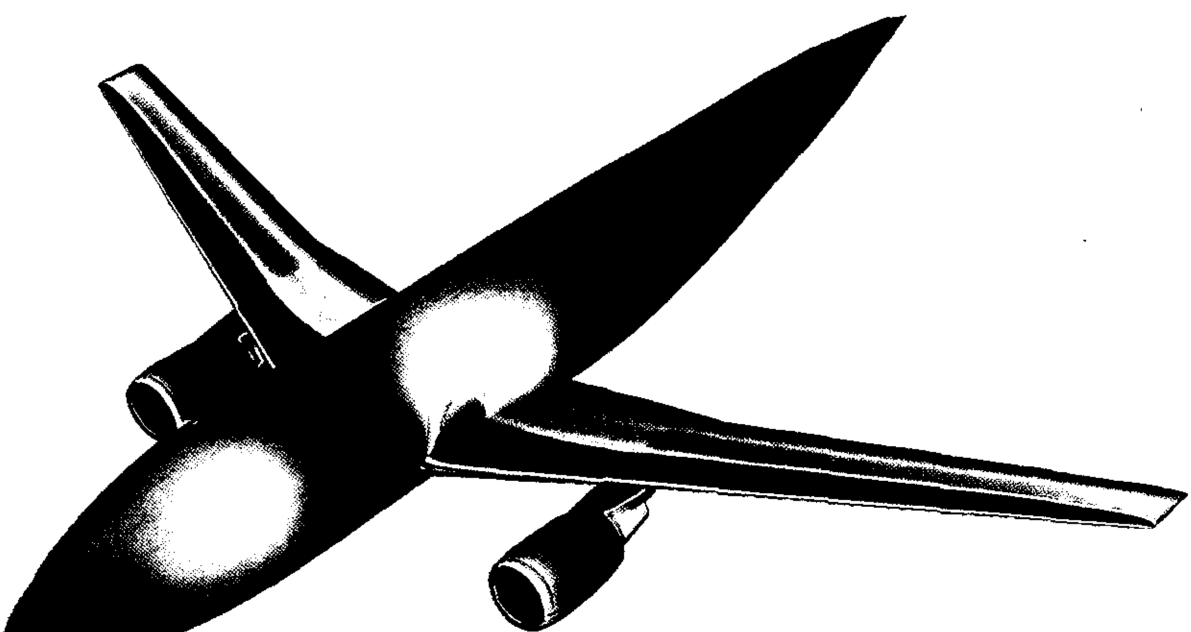
Annual Report 1994

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR



Annual Report 1994

The Board of the Foundation NLR *

	Appointed by:
J. van Houwelingen *Chairman*	Ministers of Transport, of Defence, of Economic Affairs and of Education and Science
Ir. H.N. Wolleswinkel	Minister of Transport, for the Netherlands Department of Civil Aviation (RLD)
Drs. E.A. van Hoek	Minister of Defence
Gen.maj. drs. D. Altena	Minister of Defence, for the Royal Netherlands Air Force (RNLAF)
Ir. J.J. Kooijman	Minister of Economic Affairs
Dr. P.A.J. Tindemans	Minister of Education, Culture and Science
Drs. G.M.V. van Aardenne	Netherlands Agency for Aerospace Programs (NIVR)
Ir. A.J. van Liere	Air Traffic Control The Netherlands
Dr. R.J. van Duinen	Fokker Royal Netherlands Aircraft Factories
Ir. C. den Hartog	KLM Royal Dutch Airlines
Ir. R. Uijlenhoet	Amsterdam Airport Schiphol
Ir. C.M.N. Belderbos	Netherlands Organization for Applied Scientific Research (TNO)
Prof.dr.ir. J.L. van Ingen	Delft University of Technology, Faculty of Aerospace Engineering
Mrs. prof. dr. A.J.M. Roobeek	Board of the Foundation NLR, upon nomination by the Works Council
Jhr. mr. J.W.E. Storm van 's Gravesande	Board of the Foundation NLR

The Board of Directors of NLR *

Dr.ir. B.M. Spee	*General Director*
Prof.ir. F.J. Abbink	*Technical Director*
J.A. Verberne R.A.	*Financial Director*

* On 31 December 1994

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1 Introduction

The year 1994 has shown a strong growth of air traffic, of both passengers and cargo. Many airlines could accommodate the growth by using the overcapacity created in previous years, when they ordered large numbers of aircraft. As a result the difficult financial situation of the airlines improved somewhat, although the profits of most of them remained low and many still suffered losses. Consequently, the demand for new aircraft was limited, and therefore aircraft manufacturers have been very reluctant to initiate the development of new aircraft projects. This has had a negative effect on the need for services from the research institutes and particularly on the workload of the large test facilities of these institutes. This situation is expected to continue in the next two or three years.

The development of the Fokker 70 was one of the few exceptions. This new aircraft type obtained its certification in October 1994 and in the meantime it has already proved to be very successful from both a technical and a commercial point of view. NLR significantly contributed to the development of the Fokker 70.

An important event in the space field was the approval by the European Space Agency of the European Robot Arm programme, which will have a favourable influence on the activities in the Netherlands. Continuing co-operation and tuning between industry, users and research is expected to help maintain the Netherlands' strong position in space and earth observation activities.

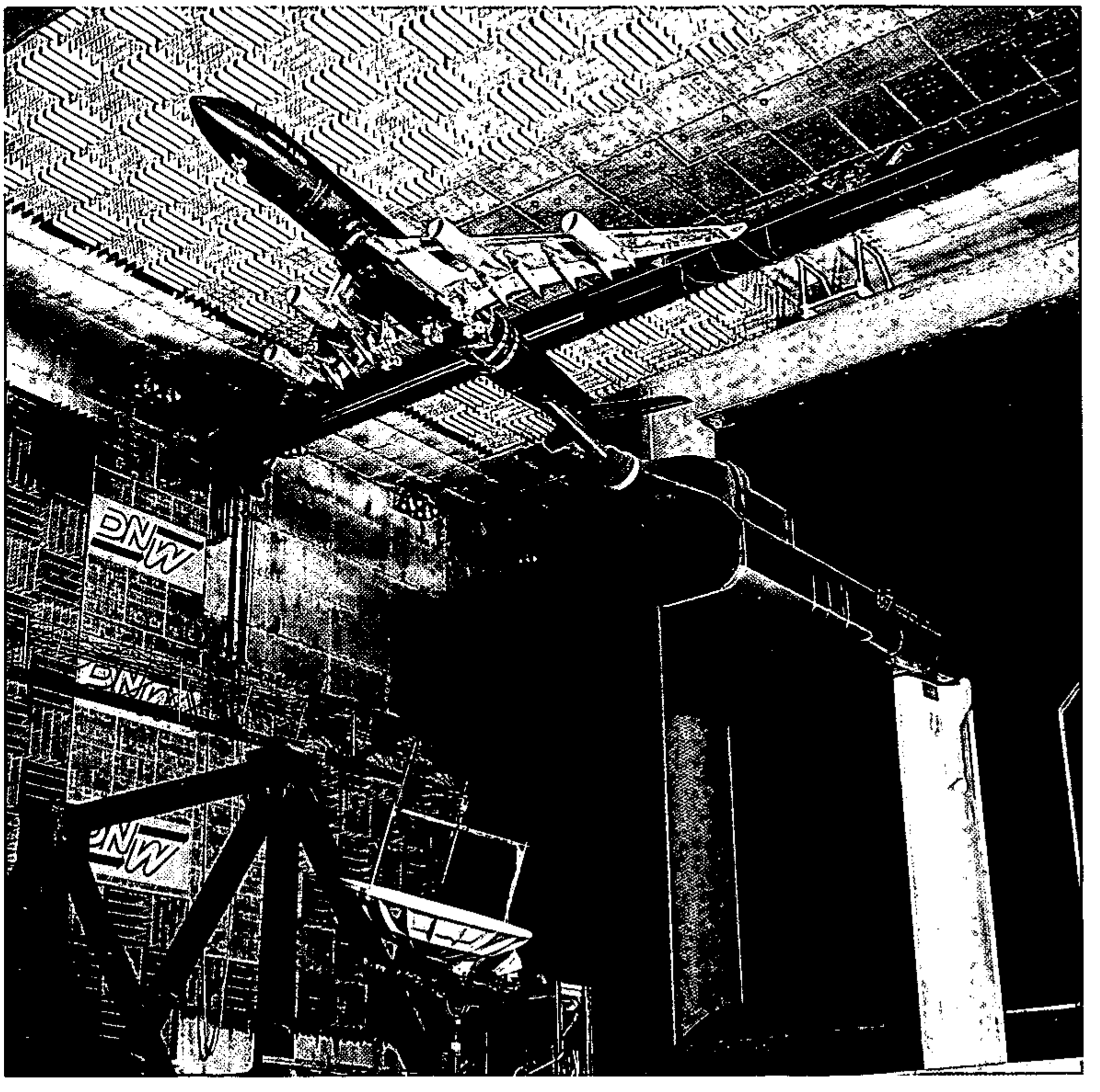
The outlook for the near future of the research establishments is positive. The continuously growing demand for air transport will have a large effect on the future air transport system. The next fifteen years will show a doubling of the number of flights and the introduction of some 12,000 new aircraft. A condition for this growth is that the capacity of the existing airports will be increased and that the efficiency of the aircraft and of the whole system will further improve. Also, air transport will have to satisfy much stricter rules with respect to the environment (noise, pollution) and safety. The development of the technical means to solve the problems of the future air transport system requires a large contribution from research institutes such as NLR.

