessment of third party risks at Schiphol indicates that a shift has taken place. The chance that people in the surrounding areas are confronted with calamities has become smaller.

No matter how safe air traffic may be, there is always a small risk that aircraft may crash or veer off the runway during takeoff or landing. Standards have been set for third party risk in the areas surrounding Schiphol. For instance, the risk of an aircraft crash in a single year, multiplied by its weight, may not exceed 9,274 kg per year. This is known as the total risk weight.

Risks are calculated on the basis of accidents and incidents that occurred in the past. Because the number of incidents has declined sharply in recent decades, it is becoming increasingly difficult to find a solid statistical foundation for risk assessment. In 2000, NLR compiled an inventory of incidents and accidents at 40 international airports that are comparable to Schiphol, including Heathrow, Frankfurt, Orly, Atlanta, and New York JFK. These airports have similar high-grade safety systems, carriers, climatic conditions, and flat surroundings. Between 1980 and 1998, these 40 airports handled in excess of 32 million aircraft movements involving so-called "third-generation aircraft." These modern aircraft account for around 95% of flights at Schiphol. Within this category, a total of nine incidents or accidents occurred over a total of 32 million flights.

In 2005, NLR reassessed these data at the request of the Directorate General for Transport and Aviation (DGTL) of the Dutch Ministry of Transport, Public Works & Water Management. NLR gathered and analyzed accident data from the same 40 airports for the period through 2004. This revealed a further 11 accidents and incidents in 43 million flights, bringing the total for the 1980-2004 period to 20 accidents and incidents in 75 million aircraft movements.

NLR can now calculate the third party risk for Schiphol with greater accuracy. Although the total risk weight is much the same, there has been a clear shift in the type of incidents. For instance, there was a lower risk of takeoff overshoots (in which the aircraft touches the ground during its initial climb) and landing undershoots (in which the aircraft lands short of the runway). These are the chief risks at locations situated more than one kilometer from the airport. On the other hand, there has been a substantial increase in landing overruns, in which aircraft run off the end of the runway and slide into the surrounding grassland. The shifting ratio of incidents types has resulted in lower risks for people living near the airport.

COLOR-CODED WARNING SYSTEM

Europe is striving to prevent terrorist attacks on aircraft. One example is a system of color codes warning of suspicious passengers. NLR is assessing the system's practical feasibility.

It is a complex challenge to protect aircraft against terrorist attack. As part of EU project Security of Aircraft in the Future European Environment (SAFEE), NLR is working on a new form of inflight security. The aim is develop an innovative airborne system that supports the crew in the event of a terrorist attack. To this end, a wide array of sensors, decision-making support systems, interfaces and data security systems are being developed and tested. SAFEE is closely allied with ERRIDS, the European Regional Renegade Information Dissemination System, which is Eurocontrol's complementary aviation security system.

SAFEE revolves around the Threat Assessment and Response Managements System (TARMS). This decision-making support system uses video images of the cabin to monitor and analyze passenger behavior and alert pilots and air marshals to suspicious passengers. Via a datalink, the system can acquire additional data in order to assess the threat. The system then assigns a color code to the situation (green, yellow, orange or red), which determines what measures should be taken.
Options are also being assessed to use fingerprint scanners and other biometric security systems to prevent hijackers from gaining access to the cockpit and taking control of the aircraft. In the event that a hijacker does manage to take control, an emergency system will be activated, ensuring that the aircraft circumnavigates obstacles on the flight route. This prevents hijackers from attacking key buildings and sites.

The technical study of the SAFEE systems is headed by NLR and four European industrial corporations; SAGEM, Airbus, BAE Systems, and Thales. NLR serves as a bridge to real-world implementation, conducting threat analyses and efficacy studies, and dealing with user issues, regulations, and system validation. NLR will also be developing a training program for pilots, cabin crew, and air marshals.

In 2005, various incidents aboard aircraft were analyzed to pinpoint weaknesses in existing airline security and to improve aviation-related laws and regulations. A workshop was held at the Paris Le Bourget Air Show, where the 100-strong SAFEE user group commented on the plans. The SAFEE systems will be tested in NLR's GRACE cockpit simulator during the coming period. Test pilots will work with a prototype of the system in the simulator, testing whether it is functional and safe.

SMALLER AIRCRAFT SEPARATION DISTANCES

Aircraft produce wake vortices that make it dangerous for them to follow each other too closely. The larger the aircraft, the stronger the vortices generated, which means larger separation distances are required. As passenger traffic increases, airlines will deploy more and more of these larger aircraft. The latest addition is the Airbus A380, the world's largest commercial passenger aircraft.

NLR is coordinating the EU project ATC-Wake, which aims to produce a system that takes into account the effects of wake turbulence and vortices. This system will allow smaller aircraft separation distances when conditions are favorable, generating capacity gains for airports. Crosswinds are one example of favorable conditions, as they cause vortices to dissipate more quickly.

Last year, NLR assessed the risks involved in reducing aircraft separation distances. We made use of WAVIR (Wake Vortex Induced Risk Assessment), a risk analysis model for vortices, previously developed by NLR. We also incorporated the actions of pilots and air traffic controllers into the model. These data were derived from earlier tests conducted in the NARSIM tower simulator and the GRACE cockpit simulator. We also made use of laser analyses obtained in an earlier study that assessed how quickly wake turbulence dissipates. We subsequently set new, dynamic, wind-dependent safety margins for landing and takeoff. We demonstrated that, under favorable circumstances, airports can achieve capacity gains of up to 5%.

During the next phase, European air traffic control centers will test the systems and prepare for implementation at airports in 2010. Eurocontrol will play a key role, coordinating the follow-up project CREDOS (Crosswind Reduced Separation for Departure Operations). European aircraft manufacturers will also participate in the program.

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SAFETY INDICATORS FOR EUROPEAN ATC SERVICES

How safe is European airspace? NLR assessed how Eurocontrol could best gain an overview of safety performance at air traffic control services and other aviation service providers.

How well does European air traffic control perform? The Performance Review Commission (PRC) at Eurocontrol annually evaluates and reports the performance of air traffic control services across Europe. Apart from costs and efficiency, safety is a key factor. But this is also a sensitive issue. Incidents are preferably kept out of the public eye. However, it is of vital importance to gain good insight into risky situations, such as near-misses (when the degree of separation between aircraft is too small) and runway incursions (when vehicles cross the runway as an aircraft approaches). This insight may be used to adjust procedures and systems in order to prevent accidents.

Eurocontrol commissioned NLR to assess how a safety study of this kind might be conducted. What indicators offer a balanced and feasible overview of safety? Eurocontrol and NLR subsequently formed a research team that conducted interviews at various air traffic control and air safety services in Europe and the United States. After compiling an inventory of response data and sensitive issues, NLR proposed a phased plan of action that the PRC could use to gain an overview of safety at European air traffic control services in the coming years. This approach would see safety indicators being stipulated more precisely over time.

European air traffic control services are already obliged to report accidents and incidents, but the precision and reliability of such reports varies greatly from country to country. Comparisons of such data, per country, offer a biased overview and are therefore not satisfactory. However, the available accident data do offer a valuable overview of safety trends within European airspace.

More systematic registration of incidents within Europe could produce valuable additional insight in the coming years. To achieve this, air traffic controllers and pilots will have to report incidents in a systematic and reliable manner. And that can only be achieved by winning the trust of the bodies in question.

Within the framework of the safety overviews, we opted for broad registration of incidents. We wish to include all incidents relating to Air Navigation Services (ANS). This includes air traffic control and aviation-related meteorological, communication and navigation services. From this perspective, near-misses that take place in non-controlled airspace are also ANS-related. In such instances, air traffic control services may not bear responsibility, but the extension of control authority could reduce risks. Registration of such incidents is therefore worthwhile, as it presents a basis for structural measures.

