FLYING DUTCHMEN:

Royal NLR — A Century of Innovation

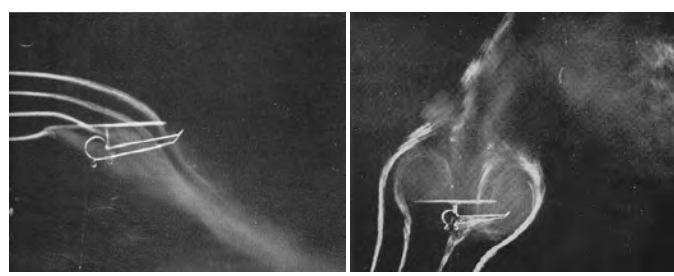
The Netherlands Aerospace Centre (NLR) recently celebrated its centennial and received the predicate "Royal" from His Majesty King Willem Alexander. The honorable designation highlights the center's role as the leading technological knowledge institute in the field of aerospace in the Netherlands.

By Ian Frain

The Royal Netherlands Aerospace Centre was originally established on April 5, 1919, as the Government Service for Aeronautical Studies (Rijks-Studiedienst voor de Luchtvaart, RSL), to pursue improvements in military aviation safety. The world had just seen the end of "The Great War," and the first use of aerial combat. Civil aviation was in its infancy but destined to grow and the RSL was quick to expand its expertise into that sector.

Albert Gilles von Baumhauer joined RSL (predecessor to NLR) in 1921, and the Centre was engaged with development and testing of his helicopter during 1924-1930. (Photo via Netherlands Institute for Military History)

In 1937, the RSL became the National Aeronautical Laboratory (Nationaal Luchtvaartlaboratorium, NLL) and changed its status to that of a foundation, with a commitment to continue its mission of conducting aerospace research. In 1961, it added astronautics to its mission and became NLR (originally standing for "Nationaal Lucht- en Ruimtevaartlaboratorium," but now just "NLR"). The advent of computers and the move into the digital age was matched by new methods of testing and improvements in technology, including the creation of both flight and air traffic control (ATC) simulators.



Jan Meijer Drees published wind tunnel test photos using smoke to study helicopter rotor flow. (NLR photos via Gordon Leishman)

In 1949, Jan Meijer Drees (who later joined Bell Helicopter), L.R. Lucassen and W.P. Hendal published a report on the airflow through a helicopter rotor in various vertical flight conditions. To better understand the phenomena, dedicated wind tunnel tests were performed whereby the flow was made visible with the aid of smoke, leading to some of the most famous early photos of helicopter rotor flow.

Since the 1950s, NLR has been involved in supporting both military and commercial rotorcraft platforms in the Netherlands and abroad. The many rotorcraft areas which NLR covers include: design and development, wind tunnel testing, flight procedures, helicopter ship qualification testing, rotorcraft performance and handling qualities, airworthiness, modelling and simulation, and unmanned aircraft systems (referred to as "remotely piloted aircraft systems," RPAS, by NLR).

Helicopter-Ship Qualification Testing

The Royal Netherlands Navy (RNLN) was one of the first operators of shipborne helicopters on small ships. Together with the Netherlands Aerospace Centre NLR and the innovative Dutch company AeroMath, the RNLN pioneered the development of helicopter-ship qualification procedures. This collaborative effort has led to the current Dutch helicopter-ship qualification method. The method is based on a thorough understanding of

Drees, Gerard Verhage and Will Kupers developed the ramjet-powered Kolibrie, with support from the Centre, including testing the rotor system at NLL Amsterdam. (NLR photo)

the helicopter (shore-based) operational characteristics and the ship's environment before executing helicopter flight trials on board a ship.