In 1994 the armed forces of the Netherlands have taken decisions on the procurement of several types of aircraft and helicopters. The diversity of means and of areas of operations require increased support by NLR also in the future.

In 1994 important steps have been taken on the way to a closer co-operation in aerospace research and development in Europe. The seven European research establishments signed an association agreement, and the Deutsche Forschungsanstalt für Luft- und Raumfahrt and NLR strengthened their co-operation through joint operation of their low speed wind tunnel facilities within the Foundation German-Dutch Wind Tunnel. Also, the joint European Transonic Windtunnel entered its operational phase.

In the second half of 1994 NLR started preparations to participate, together with other institutes and the industry, in the aerospace-related activities of the fourth Framework Programme of the European Union. Financial support from the European Union is considered to be of great help in advancing European co-operation in aerospace research.

J. van Houwelingen, *Chairman*



Investigation of the airframe noise signature of a 1/10-scale model of the Airbus A340 in the open-jet test section of the German-Dutch Wind Tunnel

2 General Survey

2.1 Mission and Means

The National Aerospace Laboratory NLR is the central institute for aerospace research in the Netherlands. NLR provides scientific support and technical assistance to aerospace industries and organizations, civil and military aircraft operators and government agencies all over the world. NLR is a non-profit organization, and conducts a basic research and development programme sponsored by the Dutch Government.

With sites in Amsterdam and in the Noordoostpolder, NLR operates several wind tunnels, laboratory aircraft and research flight simulators. NLR has available an extensive set of equipment for gathering, recording and processing flight test data. NLR also has facilities for research in the areas of Air Traffic Control, structures and materials, space technology, remote sensing and environmental testing. NLR's extensive computer network includes a 5.5 GFlops NEC SX-3/22 supercomputer, tools for software development and advanced software for computational fluid dynamics and for calculations of aircraft and spacecraft structures.

NLR participates, on an equal base together with the Deutsche Forschungsanstalt für Luft- und Raumfahrt, in the German-Dutch Wind Tunnel, located in the Noordoostpolder. Together with DLR, the Ministry of Defence of the UK and the Office National d'Etudes et de Recherches Aérospatiales of France, NLR also takes part in the European Transonic Windtunnel (ETW) in Cologne.

2.2 Activities in 1994

In 1994 NLR's turnover was 143 million guilders compared to 144 million in 1993. The income from contracts was 98 million guilders compared to 101 million in 1993.

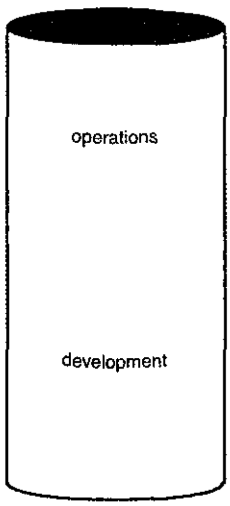
In 1994 about 60% of the total of NLR's activities were related to the development, and 40% to the operation of aircraft and spacecraft; 85% of NLR's activities were related to aeronautics and 15% to space. Civil and military research amounted to 70% and 30%, respectively. About 20% of the work under contract was carried out for foreign customers.

The total operating costs of NLR, amounting to 143 million guilders, included personnel costs of 89 million guilders.

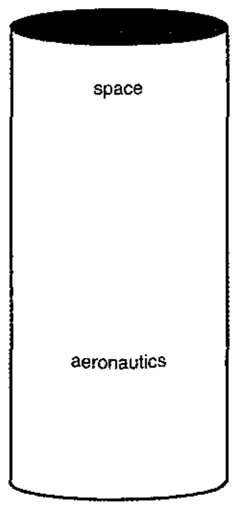
Services Provided under National Contracts

Activities under contract to Dutch customers amounted to 76 million guilders. These contracts included work for the Netherlands Agency for Aerospace Programs (NIVR), under its programme for aeronautics and space research and technology and for the development of Fokker aircraft. A number of research programmes were executed under contract to the Royal Netherlands Air Force, the Royal Netherlands Navy, the Netherlands Department of Civil Aviation (RLD), Air Traffic Control The Netherlands, Fokker Aircraft and Fokker Space & Systems. NLR also carried out work to support the Ministry of Defence, the German-Dutch Wind Tunnel (DNW), the European Transonic Windtunnel (ETW) and several other government services and private companies.

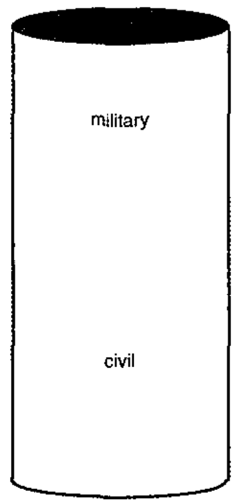
Contracts from Fokker concerned the development of the Fokker 70, the further developments of the Fokker 50 and Fokker 100, the development of the NH90 helicopter and the development of the Italian-Dutch X-ray satellite SAX. A major part of the work for the RLD was related to studies on airworthiness and



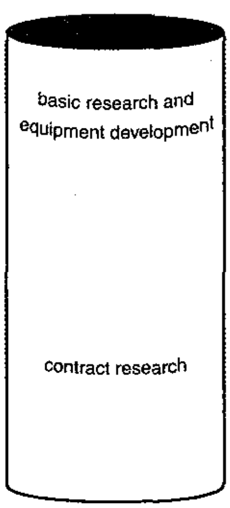
Division of the work into development and operations support



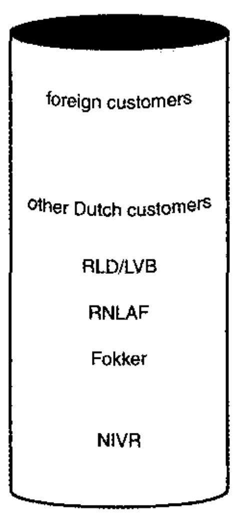
Division of the work into aeronautics and spaceflight support



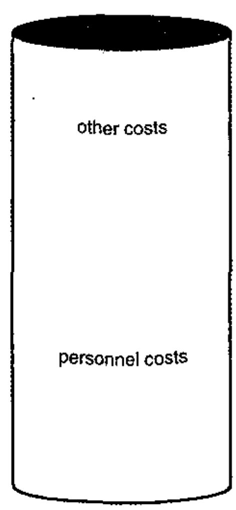
Division of the work into civil and military support



Division of the work into contract research and the programme for basic research and equipment development



Distribution over customers of the contract research



Division of the costs

regulations, on present and future Air Traffic Control systems and on safety and environmental aspects of aeronautics. Research on present and future ATC systems was also done under contract to Air Traffic Control The Netherlands, KLM Royal Dutch Airlines and Amsterdam Airport Schiphol.

Services Provided to Foreign Customers

Research and research support carried out under contract to foreign customers amounted to 22 million guilders. Major customers were the European Space Agency, the Commission of the European Communities, Eurocontrol and Lockheed. The contracts for Lockheed included research for the development of the F-16 Mid Life Update and for the F-16 mission planning system MSS/C.

Research and Equipment

NLR spent 22 million guilders on its basic aerospace research programme sponsored by the Government, aimed at preserving NLR's capability to support its customers in the future. Research aimed at the development and modernization of NLR's research facilities amounted to 24 million guilders, for the greater part used for the modernization of NLR's transonic wind tunnel HST and on the extension of NLR's research flight simulation facilities with a versatile National Simulation Facility (NSF). A total of 20 million guilders was used for capital investments, of which the development of the NSF was the most important one.

National and International Co-operation

A large part of NLR's basic research is carried out in connection with co-operative programmes under the aegis of GARTEUR, the Group for Aeronautical Research and Technology in Europe, in which Germany, France, the United Kingdom, the Netherlands and Sweden take part.

NLR and the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) jointly operate the German-Dutch Wind Tunnel (DNW). The co-operation between NLR and DLR was extended. A DLR-NLR Partnership Agreement aiming at the joint operation and mutual use of research facilities and the joint execution of research projects was signed in January 1994.

In 1994 the European Transonic Windtunnel (ETW), located near Cologne, Germany, terminated the phase of commissioning and calibration. Germany, France, the United Kingdom and the Netherlands participate in this facility. Initial operation was started.