This is a novel approach because it does not focus on assigning responsibility or blame, but on the role that the bodies in question could play in improving safety. Air Navigation Services play a part in nearly half of the 28 categories of aviation incidents, which range from collisions to fire and lightning, and from wind and turbulence to system failure. We specify what data should be registered for these ANS-related incidents.

ENVIRONMENT

Evaluating Schiphol policy

Polder Runway takeoff noise

Aircraft could be a lot quieter

Making noise visible

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.

EVALUATING SCHIPHOL POLICY

NLR conducted several studies to support a parliamentary debate on policy related to Amsterdam Airport Schiphol. NLR reconstructed how environmental impact and third party risk at the airport have developed since 1993.

Government policy on Schiphol was scheduled for review by parliament in February 2006. In preparation, NLR conducted several studies in 2005, mapping out how environmental impact and third party risk in the greater airport area had developed, as well as the effects of government policy. Although it was evident that the number of flights had almost doubled since 1990, there was no clear overview of the effects on the environment and third party risk. Insight into developments was obscured by interim adjustments of aircraft noise standards and the noise monitoring system.

NLR's Fanamos system has been used since 1993 to register all movements and specifications of aircraft landing and taking off at Schiphol. These data enabled us to reconstruct noise and safety patterns for the past 12 years, and to recalculate emissions and risks in a uniform manner. This gave us a full overview of developments.
The noise and external safety contours we compiled for airport utilization from 1993 through 2005 offer detailed insight into these developments. Noise impact and individual risks did not increase at the same rate as flight volume. Owing to renewal of the Schiphol fleet, aircraft became quieter and safer, thus substantially reducing noise and risks.

The Fanomos system records the radar tracks of all aircraft taking off and landing at Schiphol. These data indicates that flight corridors have shifted over the years. When the Polder Runway was taken into operation, traffic was guided away from densely populated areas such as Amstelveen and Amsterdam-Southeast. Noise and risk were shifted to the less densely populated area north of the airport. Despite the sharp increase in aircraft movements, the number of homes exposed to noise and risk declined. Using existing ratios between noise impact and nuisance, we calculated that the number of people in the airport area experiencing serious noise impact and nighttime disturbance dropped substantially between 1993 and 2005. Our analyses indicate that this may be directly attributed to new Schiphol policies and particularly to regulations stipulating maximum values for noise impact at 35 monitoring points.

We also looked to the future. Our calculations indicated that existing environmental regulations will limit the number of aircraft movements to approximately 453,000 a year. These regulations will ensure that, in 2008, thousands of people will be less seriously annoyed or suffer nighttime disturbance due to aircraft noise than if Schiphol were allowed to develop without constraints.

Clear and objective information on aircraft noise is a key factor when involving the general public in policy formulation. It can also increase public acceptance of the environmental effects and risks of an airport. On our own initiative, we drafted a series of proposals ensuring that risk and environmental data would be presented in a more accurate, transparent and accessible way in future. Our proposal includes various additional noise indicators that coincide more closely with the general public's own experience of aircraft noise. Noise impact has its own specific characteristics: people are more sensitive to noise peaks than to background noise. Moreover, people are less disturbed by noise if they feel they can influence it one way or another.

Our contribution to the Schiphol assessment included two studies involving application of the NA60 and NA70 indicators at Schiphol. These two standards count the number of flights that create a local noise peak exceeding 60 and 70 dB(A) respectively. In a house with open windows, a 70 dB(A) noise peak disturbs conversations held indoors and drowns out radio and television programs. We demonstrated that these indicators supplement the broader overview of noise impact in the Schiphol area.

RATTLING HOMES IN HOOFDDORP

Residents in the Vrijschot and Houtwijkerveld districts of Hoofddorp often hear a deep droning sound in their homes. Teacups rattle, cupboard doors flap, and window panes vibrate.

The residents say this is caused by aircraft taking off on the Polder Runway. The effect is totally unexpected, as calculation models used in environmental studies gave no indication that this might occur. How could vibrations pass from the runway to homes more than two kilometers away? There are various possible explanations. For instance, the vibrations may propagate the ground, or they could be generated during takeoff, or just after the aircraft becomes airborne.

NLR, TNO and GeoDelft conducted a joint monitoring project to assess the problem. Accelerometers, geophones and microphones were installed in and around the runway, in and above the fields around the airport, and in residents' homes. US-based company Wyle was contracted to oversee the project to ensure that the study was fully objective.

The study revealed that the vibrations were mainly propagated through the air. Noise levels in the districts were especially high when heavier aircraft were involved and when the wind was blowing from the northeast. This finding will be important when taking measures to limit nuisance.

AIRCRAFT COULD BE A LOT QUIETER

By repositioning engines, aircraft can become a lot quieter. NLR computations prove that a different configuration would not impair airborne efficiency.

Jet engines are mostly mounted beneath an aircraft's wings. This makes them easily accessible to engineers and, above all, highly efficient, because air flows over the wings at high speeds, while speeds are lower under the wings. Unfortunately, this is an unfavourable position when it comes to emitting engine noise, which reaches the ground unimpeded and even reflects off the underside of the wing.

NLR teamed up with Airbus, engine manufacturers and its counterparts DLR, ONERA and CIRA to conduct conceptual studies for alternative aircraft configurations, as part of the EU project Research on Silent Aircraft Configurations. One of the alternatives is to mount the engines on top of the wing. The noise would then propagate upwards, instead of being reflected downward off the wing. Unfortunately, an aircraft in this configuration does not fly efficiently. Aerodynamic calculations indicate that the engines would seriously disturb the high-speed airflow over the wings and cause serious shockwaves.

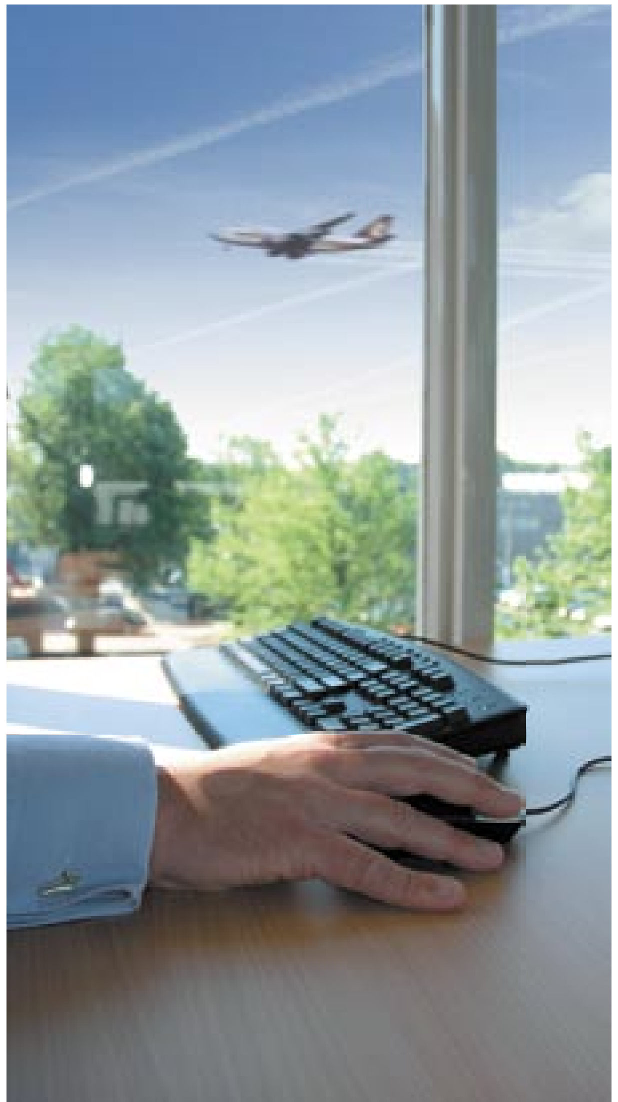
The second alternative is a configuration with engines mounted above the horizontal tail, which would impede the noise to a certain degree. NLR developed a calculation model for assessing the reduction in engine noise. Wind tunnel tests at ONERA demonstrated that, by positioning the engines at the tail, noise below the aircraft is reduced by 6 to 10 dB because it is impeded by the fuselage and horizontal stabilizers. That means two to three times less noise.