In 1952, in the Netherlands, military helicopter operations from ships started with a single Sikorsky S-51 helicopter on board of the aircraft carrier HNLMS Karel Doorman. In 1954, the S-51 was followed by three Sikorsky S-55s and in 1960 the Sikorsky S-58. Again, both helicopter types operated from the aircraft carrier HNLMS Karel Doorman. In 1963, the first Dutch replenishment-at-sea ship HNLMS Poolster made its maiden voyage. It was also the first Dutch navy ship equipped with a relatively small helicopter flight deck and a hangar at the stern of the ship. Concerns about the feasibility of helicopter operations in disturbed air from the ship's superstructure resulted in 1964 in an order for investigation of the air flow around the helicopter flight deck in a wind tunnel. This started the NLR involvement in helicopter operations from ships. Since then, NLR has performed or participated in helicopter/ship qualification tests with twelve different helicopter types, such as the Bell 204B, Westland Wasp and Westland Lynx, before today's NH Industries NH90 NFH (NATO Frigate Helicopter), on nearly twenty different classes of ships for several different countries.

More than 55 years of joint experience with the Dutch helicopter-ship qualification method resulted in a safe and efficient test program to obtain Ship Helicopter Operational Limitations

The HNLMS Poolster, the first Dutch navy ship equipped with a helicopter flight deck and a hangar made its maiden voyage in 1963. This photo is of the Sikorsky S-58 Seabat shipborne trials the following year. (NLR photo)

(SHOLs) for operations of a helicopter on board a ship. This unique approach to achieve an initial estimate of the operational limitations for each specific helicopter/ship combination, relies on the so-called Candidate Flight Envelope (CFE). The CFE is based on (steady) wind tunnel measurements of the airflow around the ship, combined with the helicopter low-speed characteristics, determined during shore-based hover trials (because most often the manufacturers' data are considered insufficient). This approach allows safe testing at the boundaries of the SHOLs, whilst significantly reducing the required number of test points during the sea trials.

NLR was a key player in the development of the NH90, including support for shipborne testing, such as these sea trials with the NH90 NFH onboard a RNLN ship in 2011. (NLR photo)

Smarter Way on the High Seas or Battlefield: The NH90

The NH Industries NH90 was developed between four nations, France and Germany (Airbus), Netherlands (Fokker, now GKN Aerospace) and Italy (Leonardo). France and Germany share the largest proportion of the project with Airbus Helicopters France (31.25%) and Airbus Helicopters Deutschland (31.25%), then Leonardo (32%) and lastly GKN Aerospace (5.5%).

The NH90 developed and produced two versions: the battlefield Tactical Transport Helicopter (TTH) and NATO Frigate Helicopter (NFH). This platform replaced several legacy types in use in Europe such as the Agusta-Bell 205, 212 and 412, Westland Lynx, Bell UH-1D, etc.

The Royal Netherlands Navy, or Koninklijke Marine, operates the NH90, albeit that it is owned by the joint Defence Helicopter Command (DHC). NLR is not only involved in supporting the helicopter for the Dutch Ministry of Defence but also for other NATO nations that operate both versions.

Since 1984, NLR, together with Fokker, has assisted with the design of NH90 (from wind tunnel testing in the early days, up to flight testing in the late 1990s) and had a representative with then-Eurocopter in Marignane, France, overseeing the testing program. NLR Senior Scientist Jos Stevens said NLR was responsible for overseeing everything from design to certification and production, and that is still ongoing. There are also many levels of support within the program, bringing it up to the operational standard required by the Dutch MoD, including support with management, overseeing the design process and covering the entire program from initial inception to end of life. NLR uniquely develops and provides the Sustainability Data Exchange (SDE) for eight countries in the NH90 program as a tool to support the platform in a cost-effective manner.

Smart Three Levels

The NH90 SDE comprises three layers: Occurrence Reporting System (ORS), Reliability Assessment System (RAS) and Aircraft Integrity Management (AIM). In the first level, an occurrence is classified as an anomaly, such as an incident, event, issue or failure. The ORS enables the storing, analyzing and reporting of all the NH90 SDE occurrence data in a secure flexible environment. The information is provided from many sources, from high in the chain of command down to the front-line squadron and forward operating/deployed units, plus the line and base maintenance teams.

Each of the countries has to provide the occurrence data for the SDE ORS module. Ease of use is achieved by a number of features, such as a business-to–business (B2B) interface and corresponding interface control document (ICD) to allow automatic input. It is akin to a Microsoft Windows-type operating system with the capacity to store documents and images from Word .doc files to JPEGs, and a quick search function. Finally, a notification module is available to inform the operator if there are any additional occurrences.