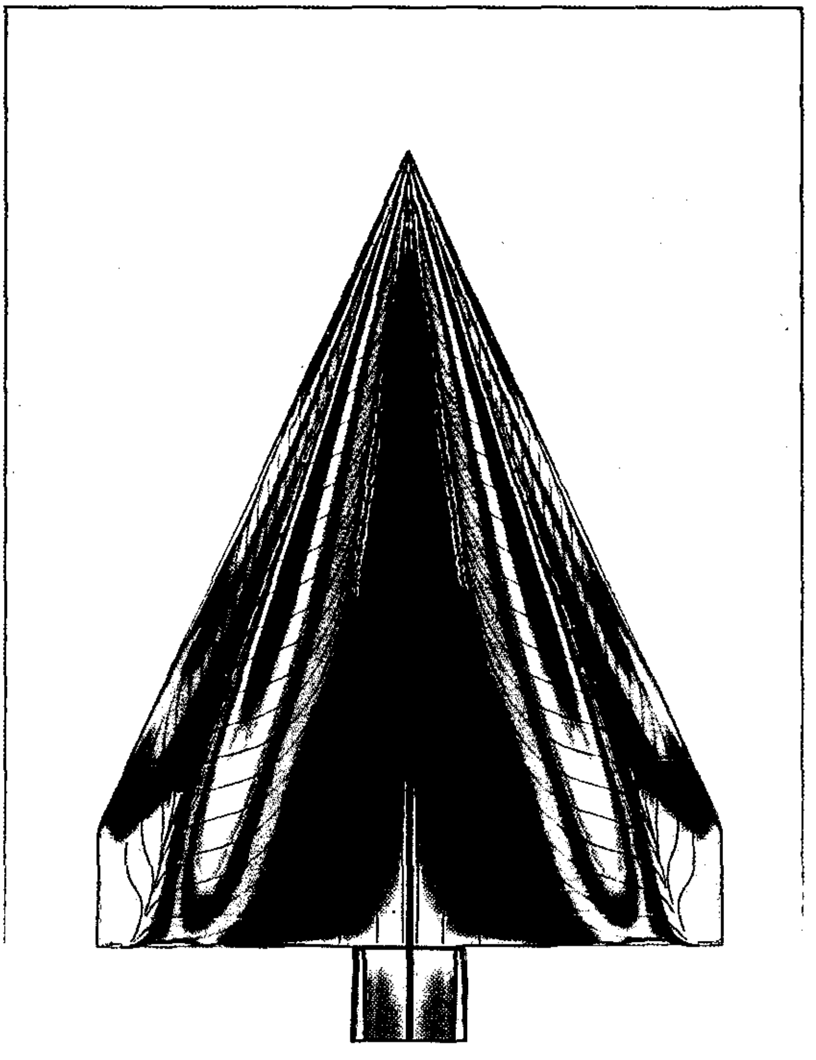
In 1994 the seven aeronautical research establishments of the countries of the European Union signed an agreement for co-operation within an Association of European Research Establishments in Aeronautics. The Association will execute joint research programmes and establish a joint approach towards the planning, use and management of large facilities.

In several projects, NLR co-operates with research institutes and universities in the Netherlands. NLR and the Delft University of Technology (DUT) jointly operate a Citation II aircraft, which is used as a research aircraft. Several members of NLR's staff are part-time professors of the DUT's Faculty of Aerospace Technology

Following the design and construction of the Indonesian Low Speed Wind Tunnel (ILST), collaborative activities of the research institutes Aero-Gas Dynamics and Vibration Laboratory (LAGG) of Serpong and NLR, together with the industries Fokker and Nusantara Aircraft Industries (IPTN) and the universities Delft University of Technology and Institut Teknologi Bandung were continued under an Aerospace Programme for Education, Research and Technology. The co-operation is co-ordinated by NLR and by the Agency for the Assessment and Application of Technology of Indonesia.

As in previous years, NLR has been very active in AGARD, NATO's Advisory Group for Aerospace Research and Development. NLR is represented in most of the AGARD Panels, and participates in the activities of many Working Groups.

Co-operation between NLR and the US National Aeronautics and Space Administration (NASA) included research on air-ground integration for Air Traffic Control. Preparations are being made for extensions of the co-operation in the areas of structures and computational fluid dynamics.



Flow solution of the Reynolds-averaged Navier-Stokes equations for a WEAG-TA15 configuration at a Mach number of 0.5 and an angle of attack of 20 degrees; picture shows leading edge vortex induced skin friction magnitudes (colours) and skin friction direction (black lines)

2.3 *Organization and Personnel*

The Board of the Foundation NLR consists of members appointed by the Netherlands government, the industry and other organizations having an interest in aerospace research. The meetings of the Board are normally attended by Prof.dr.ir. P.J. Zandbergen, Chairman of the Scientific Committee NLR/NIVR, and by the members of the Board of Directors. The Scientific Committee, consisting of experts from the aerospace community (industry, universities), advises the Board on the long term programme of basic research and on results of research carried out, described in NLR reports and in the annual report of NLR's basic research programme.

Per 1 January 1994 the appointment of Mrs. prof.dr. A.J.M. Roobeek, nominated by the Works Council, took effect. On 21 December 1994 the Board was extended with two additional members: Ir. R. Uijlenhoet was appointed by Amsterdam Airport Schiphol and Ir. A.J. van Liere by Air Traffic Control The Netherlands. As a result of this extension almost the entire aerospace community in the Netherlands is represented in the Board of the Foundation NLR.

The laboratory was headed by the directors mentioned on page 3.
Drs. A. de Graaff was *Associate Director.*

On 31 December 1994 the Heads of Divisions and Services were:
Prof.ir. J.W. Slooff, *Fluid Dynamics Division*
Ir. J.T.M. van Doorn, *Flight Division*
Dr.ir. G. Bartelds, *Structures and Materials Division*
Ir. B.J.P. van der Peet, *Space Division*
Ir. W. Loeve, *Informatics Division*
Ir. G. Brink, *Engineering and Technical Services*
Ir. W.F. Wessels, *General Services*
J.A. Verberne R.A., *Administrative Services*

The senior staff further included Mr. E. Folkers, *Secretary*, Ing. F.J. Sterk, *Head Support Staff*, and Drs. H. de Heer, *Head Personnel Department.*

As of 1 January 1994, the Flight Division was reorganized into nine Departments reflecting the variety of its current activities.

In December 1994 NLR decided to concentrate its activities in avionics, electronics and instrumentation in the new *Electronics and Instrumentation Division*, effective from 1 Januari 1995.

The organization of the laboratory on 31 December 1994 is shown on page 14.

At the end of 1994 NLR employed a staff of 939 (compared with 923 at the end of 1993), of whom 379 (355) were university graduates. Of the total, 839 (837) were employed on a permanent basis, and 100 (86) had temporary appointments. About 55 per cent of the staff are posted in Amsterdam, 45 per cent in the Noordoostpolder. A breakdown of the staff is given on page 15.

Technical Director
Prof.ir. F.J. Abbink — **DT**

General Director
Dr.ir. B.M. Spee — **D**

Financial Director
J.A. Verberne R.A. — **DF**

Associate Director	Drs. A. de Graaff	**DO**
Support Staff	Ing. F.J. Sterk	**DD**
- Public Relations	Ms. J.F. van Esch (DPR)	
- Publications	Dr. B.J. Meijer (DPI)	
Co-ordinators:		
- Defence Projects	Ir.J.M.A. van den Heuvel (CPD)	
- Aircraft Development Projects	Ing. P. Kluit (CPO)	
- Spaceflight Projects	Drs. J.C. Venema (CPR)	
- Aircraft Operations Projects	Ir. J.A.J. van Engelen (CPG)	
- Basic Research and Equipment Development	Ir. J.A.J. van Engelen (CEW)	
- Quality Assurance NLR	H. Blokker (CKZ)	

Secretary		E. Folkers	**DJ**
- Legal	**DJ**		
- Filing	**DB**		
- Security	**DB**		
Co-ord. AGARD / GARTEUR		Ir. L. Sombroek	**DA**
Co-ord. Indonesia		J.P. Klok	**DI**
Personnel		Drs. H. de Heer	**DZ**
Company Welfare Work		Ms. M.Th.F.J. Simons	**DM**
		Ms. C. Diekema	**DM**

Fluid Dynamics Division
Prof.ir. J.W. Slooff — **A**

- **Aerodynamic Facilities** — Ir. F. Jaarsma, Ir. H.A. Dambrink — **AF**
- **Experimental Aerodynamics** — Ir. A. Elsenaar — **AX**
- **Theoretical Aerodynamics** — Dr. B. Oskam — **AT**
- **Unsteady Aerodynamics & Aeroelasticity** — Prof. ir. R.J. Zwaan — **AE**
- **Aeroacoustics** — Dr. H.H. Brouwer — **AK**