It was no easy task to prove that an aircraft with tail-mounted engines can fly efficiently. Significant air resistance builds up in the narrow opening between the round engine cowlings and vertical stabilizer. Other institutes attempted to redesign the tail, but failed. Ultimately, NLR did succeed. The airflow was not calculated along customary lines, but on the basis of a reversed mathematical model. The optimum surface was calculated based on the desired characteristics of the airflow. This resulted in a design with two "dents" in the tail. In addition, the pylons on which the engines are mounted were placed at a different angle.

This conceptual study will not prompt the development of new aircraft types. The main aim of the project was to explore the potential for further noise reduction by means of alternative aircraft configurations, supplementing general engine improvements. The project also offered all the partners an opportunity to master new techniques. We will, for instance, use our engine noise model to study the noise emitted by future supersonic business jets as well as the successor of the F-16 fighter.

MAKING NOISE VISIBLE

The screen shows that flight 6FBD2362 is passing just a little too close to Sachsenhausen, a Frankfurt suburb. Since July, residents around Frankfurt airport can access a website and see exactly what is hanging over their heads. They can also check noise indicators for specific flights.



Anyone who hears an aircraft overhead when operations are prohibited can trace the source of the noise on a website. Residents can use this precise data to backup complaints. Frankfurt is Europe's first airport to expose its air traffic to such close scrutiny. The system in question, STANLY_Track, displays the Frankfurt-Mainz region on a specially developed website. Orange, yellow and green aircraft cross the screen on their way to and from the airport's three runways. The color indicates the altitude of the flights. Each has its own number, which cannot be directly linked to a specific airline or pilot. Flights appear on-screen with a 30-minute delay, thus preventing abuse of the data. The complaints desk can link the on-screen numbers with the actual flight number. The system stores flight data for a two-week period. All the flights in a selected period can be displayed on-screen as tracks, thus visualizing which neighborhoods suffer the most impact, and whether pilots are adhering to regulations.

The website is an initiative of the Regionales Dialogforum in Frankfurt. This broad forum for stakeholders was founded as part of noise-abatement pact between the airport and the surrounding community. Residents of Eddersheim, a village halfway between Frankfurt and Mainz, had launched a campaign demanding publication of flight data. Since the system provides neutral information, the Forum expects it will result in a more fruitful dialog between air traffic control, the airport authority, and residents.

DFS Deutsche Flugsicherung, the German air traffic control authority, commissioned NLR to build the system. Security was a key aspect of design. For instance, the interface between the web server and the internal systems that provide data was extensively tested. The web server gets its data from a newly developed central acquisition system linked to Fanamos, another NLR product, which records all flight data at Frankfurt airport. Gelsenkirchen University tested the algorithm that strips each aircraft of its true identity.

STANLY_Track is a product of 3DFlight, an NLR research project. 3DFlight was used to develop a web application that displays flight data in a three-dimensional landscape. Besides displaying topographical information such as rivers and hills, the software can be used to display air corridors and satellite data in three-dimensional form or as a flat map. STANLY_Track uses only a fraction of the system's full potential. DFS is currently considering extending the system with flight data for the airports in Munich, Hamburg, Cologne-Bonn, and Dusseldorf.

DEFENSE & PEACEKEEPING MISSIONS

Replacing the F-16

Looking over hills

Helicopters at sea

F-16 Orange Jumper updated

DEFENSE & PEACEKEEPING MISSIONS

Times are changing – and this certainly applies for 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.

REPLACING THE F-16

Replacing the F-16 fighter is a major operation for the Dutch Ministry of Defense. NLR is involved on many fronts.

The second part of the next decade the Netherlands will start phasing out its F-16 fighters. NLR is closely involved in the Dutch participation in development of the F-35. NLR advises the Dutch Ministry of Defense on the practical aspects of introducing a new fighter. In addition, NLR provides support for the political decision-making process by closely monitoring technical development of the F-35 Lightning II (formerly known as the Joint Strike Fighter), the main candidate successor, and its competitors. In view of the project's political and commercial sensitivity, NLR has formed a special project team for government support that is carefully shielded from commercial projects and from contact with the F-35 aircraft industry.

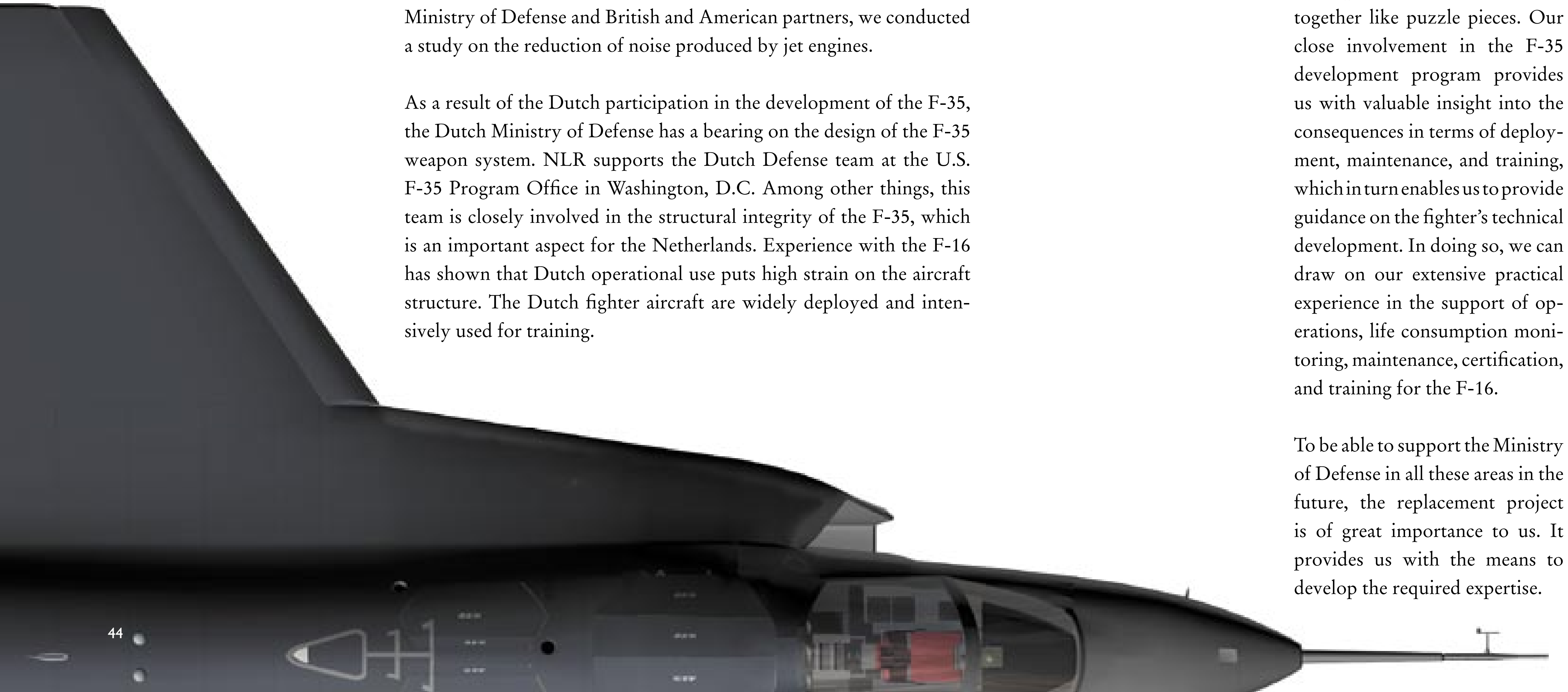
The procurement of a new fighter aircraft is complex. Its operational features must meet Dutch requirements for intended deployment. Introduction of a new weapon system involves a whole range of consequences for maintenance and supply logistics. In the course of 2005, we listed an inventory of the F-35-related technical data NLR would require for supporting the Ministry of Defense in its roles as smart buyer, smart operator, and smart maintainer. This offers the Ministry of Defense maximum leverage in its negotiations with the U.S. F-35 Program Office.
Environmental issues are important to the Netherlands. The F-35 may not contain hazardous materials that are prohibited in the Netherlands. Also in 2005, we studied F-35 sound production. The aircraft's noise impact may limit its deployability. In a joint initiative with the Dutch Ministry of Defense and British and American partners, we conducted a study on the reduction of noise produced by jet engines.