The second level provides the operators with reliable analysis tools generating experienced failure rates of different NH90 components. Reliability figures are based on participating nations' information, on maintenance tasks and failures, and admin data of parts and equipment.

Lastly, the third level, the SDE Aircraft Integrity Management (AIM), provides the NH90 operator with structural integrity and fleet life management tools, combined with a standard reporting facility on operational usage loads/damage accumulation and "lifing" of helicopter components. The SDE AIM functions include quantifying the operational service usage spectrum, as well as monitoring component fatigue life and deriving consumption figures. The SDE AIM also determines the relation between airframe corrosion, delaminations, cracks, etc., and how the airframe is flown/handled under different conditions, such as high-speed regime, hard landings and so on. On the mission side, the SDE AIM has other functions that include breaking down the missions, by dividing them into either separate or subsequent flight events/regime categories. They can also construct imaginary (virtual) missions to provide an estimation of future usage of the airframe. SDE AIM receives and stores information on usage from national systems, for example from flight logs, in order to keep the three levels running.

Korean Connection

The KUH-1 Surion military transport helicopter manufactured by Korea Aerospace Industries (KAI) recently obtained its ice certification in Korea, enabling equipment and troops to be transported safely in this helicopter even in icy conditions.

In order to check the air intake anti-icing system design, anti-icing qualification tests were performed. NLR designed and manufactured several full-scale air intake models, for aerodynamic verification tests and another equipped with an electro-thermal anti-icing system. Models were tested in the Italian Aerospace Research Centre (CIRA) icing wind tunnel and in the Rail Tec Arsenal (RTA) Icing Wind Tunnel in Austria. NLR also assisted in the Surion icing flight test campaign that was recently concluded at Michigan's Sawyer Air Force Base in the United States.

NLR designed and manufactured air intake models for the KAI Surion. This one was tested in the German-Dutch Wind Tunnels' (DNW) Low-Speed Wind Tunnel in Braunschweig, Germany (NWB). (NLR photo)

NLR researcher Stefan van 't Hoff explains: "An ice protection system (IPS) is indispensable for helicopters that often encounter situations where icing conditions may occur and where operational availability is very important. Search and Rescue (SAR) operations above sea are a prime example. Above large bodies of water and along the coast, there is often a moist atmosphere that leads to cloud formation. As soon as the temperature in the clouds drops below freezing, it is possible for water droplets in the cloud to become supercooled and, after contact, to form an ice layer on vital parts of the helicopter, like the rotor blades and the engine intake. In general, the engine intake represents a particular risk, because of the possibility of large pieces of ice being sucked into the engine, causing damage, or in the worst case, engine failure."

On the Surion helicopter, an ice detector alerts the pilot when icing conditions are detected. The pilot then manually activates the IPS. The de-icing system of the main rotor periodically allows a layer of ice to accumulate and then heats the blades, causing the ice to shed under centrifugal loads. This is accompanied by periodic variations in the required power and vibration level. In contrast, the engine intake is permanently heated, enabling icing accretion to be prevented completely. The same anti-icing principle is used for the helicopter windscreens and, in the case of the Surion, also for the wire cutter located on top of the helicopter cabin near the engine intake.

Unmanned Integration

NLR has a dedicated RPAS Test Centre with associated airspace and airstrip in the Flevoland Polder, which is in the northeast of the country in reclaimed land. NLR carries out research and support of drones for both fixed- and rotary-wing platforms. NLR has onsite a variety of unmanned systems ranging from micro air vehicles (MAV) to a 220 lb (100 kg) twin-turbine drone. NLR is converting the latter into an electrically-powered RPAS as a major project.

Some examples of projects that have been carried out include working with the Schiebel Camcopter S-100 drone. This 440 lb (200 kg) platform flies at around 120 kt (222 km/h) and has an endurance of six hours with normal payload of 75 lb (34 kg). It is used predominantly for surveillance with several different types of sensors. NLR developed the AirScout detect and avoid

NLR is converting this Geocopter GC-201 drone to electrical power. (NLR photo)

NLR developed the AirScout detect-and-avoid system, using a Camcopter as the testbed. (NLR photo)

system for drones to autonomously detect and avoid other traffic in the air, and also the software and hardware package, using a Camcopter as the testbed.