Flight Division
Ir. J.T.M. van Doorn — **V**

- **Flight Testing and Safety** — Ing. M.A. Piers — **VV**
- **Helicopters** — Ir. L.T. Renirie — **VH**
- **Flight Simulation** — Ir. W.G. Vermeulen — **VS**
- **Flight Mechanics** — Ir. W.P. de Boer — **VM**
- **Operations Research** — Ir. G.J. Alders — **VO**
- **Aircraft Instrumentation** — Ir. R. Krijn — **VA**
- **Air Traffic Management** — Ir. J. Brüggen — **VL**
- **Man Machine Integration** — Drs. P.G.A.M. Jorna — **VE**
- **Transport and Environmental Studies** — Ir. G. Bekebrede — **VT**

Structures and Materials Division
Dr.ir. G. Bartelds — **S**

- **Loads** — Ir. J.B. de Jonge — **SB**
- **Structures** — Ir. H.H. Ottens — **SC**
- **Materials** — Dr. R.J.H. Wanhill — **SM**
- **Testing Facilities** — Ing. H.J.C. Hersbach — **SL**

Space Division
Ir. B.J.P. van der Peet — **R**

- **Remote Sensing** — Dr. G. van der Burg — **RR**
- **Systems** — Dr.ir. H.F.A. Roefs — **RS**
- **Laboratories and Thermal Control** — Ir. H.A. van Ingen Schenau — **RL**

Informatics Division
Ir. W. Loeve — **I**

- **Electronics** — Ir. H.A.T. Timmers — **IE**
- **Mathematical Models and Methods** — Dr. R.J.P. Groothuizen — **IW**
- **Numerical Mathematics and Application Programming** — Ir. F.J. Heerema — **IN**
- **Computing Centre and Systems Programming** — Ir. U. Posthuma de Boer — **IR**

Engineering and Technical Services
Ir. G. Brink — **T**

- **Technical Projects** — Ir. C.C. Groothoff — **TP**
- **Technical Design** — A. van den Berg — **TO**
- **Workshops** — Ir. H.Th.J.A. Lafleur — **TW**

General Services
Ir. W.F. Wessels — **G**

- **Buildings** — Ing. H. van der Roest — **GC**
- **Electrical Engineering** — A.M.G. Reijntjens — **GS**
- **Domestic Services** — G. Lipsius — **GZ**
- **Guarding** — G.M. Zwierink — **GX**
- **Library and Information Services** — Ir. W.F. Wessels — **GB**
- **Document Processing** — Ing. D.J. Rozema — **GT**

Administrative Services
J.A. Verberne R.A. — **O**

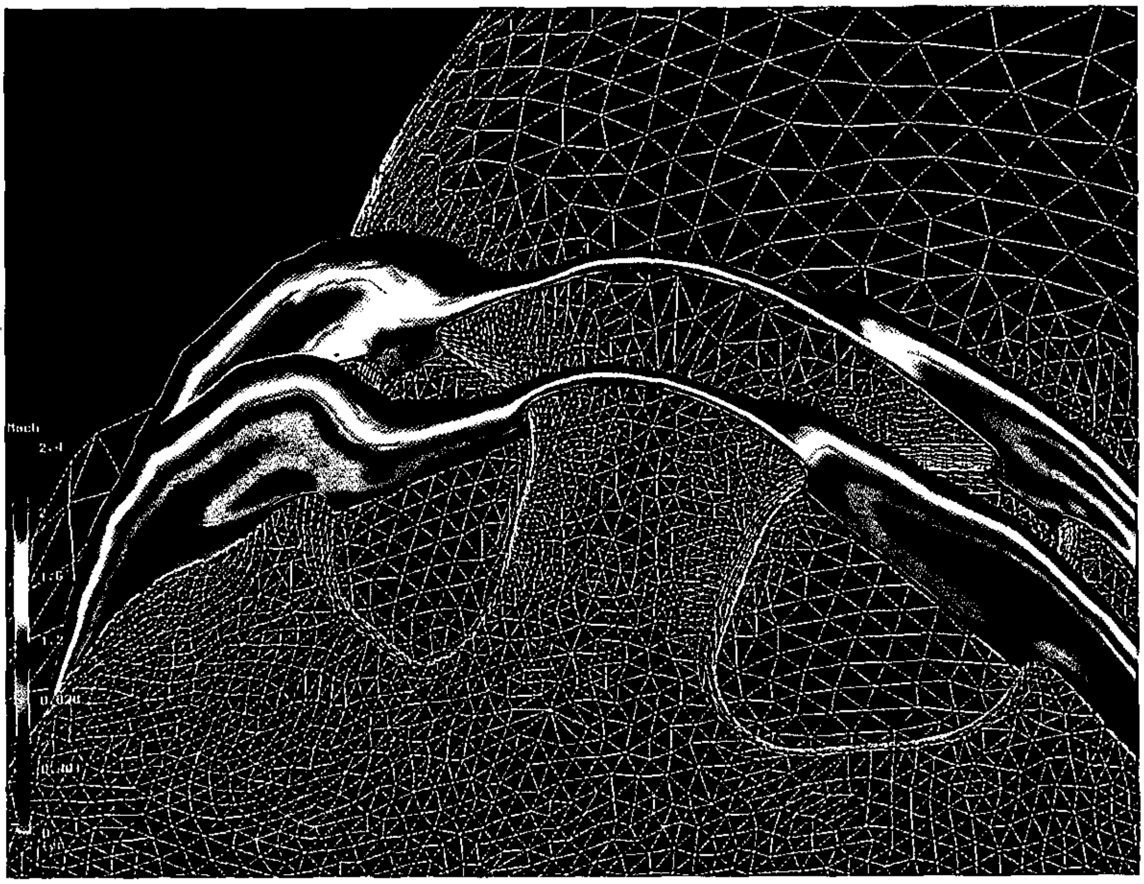
- **Administration** — Drs. B.P.E. Haeck — **OA**
- **Stores and Transport** — Drs. B.P.E. Haeck — **OM**
- **Purchasing** — J.F. Post — **OI**

Organization diagram of the laboratory, 31 December 1994

Table 1 - NLR staff at the end of 1994 (between brackets the numbers at the end of 1993)

		University graduates		Advanced technical college graduates		Others		Total	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
- Support Staff		15	(15)	7	(9)	7	(6)	29	(30)
		18	(18)	7	(9)	7	(6)	32	(33)
Fluid Dynamics Division	A	3	(3)	1	(1)	3	(4)	7	(8)
- Aerodynamic Facilities	AF	12	(12)	26	(25)	28	(39)	66	(76)
- Experimental Aerodynamics	AX	17	(18)	13	(15)	–	(–)	30	(33)
- Aeroacoustics	AK	7	(7)	3	(3)	–	(–)	10	(10)
- Theoretical Aerodynamics	AT	19	(18)	–	(–)	–	(–)	19	(18)
- Unsteady Aerodynamics & Aeroelasticity	AE	8	(7)	3	(3)	–	(–)	11	(10)
- DNW	AD	3	(3)	13	(13)	17	(18)	33	(34)
- LST	AL	1	(–)	3	(–)	5	(–)	9	(–)
		70	(68)	62	(60)	53	(61)	185	(189)
Flight Division [1]	V	3	(3)	1	(1)	1	(1)	5	(5)
- Flight Testing and Safety	VV	7	(18)	6	(6)	2	(3)	15	(27)
- Air Traffic Control and Avionics	VG	–	(37)	–	(8)	–	(1)	–	(46)
- Flight Simulation	VS	11	(21)	13	(13)	3	(3)	27	(37)
- Operations Research	VO	21	(23)	6	(8)	2	(2)	29	(33)
- Aircraft Instrumentation	VA	14	(16)	33	(39)	9	(11)	56	(66)
- Man Machine Integration	VE	18	(–)	–	(–)	–	(–)	18	(–)
- Helicopters	VH	13	(–)	1	(–)	1	(–)	15	(–)
- Air Traffic Management	VL	24	(–)	3	(–)	1	(–)	28	(–)
- Flight Mechanics	VM	12	(–)	–	(–)	–	(–)	12	(–)
- Transport and Environmental Studies	VT	9	(–)	4	(–)	–	(–)	13	(–)
		132	(118)	67	(75)	19	(21)	218	(214)
Structures and Materials Division	S	1	(1)	1	(1)	–	(–)	2	(2)
- Loads	SB	7	(8)	6	(4)	2	(1)	15	(13)
- Structures	SC	12	(12)	2	(2)	1	(1)	15	(15)
- Materials	SM	7	(7)	4	(4)	–	(–)	11	(11)
- Testing Facilities	SL	–	(–)	15	(11)	19	(18)	34	(29)
		27	(28)	28	(22)	22	(20)	77	(70)
Space Division	R	2	(2)	–	(–)	1	(1)	3	(3)
- Remote Sensing	RR	6	(6)	4	(4)	–	(–)	10	(10)
- Systems	RS	15	(14)	–	(–)	–	(–)	15	(14)
- Labatories and Thermal Control	RL	7	(6)	7	(7)	1	(1)	15	(14)
		30	(28)	11	(11)	2	(2)	43	(41)
Informatics Division	I	2	(2)	–	(–)	3	(4)	5	(6)
- Electronics	IE	18	(17)	25	(24)	5	(7)	48	(48)
- Mathematical Models en Methods	IW	15	(13)	–	(–)	–	(–)	15	(13)
- Numerical Mathematics and Applications Programming	IN	28	(24)	24	(24)	2	(2)	54	(50)
- Computing Centre and Systems Programming	IR	25	(23)	18	(16)	12	(13)	55	(52)
		88	(79)	67	(64)	22	(26)	177	(169)
Engineering and Technical Services	T	1	(1)	–	(–)	1	(1)	2	(2)
- Technical Projects	TP	5	(6)	4	(4)	2	(2)	11	(12)
- Technical Design	TO	1	(1)	11	(11)	1	(1)	13	(13)
- Workshops	TW	1	(1)	14	(14)	22	(23)	37	(38)
		8	(9)	29	(29)	26	(27)	63	(65)
General Services	G	1	(1)	2	(2)	–	(–)	3	(3)
- Buildings	GC	–	(–)	2	(2)	1	(1)	3	(3)
- Electrical Engineering	GS	–	(–)	5	(5)	5	(6)	10	(11)
- Domestic Services	GZ	–	(–)	2	(2)	29	(30)	31	(32)
- Guarding	GX	–	(–)	–	(–)	8	(8)	8	(8)
- Library and Information Services	GB	2	(2)	2	(1)	5	(5)	9	(8)
- Document Processing	GT	–	(–)	5	(5)	30	(29)	35	(34)
		3	(3)	18	(17)	78	(79)	99	(99)
Administrative Services	O	–	(–)	–	(–)	–	(–)	–	(–)
- Administration	OA	2	(3)	16	(16)	16	(13)	34	(32)
- Stores and Dispatch	OM	–	(–)	1	(1)	4	(4)	5	(5)
- Purchasing	OI	1	(1)	5	(5)	–	(–)	6	(6)
		3	(4)	22	(22)	20	(17)	45	(43)
Grand total		379	(355)	311	(309)	249	(259)	939	(923)