As a result of the Dutch participation in the development of the F-35, the Dutch Ministry of Defense has a bearing on the design of the F-35 weapon system. NLR supports the Dutch Defense team at the U.S. F-35 Program Office in Washington, D.C. Among other things, this team is closely involved in the structural integrity of the F-35, which is an important aspect for the Netherlands. Experience with the F-16 has shown that Dutch operational use puts high strain on the aircraft structure. The Dutch fighter aircraft are widely deployed and intensively used for training.

Replacement of the F-16 has major practical consequences. NLR is involved in all facets of adjustments to be made at the Dutch Air Force. For instance, ground command must be equipped for optimum communication with the new fighter's onboard systems. Pilots must be trained to fly the new aircraft. Maintenance services require restructuring to adjust to the modern maintenance approach applied in new types of fighter aircraft. The F-35 differs significantly from the F-16 in this regard, reporting maintenance requirements well before the fighter actually lands. Every thing is then put in place to take action immediately upon return of the aircraft and to get it airborne again as soon as possible.

The various activities regarding the replacement of the F-16 fit together like puzzle pieces. Our close involvement in the F-35 development program provides us with valuable insight into the consequences in terms of deployment, maintenance, and training, which in turn enables us to provide guidance on the fighter's technical development. In doing so, we can draw on our extensive practical experience in the support of operations, life consumption monitoring, maintenance, certification, and training for the F-16.

To be able to support the Ministry of Defense in all these areas in the future, the replacement project is of great importance to us. It provides us with the means to develop the required expertise.



LOOKING OVER HILLS

Soldiers sometimes wish they could rise up off the ground and see what is behind the next hill. Have the enemy laid an ambush? Are there terrorists in the area? Various manufacturers are developing small, remotely-controlled robot helicopters that can be deployed for short-range reconnaissance of this kind.

A soldier could take a mini helicopter out on patrol. This would be ideal in the hostile territories where Dutch troops often operate and where guerilla fighters may be active.

If these unmanned helicopters are to serve this purpose, their camera, navigation, flight and other onboard systems must work together perfectly. A soldier should be able to operate the helicopter with the aid of a robust laptop. No special training should be required.

NLR is currently studying which requirements these mini helicopters must meet if these platforms are to operate unmanned missions. We developed an onboard computer to gather data from all the sensors, which was then relayed to a ground unit. During the next phase, this computer will also be used to pilot the Unmanned Aerial Vehicle (UAV). All the soldier needs to do is plot a course on his laptop. The helicopter will then automatically start up and take off. During its flight, the onboard camera relays images to the soldiers on the ground.

The first test flights were completed in 2005, giving NLR insight into crucial aspects of these UAVs, thus better enabling us to support the Dutch Ministry of Defense in the purchase and utilization of such equipment.

HELICOPTERS AT SEA

Helicopters are not only used for missions over land. They are also used at sea, where conditions may impose completely different demands on crews and equipment.

© CAVDKM

Landing on a ship's deck can be especially difficult. That is why each type of helicopter must be tested on each type of ship, to establish under which circumstances a pilot can land safely. In 2005, NLR conducted several trials of this kind for the Dutch defense force. The data are used to formulate detailed operational instructions for helicopters to operate under various conditions.

These tests often start when a ship is being designed, because any adjustments are still relatively inexpensive at this stage. We test scale models in our wind tunnels, for example, to see if the ship's exhaust emissions may hamper helicopter operations. We also assess the airflow around the ship under various wind conditions. These factors are later also tested aboard the actual ship, to check and supplement our wind tunnel data. The pitch and heave of the ship are then also recorded, giving accurate insight into the movements of the flight deck.

We also assess the helicopter's engine performance and control capabilities at an early stage, taking all sorts of variables into account, including weight, wind and temperature. All these data enable us to determine the operating parameters within which a helicopter can land on a ship. This is subsequently tested at sea. In 2005, NLR experts spent many weeks aboard the landing platform dock "Hr. Ms. Rotterdam" and the frigate "Hr. Ms. De Ruyter," which are deployed by Naval Command. The two ships embarked on special voyages to test the operational capabilities of the Cougar and Lynx helicopters.

The ships deliberately sought rough weather conditions in North-European waters, in order to conduct these tests. This was especially important for the Lynx helicopter, which is designed to operate under extreme weather conditions without imposing too many restrictions on the carrier ship. On the other hand, rotor thrust margin is crucial when helicopters are used for transport tasks. This is especially critical when helicopters are deployed in warm, thin air. These tests were therefore conducted in subtropical waters.

The operating limits that are finally set should ensure maximum safety for pilots, even if they have limited experience at sea. During the tests, NLR and military experts assessed which circumstances offer sufficient operating safety. These data will allow helicopters to be deployed with greater flexibility, thus substantially improving operational mobility. This is crucial, because there is a growing need for logistic support and transportation capabilities during peacekeeping missions. Ships are increasingly being utilized as hospital bays and for transportation of relief goods. And rapid transportation by helicopter is a key component of these missions.

F-16 ORANGE JUMPER UPGRADED

The F-16 Orange Jumper is the test aircraft of Air Force Command. NLR has equipped this jet fighter with a complete set of monitoring systems. The aircraft recently underwent an extensive upgrade.

The tail of this test aircraft now features a new logo – an orange kangaroo, a farewell present from the former chief test pilot. The Orange Jumper is the permanent F-16 test aircraft of the Royal Netherlands Air Force. NLR has equipped the aircraft with instruments measuring and recording a wide range of data, from altitude, speed, and acceleration to vibrations, steering power, fuel burn, and control surface positions. The data-acquisition units have been integrated into the aircraft at various places within the airframe. The units collect the data and relay them to a central unit in the aircraft's aft avionics bay. The data are recorded and can be checked immediately by the flight test engineer aboard the aircraft. If anything unexpected occurs, the engineer can immediately abort the test flight or adjust the program. The test system is often extended with specific instruments, such as video cameras for recording e.g. the discharge of a reserve fuel tank.

The Orange Jumper is not only a test aircraft, but also fully combat operational, a combination that is unique in the world. The monitoring system has been kept as compact as possible to allow all components to be installed. This demanded ingenious utilization of the available space on board, which has gradually diminished as standard onboard systems have been extended.