When it came to airspace integration with other aircraft, NLR carried out tests with fixed- and rotary-wing platforms at the end of 2015 at their RPAS Test Centre and within a controlled traffic region on the Dutch North Sea coast. There were three aircraft involved with the Camcopter/AirScout trials: a Dutch Coastguard Dorner Do-228 twin-engine patrol aircraft, a Dutch Air Force Aerospatiale Alouette III, and NLR's only aircraft — a Cessna Citation corporate jet modified as a testbed. There were many exercises accomplished, such as flying head on, from across, line of sight and from the rear, representing a realistic coast guard mission, with the drone having to take evasive action in each case. The whole exercise was a challenge for the RPAS operator, as well as the other fixed- and rotary-wing air crews. Ultimately these trials were part of an overall European program called AIRICA — funded by the Single European Sky Air Traffic Management (ATM) Research (SESAR) program — involving various coast guard operators in the continent.

Military and Commercial

NLR provides support with regard to safety of operations for both commercial and military rotorcraft in Holland. One example of this is assisting the Air Force's AH-64D Apache Demo Team crew with their aerobatics by way of simulations and flight test support so that the team can successfully and safely perform at airshows around Europe. The Air Force operates the Boeing CH-47D and the newer -F "Foxtrot" model Chinook helicopter. Here, NLR among others studies sling loads to ensure safe and efficient underslung operations. This is achieved by studying the behavior of the load fixed underneath, recording its stability and any movement. Some of the work can be carried out in the NLR flight simulator to simulate the loads or by flight testing.

Both Belgium and the Netherlands have been sharing the offshore helicopter support to the southern North Sea oil and gas platforms for 50 years. In the Netherlands, it was traditionally KLM Helikopters — which then became part of Schreiner Aviation in 1998 and then CHC Helicopter in 2005 — and Bristow Helicopters from a base at Den Helder Airport in the north, with the Sikorsky S-61N and S-76B in the early days. In the late 1980s, NLR developed the Category A "confined area take-off and landing procedures" for the Sikorsky S-76B for KLM Helikopters as a supplement to the flight manual — but for KLM only, as they owned the rights. Indirectly, it spread to Sikorsky and then became the standard for all Sikorsky S-76B operators worldwide.

When the Dutch Dienst Luchtvaartpolitie (police air support unit) needed a replacement for their legacy Messerschmitt-Bölkow-Blohm (MBB) Bo 105 helicopters in the mid-2000s, NLR supported the process, from initial requirements to selection of the new Eurocopter EC135 and the larger Leonardo AW139. The same methodology was applied to the Royal Dutch Touring Club (ANWB) Medical Air Assistance (MAA) helicopters. It operated the legacy MBB Bo 105 for a long time and needed a replacement, which is where NLR came in. The ANWB-MAA currently operates the EC135. In the last two years, the ANWB-MAA took delivery of the larger Airbus H145 (albeit used primarily for patient transportation in the remote islands) and ordered another batch of newer H135s.

Research Simulator

NLR has a Helicopter Pilot Station (HPS), which is a reconfigurable research simulation facility for a two-person crew. The platform provides a very realistic model for complex tasks ranging from underslung cargo loading to flying tactical maneuvers, shipborne operations, etc. The HPS also supports a broad range of research activities for air accident investigations, creating new flying and operating procedures, aircrew training and human factors. The HPS can be configured for most conventional rotorcraft, such as the NH90, Airbus Helicopters AS532U Cougar and MBB BO105. The HPS is also configured for more complex and unconventional rotorcraft such as the Boeing CH-47 Chinook, co-axial Kamov Ka-32 Helix and even tiltrotor.

The Mk.1 Eyeball

NLR's Human Factors Department contributes to the improvement of the pilot's performance. This is done by an eye tracking mechanism, a non-invasive scanning of the pilot's eyeball, tracking the visual scanning movements in real time to

The author flying the NLR Helicopter Pilot Station (HPS), a reconfigurable research simulation facility. (Photo via the author) see how the pilot behaves in both stressful and non-stressful environments. This allows, for example, flight instructors to improve training results by giving direct, in-flight feedback.