[1] The Flight Division was restructured as of 1 January 1994



Flow solution of the full Navier-Stokes equations for the canopy of the Hermes space vehicle with an upstream Mach number of 10, an angle of attack of 30 degrees and a slip angle of 3 degrees; the blue areas in the cutting planes indicate decelerated flow with a local Mach number of 0.8

3 Activities

3.1 Fluid Dynamics

Summary

Technology research and development activities in fluid dynamics were executed in the areas of Experimental Aerodynamics, Computational Fluid Dynamics, Applied/Configuration Aerodynamics, Aeroelasticity and Aeroacoustics, both under contract and as part of NLR's basic research programme. Furthermore, work was done for the development and improvement of Aerodynamic Facilities.

The total volume of contract research and development activities in fluid dynamics increased slightly. This increase was entirely due to national customers. Wind tunnel occupation remained low, as a result of the current low level of activities in development programmes of the international aerospace industry.

NLR continued active participation in GARTEUR Action Groups and BRITE/EURAM projects in the areas of aerodynamics and aeroacoustics.

The main thrust of the research and development activities in the field of *Computational Fluid Dynamics (CFD)* is directed towards achieving CFD technology readiness in the area of propulsion/airframe integration and improving the capabilities in wing design and analysis.

A new activity involved the acquisition of a 3D unstructured-grid Euler code and its further development. The latter is directed towards the realization of a highly automated and accurate code system for geometrically very complex configurations. Other activities included the continued development of an unstructured-grid Reynolds-averaged Navier-Stokes (RANS) solver, studies on turbulence models for the Reynolds-averaged Navier-Stokes equations, and Large-Eddy type Navier-Stokes Simulations (LES).

In the area of *Applied/Configuration Aerodynamics* of civil aircraft, the activities were aimed at supporting Fokker Aircraft in aerodynamic design studies, involving wing design, propulsion/airframe integration, ice accretion and the evaluation of computational methods for high-lift systems.

Furthermore, NLR continued the verification and validation of the Euler and Reynolds-averaged Navier-Stokes computer code system ENFLOW for fighter type aircraft exploiting high-angle-of-attack vortex lift.

The activities in *aero-thermodynamics* involved the completion of the flow analysis for the HERMES space vehicle using hypersonic flow solutions of the full Navier-Stokes equations.
Within the framework of the national AEOLUS programme, research on the aero-thermodynamics of the inlet of airbreathing spaceplanes was continued.

Activities in the area of *Aero-elasticity* concentrated on the continued development of a pilot code (AESIM) for the computational aero-elastic simulation of transport type aircraft in transonic flow, on the continued research of Limit Cycle Oscillation (LCO) phenomena of fighter aircraft and on the dynamic (flutter) characteristics of Thermal Protection Systems for spacecraft.

In the field of propeller *Acoustics*, the main activity concerned the continued development of a computer code for advanced high-speed, counter-rotating propellers. The development of a mathematical model for sound generation by supersonic ducted fans was completed. The activities on acoustic inlet liners

concentrated on the application of bulk-absorbing materials and active acoustic impedance control techniques.

In the area of *Experimental Facilities*, the main efforts were directed at the finalization of Phase I of the modernization of the High Speed (transonic) wind Tunnel HST. Preparations for Phase II, involving replacement of the power plant and the drive motors, to be executed in 1996 to 1997, were made. A number of other activities in the areas of testing and hardware and software development were carried out.

Research

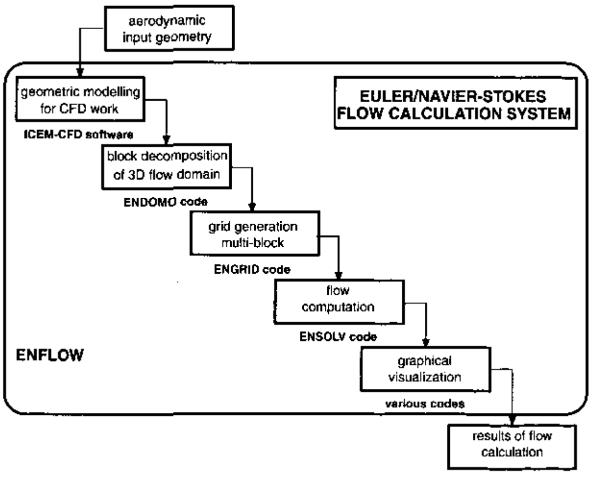
Computational Fluid Dynamics

Methods Based on the Reynolds-averaged Navier-Stokes Equations

ENFLOW (Euler/Navier-Stokes Flow calculation) is a system of CFD computer codes for industrial applications of CFD. The ENFLOW system is based on the use of multiblock grids, fully-conservative central-difference methods, and explicit time-integration methods accelerated by a multiblock/multizone multigrid method.

The ENFLOW system is in fact a set of standard CFD computer codes. These codes are loosely interfaced by standard files. The system contains codes for:

- preparing geometric shapes of surfaces in 3D space for CFD work (ICEM CFD),
- decomposition of 3D flow domains into blocks (ENDOMO),
- construction of multiblock grids in 3D space (ENGRID),
- execution of 3D-flow calculations (ENSOLVE), and
- graphical inspection and further processing of calculation results.



Schematic of flow calculation system ENFLOW

In 1994 the implementation of the Johnson-King turbulence model in the ENFLOW system was improved by replacing the central difference approximation of the Johnson-King equation with an upwind discretization. The implementation of this turbulence model was further improved by introducing an integral representation for the location of maximum turbulent shear stress.
The numerical accuracy of the underlying fully-conservative central-difference method was increased by replacing the scalar artificial dissipation with matrix dissipation; the computational results show improved accuracy for boundary layer velocity profiles.

The ENFLOW system contains provisions for the calculation of inlet and outlet flows of turbofan engines; the boundary conditions representing these inlet/outlet flows were reformulated for improved numerical stability.

To facilitate routine industrial applications of the ENFLOW system, activities in the area of grid adaption were extended from 2D to 3D.

Future further validation of ENFLOW results is planned by GARTEUR (AD) EG 28. The corresponding Action Group will validate CFD methods for high aspect ratio wings starting from code-to-code comparisons and working towards validation based on comparison with detailed experimental data.

The extension of a two-dimensional Euler solver based on unstructured grids to the level of Reynolds-averaged Navier-Stokes equations was continued. This flow simulation system bears the acronym FANS (Fully Automatic Navier-Stokes). The geometry-adaptive automatic grid generation algorithm was further developed. Preliminary test results obtained on shared memory parallel computers demonstrate that the data structure associated with unstructured grid methods is well suited for automatic parallelization of the flow solver code.

Turbulence Research

The quality of the results of calculations with Reynolds-Averaged Navier-Stokes (RANS) methods strongly depends on the capability of the turbulence model of representing the relevant flow physics. An evaluation and comparison of turbulence models is made by testing both conventional and more advanced models in a relatively simple and robust boundary layer code for a range of theoretical and experimental test cases. The evaluation of algebraic models was completed and the attention was shifted to the class of so-called two-equation models with the k-ω model emerging as the most representative candidate.