As a consequence the third phase (M3) of the F-16 Mid-Life Upgrade, completed on the Orange Jumper in 2005, spare space aboard the aircraft was reduced by ten liters. That is approximately 20% of the total volume of the monitoring system. We partly redesigned the system and fitted it into spaces which were still unoccupied. In some cases, NLR engineers fitted the electronics into spaces no bigger than an oversized matchbox. We replaced tape recorders with solid-state data recorders, which are more compact and made the existing encoders redundant.

Apart from its intensive annual test program for Air Force Command the Orange Jumper is increasingly attracting the attention of European and American manufacturers for the purpose of certification and system evaluations. This included test flights for Stork SP AEROSPACE and Lockheed Martin Aeronautics. The appeal of this test aircraft may certainly be attributed to its immense flexibility and broad testing potential. We are currently working on telemetry that can relay some of the data from the Orange Jumper to ground control, allowing test flights to be monitored via computers on the ground.

EXPLORATION & SPACE TECHNOLOGY

Sloshing in space

Keeping temperatures constant

Automated aircraft design

Monitoring mono-crystalline cracks

Tilting propellers

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.**

FLUID SLOSH STUDY IMPROVES SATELLITE EFFICIENCY

The Dutch satellite Sloshsat carried out an eight-day experimental mission in 2005, to gain insight into the complexities of fluid sloshing in space.


© ESA

Fluid loads aboard spacecraft display erratic sloshing patterns. Precision forecasts of these patterns are especially crucial during docking maneuvers and orbit adjustments. The Dutch Sloshsat satellite was launched on February 12, 2005, to gain better insight into and control over fluid motion in space. This is the first time that slosh experiments have been conducted on this scale. NLR initiated, developed and constructed its mini-satellite with financial support from ESA and the Dutch government.

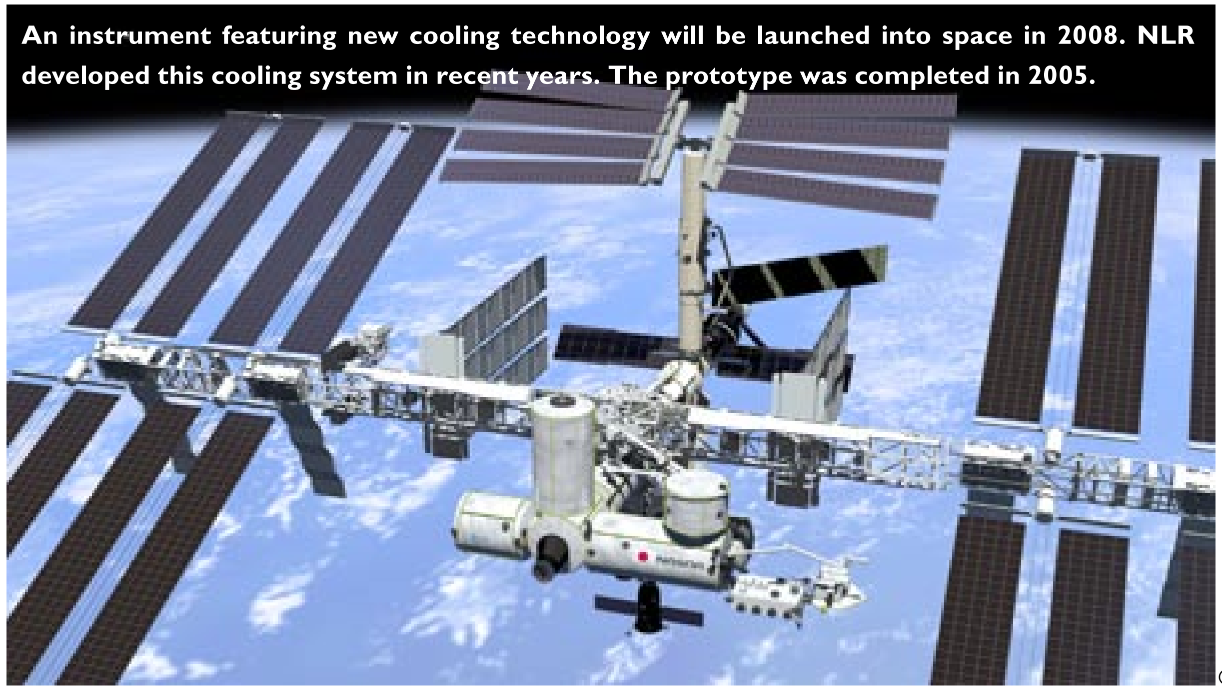
The satellite conducted fluid motion experiments over a period of eight days. Twelve exterior control rockets were used to move Sloshsat in any given direction, at any given thrust. Gyroscopes and accelerometers offered full insight into the satellite's movements. Fluid sensors in the cylindrical tank recorded the exact position of the contents. Although these sensors proved not to be sufficiently precise, NLR was still able to gather 80% of the required data. The exact position of the fluid could also be indirectly concluded from this data.

The data obtained served to validate a computer model simulating fluid slosh patterns. Many of the results have already been compared with the ComFlo computer model developed by Groningen University. Initial conclusions indicate that, generally speaking, there is a correspondence between the model's calculations and the experimental data. However, especially in the case of high-speed fluid motion, the model has been shown to exaggerate the damping of the fluid's motion. At low satellite rotation speeds and when fluid motion is minimal, fluid adhesion to the tank walls has been found to be an important factor, due to the absence of gravity. The model is now being revised on the basis of the experimental data.

Groningen University's computer model should result in more efficient designs for spacecraft with fluid loads. Until now, satellite engineers have worked around the slosh problem.

The experimental data will also be utilized to develop a much simpler and faster model: the Sloshsat Motion Simulator. As this model does not require extensive computation, it can be easily integrated into the system that regulates the satellite's orientation in space. This allows the satellite to save fuel, and thus reduce the overall satellite weight at time of launch.

COOLING IN SPACE


An instrument featuring new cooling technology will be launched into space in 2008. NLR developed this cooling system in recent years. The prototype was completed in 2005.
© NASA

The AMS02 is a particle detector that must operate under constant temperature. Cooling is therefore crucial. The instrument has a large, superconducting magnet on board, which deflects cosmic particles. The magnet is surrounded by six high-precision detectors that register the particles. To allow comparison of the results obtained by each detector, all of the electronics systems must have exactly the same temperature. Owing to the compact structure of the instrument, there is little room for heat discharge and cooling elements. Last year, NLR developed a compact, two-phase cooling system. It works on the same principle as a domestic refrigerator, using a mixture of vapor and fluid. The temperature of the cooling fluid at evaporation point remains constant. This makes it highly suitable for maintaining instruments at a constant temperature, which is exactly what the AMS02 particle detector requires.

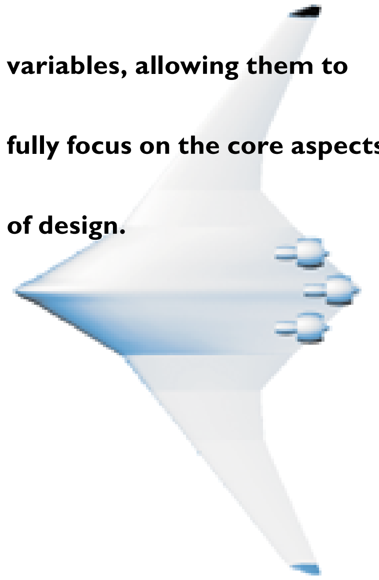
It was long unclear how this system would perform under zero-gravity conditions. NLR therefore previously conducted three experiments in space to gain greater insight into how two-phase cooling system works. There is a risk that vapor bubbles would gather in adverse patterns, causing the system to boil dry, destroying the electronics. However, NLR has now gained sufficient expertise in two-phase cooling technology to start putting it into practice. The definitive design must meet high standards. If all the support systems should temporarily fail, for instance, the instrument should not be damaged beyond repair. Furthermore, components of the cooling system could freeze up. Thawing may result in pressure of up to 300 megapascal, and the system must be able to withstand this.