NLR also carries out research into helmet-mounted displays (HMD) to study human factors research in a rotary-wing environment, concept development and experimentation, pilot-in-the-loop testing of HMD content, simulation-based acquisition, familiarization, and testing among other areas.

As part of Clean Sky, NLR is supporting tiltrotor research, including this 2013 testing of the AgustaWestland ERICA configuration in the DNW Large Low-Speed Facility (LLF) in Marknesse, The Netherlands. (DNW photo)

Clean Sky Future and Urban Trends

The European Union Clean Sky Initiative is a European research program aimed at reducing exhaust gas (CO2 and NOx) emissions and noise produced by aircraft. It is funded by the EU's Horizon 2020 program, encouraging the development of the innovative, cutting-edge technology that can achieve the program's objective. As part of Clean Sky 1, which focused on green rotorcraft research among other issues, NLR did simulations, looking especially at fuel consumption, gas emissions and noise reduction, comparing the data to current helicopter-platforms of the year 2000. NLR is also part of the Clean Sky 2 initiative, where it is largely concentrating on tiltrotor research, evaluating the technology for the potential benefits of replacing conventional rotorcraft. Within the Clean Sky programs, NLR closely cooperates with the major European research institutes, universities and related industries.

There is a worldwide trend to explore urban air mobility and personal air vehicles, with scores of companies coming up with innovative designs (see the VFS website, **www.eVTOL.news**). In the Netherlands, the locally-designed and produced PAL-V Liberty is an innovative "Personal Air and Land Vehicle" that drives as a three-wheeled vehicle at up to 86 mph (160 km/h) and converts into a 97 kt (180 km/h) autogyro. The foldable rotor blades and propeller have to be compliant with EASA CS27 small rotorcraft airworthiness and design standards. NLR has been supporting developer PAL-V International B.V. throughout the design, qualification and production process.

A half-model tiltrotor test at DNW in Marknesse in 2007 as part of the TILTAERO program. (DNW photo)

With many new innovations for civil and military applications, NLR continues to support the industry to overcome challenges in developing safer, smarter, higher-performance and more advanced vertical flight systems.

Crowning Achievement

On April 5, His Majesty King Willem Alexander awarded NLR the "Royal" designation, making it now the "Royal NLR" and the "Royal Netherlands Aerospace Centre."

Joost Hakkaart, manager of the Department of Helicopters and Aeroacoustics at the Royal NLR, shows a hydrogen-powered research drone to His Majesty King Willem Alexander, with Dutch Minister of Infrastructure and Water Management Cora van Nieuwenhuizen and Hans Büthker, CEO of GKN Aerospace. (Photo by Nico Alsemgeest for NLR)

The designation was awarded by the King's Commissioner of North Holland, Arthur van Dijk: "NLR has been a strong brand for 100 years. It is the first and only research center that focuses entirely on sustainable, efficient and safe aviation and aerospace in the Netherlands. I am delighted to be able to provide your centenary with a festive and prestigious predicate."

Royal NLR CEO Michel Peters stated: "We are very proud that we can now carry the designation 'Royal'. It is the crowning glory for the work of our employees. Their knowledge and expertise is and remains the driving force behind pioneering innovations. The designation is an incentive for the future and strengthens NLR and our employees in our ambition to make aerospace increasingly sustainable. This is a huge challenge and requires an even faster speed of innovation and intensive collaboration. The dot on the horizon is flying emission-free in 2070. We are determined to make our contribution to this goal, together with the sector. This will not only be done in an evolutionary way, but requires a revolutionary approach for which NLR has to find outside-the-box solutions. And that is exactly what we are going to do."

About the Author

Ian Frain runs an aviation research consultancy from Cambridge, United Kingdom as well as based in Austria/Germany called Helian. He has a BSc in engineering studies — aerospace and mechanical — from University of Hertfordshire, and has worked in offshore and parapublic helicopter maintenance, and as a researcher in an aviation publishing company. He can be reached at *ian@hel-ian.eu*.

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