The evaluation of the k-ω turbulence model was also extended from boundary layer equations to Reynolds-Averaged Navier-Stokes equations by implementing this two-equation k-ω turbulence model in the FANS (Fully Automatic Navier-Stokes) code for two-dimensional high-lift airfoils. Preliminary test results confirm the potential generality of the k-ω turbulence model to model the merging of boundary layers and wakes in high-lift flows.

The experimental investigation of a three-dimensional boundary layer representative for transport-type aircraft in the framework of GARTEUR (AD) AG 07 was continued. Extensive comparisons have been made with laser measurements in the F2 wind tunnel of ONERA, showing good agreement in general. All experimental data are combined in a single data base for subsequent analysis and for comparison with CFD methods.

Complicated turbulent flows can be calculated using Reynolds-averaged turbulence models with limited success only. This is especially true for statistically unsteady and separated flows. Large Eddy Simulations (LES) offer an alternative by calculating the turbulence at large length scales time accurately and modelling the turbulence at small scales. The development of a code for Large Eddy Simulations was started, and significant progress has been made. In a preliminary study it was concluded that the success of LES in near-wall and separated flow regions, where the LES assumption of separation of scales does not apply, strongly depends on the ability to locally refine grids in these regions. This can only be accomplished efficiently by using sophisticated grid generation techniques. A computer code was written which solves the Euler equations using local grid enrichment. This code was applied successfully to the flow around a

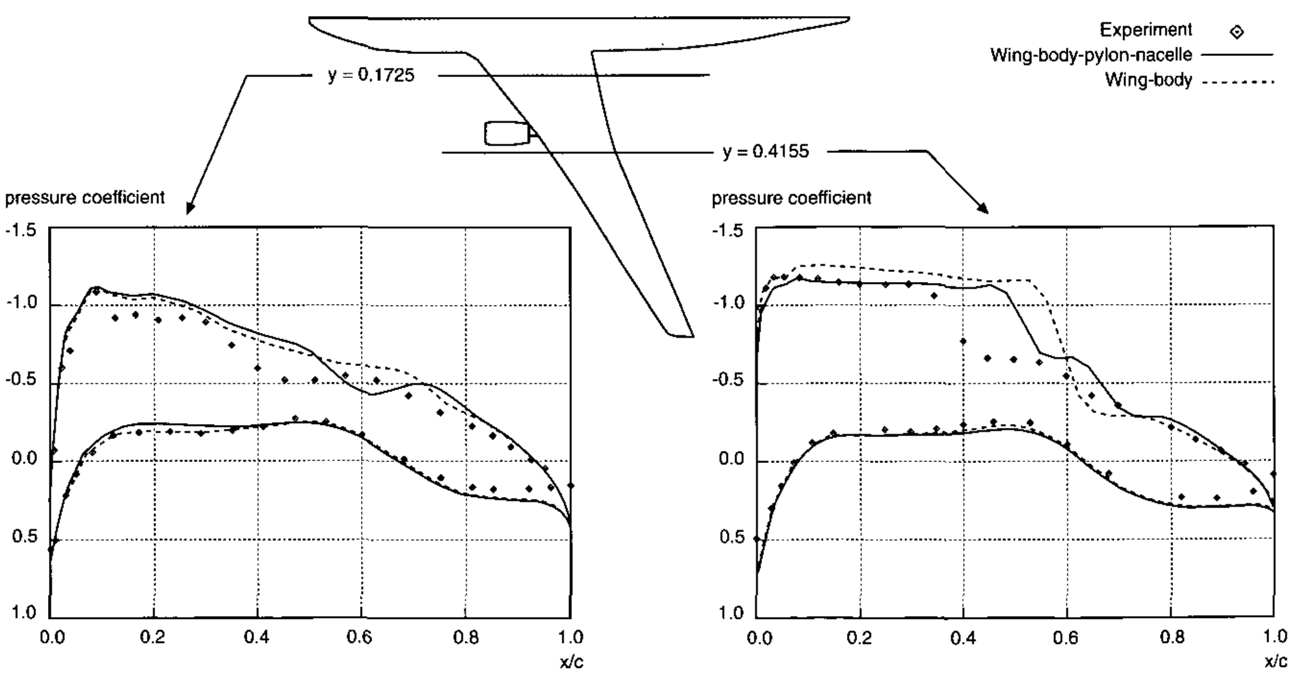
delta wing. Owing to its dynamic, unstructured data structure this method will be a very useful tool for LES after incorporation of the viscous contribution.
At the end of 1994, separate agreements were signed with the US National Aeronautics and Space Administration (NASA) and Twente University covering bilateral collaborative research in LES.

Methods Based on the Euler Equations

Further progress has been realized in the validation of the ENFLOW system at the level of the Euler equations. The configurations range from civil aircraft to missile configurations and complete fighter aircraft. Significant improvements were made to the boundary condition treatment for subsonic and supersonic jets.

The objective of GARTEUR (AD) AG 17 is to validate Euler codes for complex geometries representative of integrated airframe/propulsion system configurations for transport aircraft. Three test cases are considered: a wing, a wing/body configuration and a wing/body/pylon/nacelle configuration. The computations for the AS28 wing/body/pylon/nacelle configuration were completed. The results obtained by NLR compare well with those of DLR and Aerospatiale, demonstrating that CFD capabilities on the level of Euler equations and multiblock structured grids are becoming a relatively mature technology.

The work of GARTEUR (AD) AG 15 on the validation of Euler codes for supersonic flow was completed.



Pressure distributions at two spanwise stations of a wing-body-pylon-nacelle configuration, and a wing-body configuration, at a Mach number of 0.80 and an angle of attack of 2 degrees, compared with experimental data to validate Euler codes

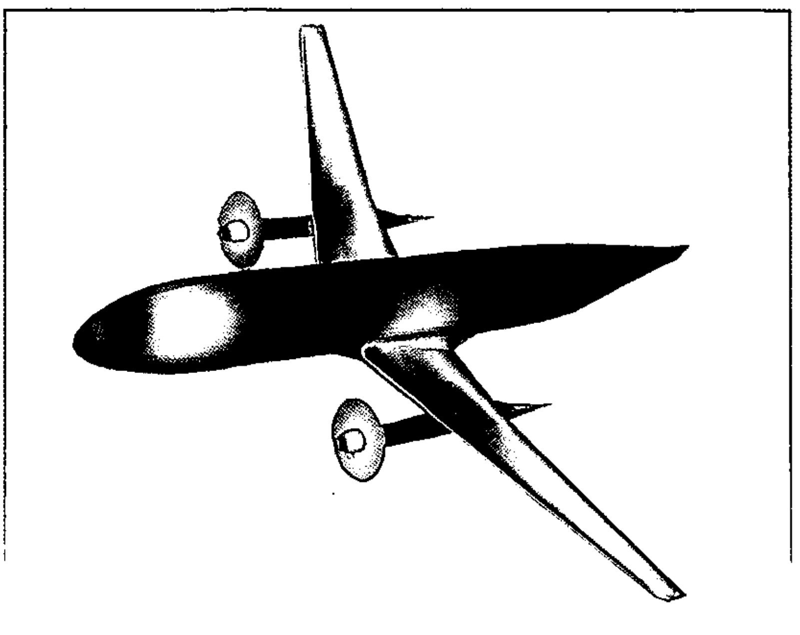
A new activity in the area of CFD development is directed towards the realization of a highly automated and accurate algorithm solving flow equations for geometrically and aerodynamically complex configurations on unstructured grids. Experience with multiblock CFD technology shows that the problem-turnaround-time for this type of grid generation for complex configurations is of the order of three to four weeks or more. In the near future the problem-turnaround-time must be reduced to the order of one day to one week. Unstructured grids offer the potential to bring about such reduction. With this in mind, DLR and NLR started a co-operative project entitled "CFD for complete aircraft" with the objective to jointly develop a fully automatic system for three-dimensional flow simulations. The first versions of a number of algorithms are based on a 3D, unstructured-grid Euler code from the University of Swansea. The potential capabilities of this CFD system were demonstrated for the AS28 wing/body configuration and a generic three-dimensional mixed-compression hypersonic inlet.

Full-Potential Flow Methods

For accurate aerodynamic analysis of wing/body combinations representative of (transonic) transport aircraft, NLR has available the MATRICS-V computer code system. The MATRICS-V system consists of a grid generation part (MATGRID) and a flow solver based on the full-potential equation and integral boundary method. The flow solver includes a special algorithm to compute aerodynamic forces, in particular drag and its physical components induced drag, wave drag and viscous drag. The system is also part of an inverse design loop capable of making a wing design for a given pressure distribution. MATRICS-V has matured to the point where the analysis of transonic drag creep at fixed lift coefficient and fixed Reynolds number is feasible with turn-around times satisfying the requirements for industrial application. The code is continually being upgraded, in response to experience obtained in operational use by industry.