NLR coordinated the design of the two-phase cooling system in a project that involved the Chinese Academy of Space Technology (CAST), the Sun Yat-Sen University of Guangzhou, the Massachusetts Institute of Technology (MIT), and other institutes. Several components were designed and manufactured by the end-user, the Italian National Institute for Nuclear Physics in Perugia. Scientists intend to use the instrument to detect supercharged particles originating from supernova explosions in distant galaxies and from other sources. They hope this will offer greater insight into dark matter and antimatter in the universe.

The instrument will probably be installed in the International Space Station in 2008, where it will monitor particles for three years. The instrument also includes an oscillating heat pipe, an NLR experiment that may result in an even more compact cooling method in future.

AUTOMATED AIRCRAFT DESIGN

NLR has developed software facilitating more rapid and uniform design of aircraft components. The new design system incorporates extensive insight into structural components and aerodynamics. This ensures that designers no longer have to check all of these variables, allowing them to fully focus on the core aspects of design.



The software utilizes parametric modeling, which is already used in many less complex design applications. For instance, in the design of office furniture, where the software ingeniously adjusts dimensions in accordance with changes made by the designer. So, if the tabletop is enlarged, the software automatically adjusts the dimensions of the table's legs to bear the extra weight. This facilitates the efficient design of a whole series of products that meet the same requirements.

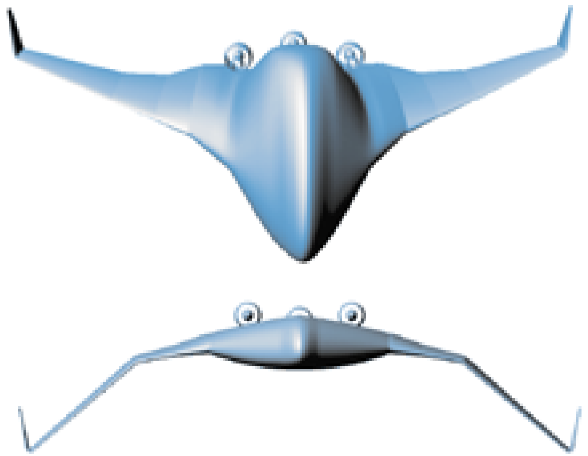
This design approach has many benefits for the aviation industry. However, the interplay of forces around an aircraft is far more complicated than for furniture. Airflow over wing surfaces results in distortions of the material, which in turn influence the airflow. Complex simulations are therefore required to establish the optimum strength of a component.

There are simulation models to calculate this interplay of forces. There are also Computer Aided Design (CAD) programs capable of modeling complex aircraft components. The trick is to link these two, so that the available insight into airflows and strengths is easily accessible for design.

Over the past year, NLR and the Delft University of Technology jointly forged this link, developing a design system for Stork NV. Together we produced a Design and Engineering Engine that enables the aviation industry to utilize parametric design.

We chose iCAD as our design system, a popular three-dimensional drafting program. We then drafted generic components, using abstract parameters to define dimensions and material properties. This meant that the drawings represented an entire series of related components. The project group then added a standardized exchange between the CAD system and the computation models for the aerodynamic properties and strengths. The two computation models were also interlinked to allow for the interplay of forces between airflow and materials. These results were then again entered in the CAD system. This facilitated swift calculation of the geometries. To do so properly, an entire aircraft was then modeled. This was the only way to ensure accurate calculation of the properties. After all, airflows over the fuselage affect the forces exerted on the tail section.

This process ultimately led to the development of a generic model for wing flaps. The design system can now be used to design flaps for every possible type of commercial aircraft. As a result, design orders for new aircraft types can be swiftly executed. The results were tested on the design of the Fokker 100, for which detailed numerical and experimental data are available. The next step involves detailed examination of designs of Airbus aircraft.



FATIGUE LIFE PREDICTION FOR TURBINE BLADES

A study of crack patterns in mono-crystalline materials is essential for calculating turbine blade fatigue life.

© SVEN DE BEVERE

Turbine blades operate at high temperatures (800 to 900 degrees Celsius) and under heavy stress of (100 to 200 megapascal), imposing extreme demands on the materials used. The Dutch Ministry of Defense commissioned NLR to investigate the fatigue life of turbine blades used in the engine of the F-16 fighter. In 2005, NLR developed a model predicting crack orientation and crack growth speed. Experiments were run to validate the model.

Turbine blades are made of nickel superalloy, a monocrystalline material that is far more durable in one direction than it is in another. The material is oriented in such a way that it can withstand the greatest force. Crack patterns in monocrystalline materials are different from those in the more commonly used polycrystalline materials, which tend to fracture straight along the stress axis. Monocrystalline materials also crack in various other directions.

Turbine blade manufacturers are relatively conservative when specifying fatigue life. The Dutch Ministry of Defense wants a second opinion. Not a single crack may form during a blade's guaranteed fatigue life. If it does, the crack grows quickly, and a broken blade is disastrous for an engine. Should the fatigue life prove to be longer than the manufacturer indicates, then, after consultation with the manufacturer, the blades can be used for a longer period. This saves replacement costs.

TILT ROTOR TURNS PLANE INTO HELICOPTER

Special rotors are required to allow a plane to take off and land like a helicopter. A new NLR measurement system is crucial for the design process.

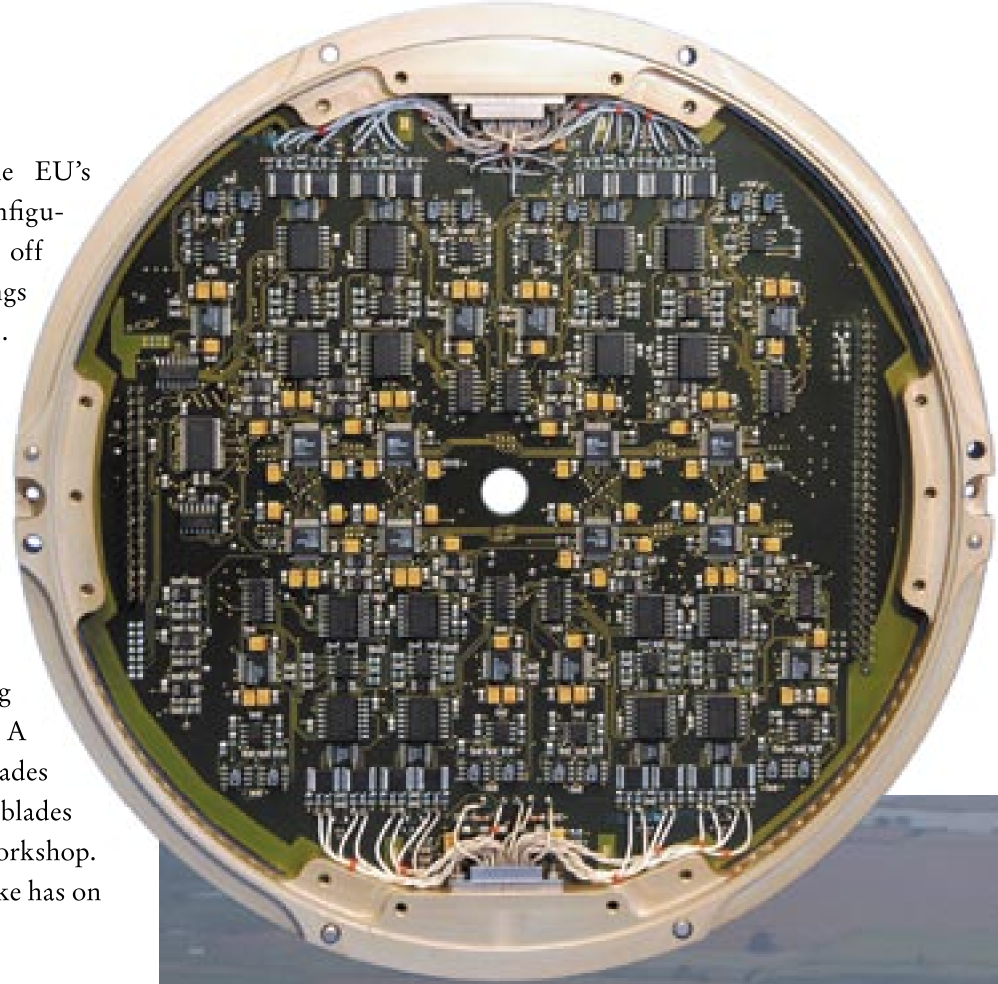
Italian helicopter manufacturer Agusta coordinates the EU's TILTAERO project that is devoted to a tilt rotor aircraft configuration suitable for commercial aviation. The plane can take off and land like a helicopter by tilting the two rotors on its wings upward. Efficient rotor blades are required to achieve this. Once the aircraft is airborne, the rotors tilt forward and it flies like any other airplane. However, conventional rotor blades are actually too long to allow this. Agusta is therefore studying how rotor blades can be made as short and efficient as possible, but still allow the aircraft to take off and land vertically. Wind tunnel tests play a major part in this study.

NLR is testing a 1:2.5 scale wind tunnel model of the wing and tilt rotor, but the blades still have a span of 2.5 meters. A total of 128 sensors are mounted in the four composite blades to measure the pressures and stresses exerted on them. The blades themselves were made at the NLR precision engineering workshop. One of the focal points of research is the effect that rotor wake has on the aircraft's wing.

During the wind tunnel tests, measurement data are transmitted at a speed of a 100 megabit per second. All of these data are first amplified and converted into a digital signal. Agusta commissioned NLR to develop a dedicated signal transmission system. This is a 6.5-kilogram cylindrical measurement instrument that rotates at the same speed as the rotor blades; i.e. 1,400 revolutions per minute. The weight alignment of this instrument must be balanced with great precision to avoid causing vibrations in the model.

After amplification and conversion, the measurement data are sent to a base station 100 meters away. Previously, such experiments required almost 400 power cables, each 100 meters long. These have now been replaced by just one fiber-optic cable. Fiber-optic data transmission is much less sensitive to interference than electrical transmission. The system is highly functional. Agusta also intends to use it for other wind tunnel models. The measurement data will ultimately be used to optimize the aerodynamics of the tilt rotor blades and wing design.

The TILTAERO research program is partly funded by the European Union. NLR delivered the system at the end of 2005. During the course of 2006, Agusta will run the TILTAERO measurement program in the Large Low-Speed Facility of the German-Dutch wind tunnels (DNW-LLF) in Flevoland, the Netherlands.



BELL-AGUSTA TILT ROTOR© AGUSTAWESTLAND

Chapter 3:

FACTS & FIGURES

This chapter gives an overview of NLR's facts & figures for 2005. This includes financial data, information on organizational structure, and the composition of the NLR Board. You will also find a series of portraits of NLR personnel.

Portraits of ← - - - - - → NLR personnel

"I WAS HOOKED STRAIGHT AWAY"

Peter Nijhuis, project engineer – Structures Technology

There was a time when I wanted to be a pilot, but I eventually opted for aircraft engineering. I'm mad about planes. During an internship, I found myself in the German-Dutch Wind Tunnel at the NLR facility in Flevoland. I was hooked straight away. The work was so varied, so many different tests to run. And the surroundings were magnificent, too. I love nature and water sports. I must have applied for three different jobs at NLR before they took me on.

I now head major testing projects. Some of the rigs are up to five meters high, for testing aircraft components. I love that – the huge forces involved. You sometimes see the steel beams bending. Experiments like this involve all sorts of specialists: designers, operators, and people who are experts in hydraulics, measurement systems, and frame construction. I enjoy bringing them all together and ensuring that everything runs like clockwork. People really want to work here. Sometimes they are so motivated that I have to rein them in: you don't always have to achieve perfection. We all have common interests here, and we all want to know what the others are working on. We all enjoy achieving project milestones together. One example is when the materials arrive after weeks of preparation at the drawing board. The rigs always look a lot bigger than they did on paper. It's also great when you start running tests after months of construction. Those are exciting moments. Some of the test components cost a small fortune. So you don't want to mess up.

"THIS WORK IS PERFECT FOR ME"

Mariska Roerdink, cognitive psychologist – Training, Human Factors & Cockpit Operations

At a very early age, my sister and I got dragged along by my father to aviation museums, air shows, and open days at the air force base. I loved it. When I graduated from Utrecht University as a cognitive psychologist in 2002, I applied for a job at NLR. This was the chance of a lifetime. Applied research in combination with aviation. I thought: "This is it!" At NLR, I became a psychologist among technicians. I think it was a bigger shock for them than it was for me.

The Human Factors department already employed psychologists, but not many. At other departments, you could see people thinking: "What is she doing here?" As a psychologist, you often have to work harder to prove yourself. But ultimately, it's great fun working with people from different disciplines. You can learn so much from each other. You can achieve a lot more together than you can working apart, as engineers or psychologists.

I actually enjoy the fact that NLR is largely a man's world. Men say things loud and clear, and I'm surprised at just how small the differences between the sexes can be. Sometimes I can sit in a meeting for an hour without realizing that I'm the only woman. This work really is perfect for me. When people ask me what I do, I enjoy telling them. For instance, about the trip I made to various Norwegian airports back in 2005, compiling a task analysis for air traffic controllers. They were planning to restructure their organization, but they didn't want to jeopardize safety. That made the project highly concrete and relevant. And people are really pleased with the work you do.

Portraits of ←- - - - -→ NLR personnel

"I'M CRAZY ABOUT HELICOPTERS"

Natalie Münninghoff, research engineer – Helicopters

I'm crazy about helicopters. I always have been. I graduated from Delft University and then joined NLR. That was the place to be, in my opinion. Helicopters are complex and very intriguing in terms of engineering. There are so many things we don't have a grip on yet. My job at NLR involves the certification and testing of helicopters. I check whether they are safe, whether they are airworthy, and whether they meet the needs of the user. I'm proud of the work I do. Especially because my job fits like a glove. I really love going to work in the morning.

What I enjoy most is bringing various parties together to solve a practical problem. It's all about listening carefully and mapping out the problem. Sometimes that means I have to dive deep into the organization. The work is varied and very pragmatic: we never sell one-dimensional technological solutions. I enjoy dealing with a broad array of issues. I also love the tension and the interaction. That's a side of myself I discovered at NLR. I used to be more of a loner.

While I was studying in Delft, people sometimes said NLR was a dusty dinosaur. But that's not what I've found. What I share with my colleagues is the satisfaction of achieving highly concrete results – the specification of a new instrument, a new maintenance procedure, or the supervision of testing procedures for a new police helicopter. That down-to-earth culture really appeals to me.