Linearized Potential Flow Methods

The development of the PDAERO panel method for preliminary design of aircraft was completed by including non-linear subsonic compressibility in a semi-empirical way, and by extending the modelling to cover ground-plane effects. The method was applied in a numerical study to assess wind tunnel wall interference effects for a semi-span model set-up in the European Transonic Windtunnel (ETW).



Surface pressure distribution of a linearized potential flow solution generated with the PDAERO computer code which includes a linearized representation of the propeller slipstream

CFD Validation

Comparisons with experiments are an essential part of the validation process of CFD codes. Work has started on the formation of a data base containing experimental data of sufficient quality for validation purposes. Part of this information comes from experiments executed in NLR's wind tunnels. NLR also contributed to the AGARD Working Group WG 14 of the Fluid Dynamics Panel on "Selection of Experimental Tests Cases for CFD Validation".

Radar Cross Section (RCS) Prediction Techniques

Radar Cross Section (RCS) prediction techniques are required for both radar analysis and RCS design of military aerospace vehicles. Prediction techniques at various levels, such as high frequency methods, boundary integral equation methods and finite difference and finite element methods are under development. RCS analyses have been performed for F117-like and YF22-like aircraft configurations. Numerical investigations are in progress to assess the accuracy of the computed RCS data for these types of aircraft configurations. This work is carried out in collaboration with the TNO Physics and Electronics Laboratory and DASA Military Aircraft.

Aerodynamics of Wings of Transport Aircraft

In collaboration with Fokker Aircraft, design and analysis codes have been applied in wing design studies. Drag predictions and analyses have been performed for several wing/body configurations, using the MATRICS-V full potential plus boundary layer code system.

The NLR aerodynamic wing design method WINGDES has been extended by the incorporation of the MATRICS-V analysis code.

Multipoint aerodynamic design techniques based on "residual corrections" and "genetic algorithms" have been evaluated in the framework of the European Computational Aerodynamics Research Programme of BRITE/EURAM.

The GARTEUR investigation on the physics of high-lift aerodynamics has been concluded with an extensive analysis. NLR contributed to the analysis of Mach number effects. The Action Group AG 13 is likely to be followed by another GARTEUR Action Group that will concentrate on the development of CFD methods for high lift.

In the Indonesian Low Speed Wind Tunnel, the first phase of an experimental programme to study the effect of wing sweep on the aerodynamic characteristics of leading-edge slats was executed. The measurements included overall force and pressure measurements and detailed boundary layer surveys.

As part of the BRITE/EURAM programme ELFIN II, stability calculations for the laminar boundary layer were made for in-flight measured pressure distributions on the Fokker 100 aircraft fitted with a laminar flow glove. On the basis of these and similar calculations, executed by various partners, a strategy will be defined to estimate boundary layer transitions for flight conditions.

A theoretical study was made to investigate the effect of simulated ice on the nose of a wing section. The results of these calculations will be compared with results of an experiment made on a two-dimensional high-lift section measured in the low-speed tunnel LST.

The applicability of the NLR computer code ULTRAN-V for unsteady transonic flow was investigated in the framework of the BRITE/EURAM project Euroshock, with the calculation of shock-boundary layer interactions.

Propulsion-Airframe Interaction

Theoretical/computational propulsion-airframe interaction studies were continued using the ENFLOW and PDAERO codes, in collaboration with Fokker Aircraft, both for turbofan and for propeller configurations.

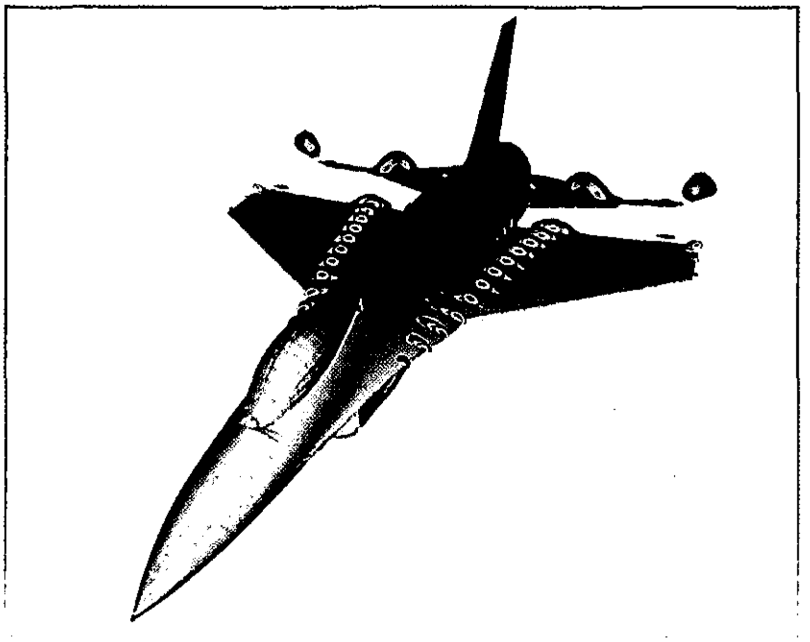
NLR participates in GARTEUR (PT) AG 02. In this common exercise, a TPS turbofan model engine, a blown nacelle and a flow-through nacelle are tested in a number of European engine calibration facilities, including NLR's calibration facility ECF. The necessary hardware was prepared.

Calibrations were performed of the CRUF-1 and CRUF-2 Counter Rotating Ultra High By-pass Ducted Fan model engines to be used in subsequent DNW tests as part of the BRITE/EURAM programme DUPRIN II (Ducted Propfan Integration). This work triggered further investigations on a flow-through nacelle in the ECF and on the isolated CRUF in the DNW, in co-operation with DLR. Transonic flow calculations were made for the DUPRIN-II wing/body/turbofan configuration. The computational results include engine inflow and outflow boundary conditions simulating the engine mass-flow and thrust characteristics at a free stream Mach number of 0.75. Transonic flow wind tunnel tests are foreseen in the next phase of the DUPRIN project.

The preparation of a propeller-slipstream/wing interaction experiment, a collaborative effort of Fokker, NLR and the Delft University of Technology from the Netherlands with Nasuntara Aircraft Industries (IPTN), the Aero-Gas Dynamics and Vibration Laboratory (LAGG) and the Bandung University of Technology (ITB) from Indonesia, was continued and almost completed. The tests are scheduled for early 1995 in the Indonesian Low Speed Tunnel (ILST).

Aerodynamics of Combat Aircraft

The participation in the collaborative research programme of the Western European Armaments Group (WEAG, formerly IEPG), Technical Area 15 (TA 15) "Computational Methods in Aerodynamics" was continued. The contribution of NLR in the collaboration is focused on the verification and validation of combat aircraft applications of the CFD system ENFLOW. Special attention is paid to the aerodynamics of fighter-type aircraft exploiting vortical flow at high angles of attack. Several geometries which are generic for fighter type aircraft are under consideration. For a sharp-edged wing-alone configuration, Reynolds-averaged Navier-Stokes results were obtained for a transonic Mach number and moderate angles of attack, and for a subsonic Mach number and high angles of attack. Detailed comparisons with the experimental data obtained in the HST show good correlation. The secondary separation caused by the adverse pressure gradient on the upper surface, induced by the primary vortex, is realistically captured. For the isolated wing with a rounded leading edge, the results for a transonic Mach number at moderate angles of attack as well as the results for a subsonic Mach number at high angles of attack show good correspondence with the experimental data. The case with rounded leading edge is essentially more difficult, because the position of the primary separation has also to be captured by the computational method whereas it is fixed at the leading edge for the sharp-edged configuration.



Flow solution of the Euler equations for an F-16-like aircraft; the red areas in the cutting planes indicate a loss in the total pressure of the vortex flow originating from the leading edge of the wing strake

The CFD technology developed in the framework of WEAG TA 15 has also been applied to an F-16-like aircraft. The flow calculations have been carried out on a computational grid of about one million grid points. Several details of the configuration, such as the inlet and outlet of the engine, the diverter above the engine inlet and ventral fins were represented in the computational grid. The analysis of the computational results has revealed new information about the behaviour of aerodynamic forces. The CFD technology represented by the ENFLOW system is now available for support on aerodynamic matters related to the operational use of fighter aircraft.

Wind tunnel tests in the HST on a model of a forebody representative of combat type aircraft, in collaboration with Aermacchi, were successfully completed. The model, provided by Aermacchi, was tested at incidences up to 70 degrees at various Reynolds numbers. The objective was to study Reynolds number effects and ways to simulate high Reynolds number conditions with artificial boundary layer fixation. The measurements combined pressure and force measurements.

Wind tunnel test on a forebody of a combat type aircraft in the HST

Helicopter Aerodynamics

In the low speed wind tunnels LST and DNW, tests on various NH90 configurations were executed as part of the NH90 development programme.