"THIS IS WHERE THE ACTION IS"

Martijn Stuip, R&D engineer – Avionics

I graduated at the best possible time. Lots of companies were looking for electrical engineers. I had several job interviews, but I really fell for the open, informal culture at NLR. And of course, aviation is always intriguing. It still fascinates me that aircraft manage to stay in the air. I'm involved in avionics at NLR – onboard electronic systems. My job is all about safety and reliability. Aviation demands that you take a broad perspective, because everything is linked in one way or another. Safety doesn't stop at the end of your system. You have to look at operating features and consider the interface with other systems. That sometimes involves tests aboard our laboratory aircraft. What a great job! There's nothing like it.

I'm proud that my work is applied in the real world; that I helped lay the foundation for the future. We are developing unmanned aircraft, and we are involved in a European project creating a blueprint for the aircraft navigation and communication systems of the future. I sit at the table with international experts. I listen to them, and they listen to me. Internationally, NLR is seen as an independent body. That opens doors, offers a great degree of freedom, and gives you a broad international network. I can gain a great deal of experience at NLR. This is where the action is."

I) ORGANIZATIONAL STRUCTURE

General Director
Fred Abbink

Financial Director
Leo Esselman

General Secretary
Ernst Folkers

Marketing
- Civil & Military Aircraft Development
- Defense & Civil Safety / Industry
- Civil Aviation
- Defense & Government
- Space Technology

- Knowledge & Technology
- Quality Management
- Public Affairs & Corporate Communication

Support Services
- ICT
- Documentation & Information
- Buildings & Facility Services

Finance & Accounting

Planning & Control

Personnel & Organization

Legal Affairs

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

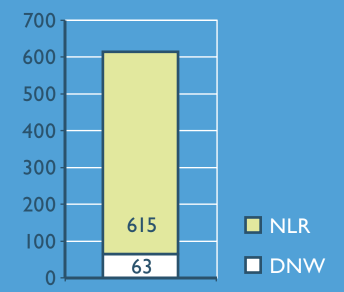
Air Transport
- Safety & Flight Operations
- Air Traffic Management & Airports
- Air Traffic Systems Technology
- Training, Human Factors & Cockpit Operations
- Environment & Policy Support

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

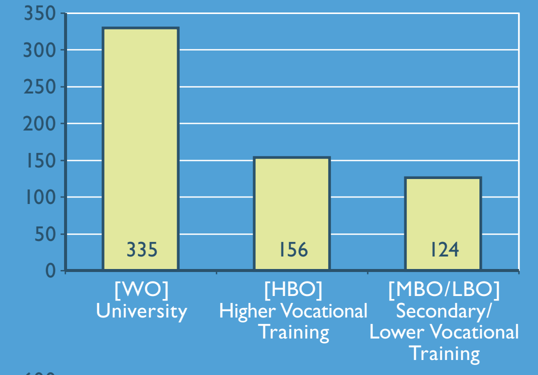
German-Dutch Wind Tunnels

II) NLR STAFF ON DECEMBER 31, 2005

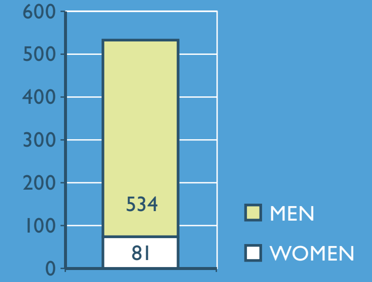
Number of staff (total = 678)



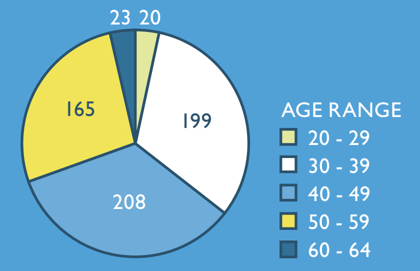
Academic level of staff (excluding DNW)



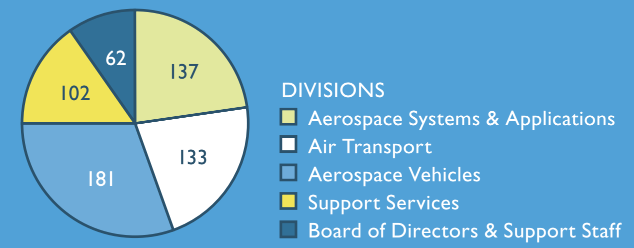
Gender division (excluding DNW)



Age breakdown (excluding DNW)



FTEs breakdown (excluding DNW)



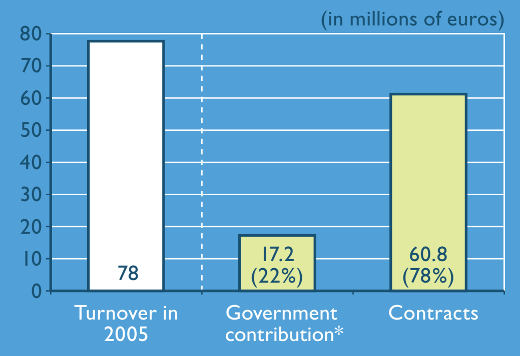
III) THE BOARD ON DECEMBER 31, 2005

Drs. A. Kraaijeveld	• Chairman
Drs. A. de Ruiter	• Ministry of Transport. Public Works & Water Management
Ir. P.J. Keuning	• Ministry of Defense (DMO)
Gen-Maj. mr. E.H. Evers	• Ministry of Defense (DMO)
Drs. A.A.H. Teunissen	• Ministry of Economic Affairs
Drs. L. le Duc	• Ministry of Education, Culture & Science
Prof. B.A.C. Droste	• Netherlands Agency for Aerospace Programs (NIVR)
Ir. R. Spaans	• Stork
Drs. Ing. P. Hartman	• KLM
vacancy	• Amsterdam Airport Schiphol
Mr. G.H. Kroese	• Air Traffic Control the Netherlands
Mr. C. van Duyvendijk	• TNO
Jhr. J.W.E. Storm van 's Gravesande	
Prof. dr. ir. M.P.C. Weijnen	
Prof.dr.ir. H. Tijdeman	• Chairman of the NLR/NIVR Scientific Commission

Drs. A. Kraaijeveld succeeded J. van Houwelingen as Chairman of the NLR Board.
Prof. H. Tijdeman succeeded Prof. P.J. Zandbergen as Chairman of the NLR/NIVR Scientific Commission.

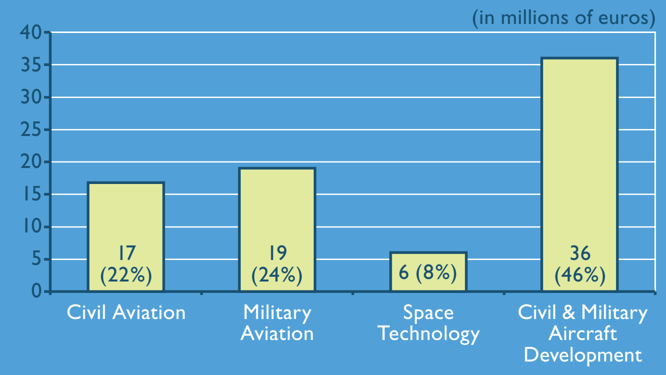
IV) FINANCIAL DATA

Turnover in 2005



* Excluding a € 2.5 million allocation to facilities and € 2.3 million investment contribution

Breakdown across sectors



WHAT IS NLR?

- The National Aerospace Laboratory (NLR) is the key center of expertise for aerospace technology in the Netherlands;
- NLR employs 700 people, including 335 university graduates and 156 graduates of higher vocational colleges;
- NLR's facilities include wind tunnels (for testing aircraft produced by Airbus, Lockheed Martin and others), simulators (for testing the safety of new flight procedures, among other things), and a laboratory aircraft;
- NLR's revenue amount to € 80 million, with contracts accounting for € 60 million;
- 75% of our contract work is directly or indirectly government-funded.

ADDITIONAL INFORMATION

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