NLR continued its participation in the BRITE/EURAM project HELISHAPE (Rotorcraft Aerodynamics and Aeroacoustics) by contributing to the formulation of a rotorcraft code based on a full potential model.

Hypersonic/Space Vehicle Aerothermodynamics

In the national programme AEOLUS, funded by NIVR, activities to develop the technology level required for industrial participation in future European space transport programmes continued. AEOLUS is a collaborative programme involving Fokker Space & Systems, Stork Product Engineering, TNO Prins Maurits Laboratory, Delft University of Technology and NLR as partners. Engineering methods for estimating the mechanical and heat loads on two-dimensional inlet geometries were refined and applied to a particular inlet configuration.

For the case of a three-dimensional mixed-compression, hypersonic intake, the first step was taken towards the analysis of highly localized aerodynamic heating due to shock-boundary layer interactions and shock-vortex interactions. This first step consists of an inviscid flow computation demonstrating the capability to accurately resolve highly swept shock-waves and their interactions. Under contract to ESA, MBB/ERNO Raumfahrttechnik (at present Daimler-Benz Aerospace Raumfahrt Infrastruktur), wind tunnel tests were executed in the HST and SST for two aerodynamic re-entry capsule shapes.

Investigations, also under contract to ESA, of various types of Flexible External Insulation (FEI) blankets representative of the heat protection system of re-entry vehicles, in the transonic and supersonic speed regime in the HST and SST, respectively, were completed. These wind tunnel tests aimed at demonstrating the feasibility of applying FEI with respect to its flutter characteristics and fatigue behaviour.

Aeroelasticity

The development of a pilot code for the computational aeroelastic simulation of transport type aircraft in transonic flow (AESIM) was continued. The flow is modelled on the basis of a full potential representation. Various parts of the code were improved, especially the algorithms for coupling with the finite element method NASTRAN, which models the flexible aircraft structure. The code was validated using several steady and unsteady, two- and three-dimensional test cases. These activities were made in close co-operation with Fokker Aircraft to ensure maximum operational efficiency. A start was made with implementing a model to represent boundary layer effects.

The research programme of limit cycle oscillations (LCO) of fighter type aircraft at transonic flow conditions was almost completed. This type of oscillations is due to the interaction of shock wave motions and flow separation. For the computational simulation of LCO, an improved empirical model was developed to represent the unsteady aerodynamic loads. Correct predictions were made for a few aircraft configurations and flight conditions. This research programme is carried out in a collaboration under an agreement with Lockheed Fort Worth Company, the US Air Force and the Netherlands Ministry of Defence.

Aeroacoustics

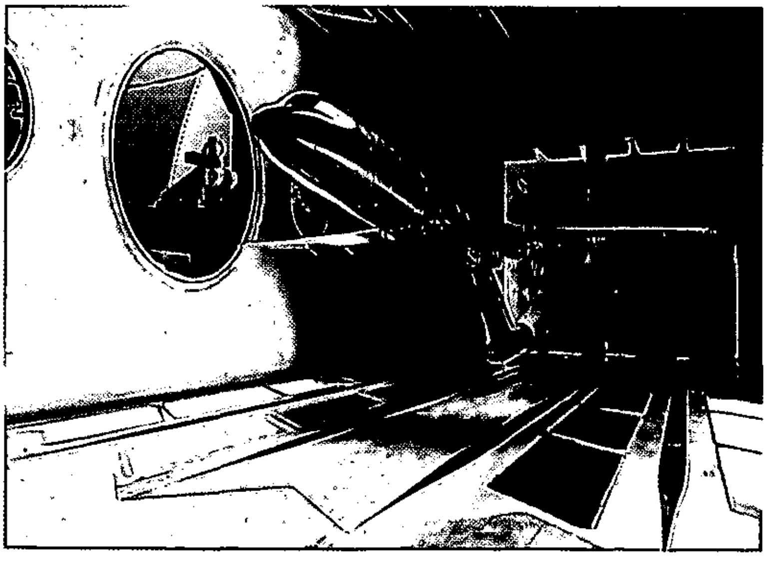
The research in the field of propeller acoustics is aimed at the development and validation of codes for the computation of the noise of installed single- and counter-rotating propellers.

Following the completion of a lifting-surface model for the aerodynamics and acoustics of single-rotating advanced propellers, research was extended to counter-rotating propellers. Descriptions of the inviscid and viscous parts of the wake of the front propeller have been developed and implemented in the software. Results of the code for single-rotating propellers compare favourably to data available from the literature.

The activities in the Study of Noise and Aerodynamics of Propellers of BRITE/EURAM comprised the development of a computer code for the diffraction and refraction of sound by a simplified aircraft fuselage of circular cross-section and its boundary layer, based on an analytical description. The mathematical modelling and a pilot code were completed. In addition, a two-dimensional hybrid finite-element/boundary-element method for general fuselage cross-sections was successfully developed.

In the field of turbofan acoustics, the research on source description (fan noise), duct acoustics and liner properties was continued, in order to improve the optimization of acoustic liners. A computer program for the calculation of the sound generated by a supersonic turbofan rotor ('rotor alone noise') was completed. A preliminary investigation was carried out with respect to the application of Computational Aero-Acoustics (CAA) to the propagation of sound in a turbofan inlet. In co-operation with the Eindhoven University of Technology, a project was initiated to extend the computer program for lined duct acoustics (LINDA), to an annular geometry. With this extension, the model can also be applied to the by-pass duct and the exhaust of a turbofan engine. In the BRITE/EURAM programme FANPAC (Fan Noise Prediction and Control), comprising an extensive test programme and code validation, several acoustic liners were tested at the NLR facilities, to select suitable inlet liners for the main fan-model test. In the flow duct facility a test was carried out to assess the possibilities to control the effective acoustic impedance of an inlet liner by means of flow injection into the boundary layer. Supported by numerical simulations, the experimental method to determine the acoustic properties of bulk-absorbing materials was further developed. The properties of several materials were measured and used as input for preliminary calculations to determine the benefits of these materials compared to the commonly used locally reacting liners.

With turbofan engines becoming continually quieter, an increasingly important noise component is the so-called airframe noise, the noise that is generated by the interaction of the airflow with airframe parts, especially protruding parts such as the landing gear or flaps. In co-operation with Aerospatiale, DNW and DLR, a test was carried out in the DNW on a model of an Airbus A340 in approach configuration, to explore the possibilities of airframe noise source localization by means of acoustic antennas.



Fokker 100 model in the modified HST

The test facility for the transmission of sound through fuselage panels at low frequencies was used for the continuation of the research on so-called add-ons. The effect of vibration damping tapes in combination with insulation material such as glass wool was investigated.

Measurements on unstiffened panels were carried out to obtain data to be used for the validation of a finite-element program for sound transmission through panels, under development at the NLR Structures Department.

The experimental contribution of NLR to the BRITE/EURAM programme BRAIN (Basic Research in Aircraft Internal Noise) was successfully completed by an experimental analysis of the sound transmission through double-wall structures at low frequencies.

Facilities and Equipment

The Transonic Wind Tunnel HST

As a follow-up to the modernisation of the test section of the HST in 1992 and subsequent validation and calibration tests, some additional semi-span model and two-dimensional model tests were executed and analysed.

Work was also done to better understand minor Mach number deviations at low supersonic speeds, possibly originating from imperfections of the nozzle.

The new articulated boom was used successfully after the incremental deflections due to boom flexure under loading were carefully calibrated.

The compressed-air system was improved to increase the possibilities for propulsion simulations.

Preparations for the second phase of the HST modernization intensified. The objective is to close the current steam boiler power plant, in order to comply with new environmental rules, and to switch to power from the local electricity grid. This operation will also require new electric drive engines. To take maximum benefit from this new situation, the compressor for the air pressure vessel will be adapted as well. The opportunity will also be used, among other things, to increase the cooling capacity and to improve the flow quality, by the introduction of a flow rectifier. The further modernization of the HST will result in higher productivity, higher achievable Reynolds numbers and reduced costs for testing. Major site work is planned in the winter of 1996/97.

Low Speed Tunnel

The Low Speed Tunnel LST is operated by the German-Dutch Wind Tunnel (DNW) from 1 January 1994.

A study was made by NLR to establish the maximum suction capability of the LST for simulating re-ingestion effects in combination with thrust reverser tests.

Propulsion and Acoustics Laboratory

The upgrade of the Calibration Facility for model engines (ECF) with a balance system for measuring all six force components was completed.

Instrumentation and Measurement Systems

In view of the growing interest in experimental flow field data, the development of flow field survey techniques was continued. A traversing rake equipped with five-hole probes was manufactured and successfully applied during an experiment on a semi-span model with blown nacelle in the HST. The probes were connected to an electronically scanning pressure measurement system. The large amount of measured data was processed on a mainframe computer of NLR. By means of graphical displays in the wind tunnel control room, the functioning of the entire system was verified almost on-line.

Work on laser-based measuring techniques such as Particle Image Velocimetry (PIV) continued. Apart from pursuing its own developments NLR participates in the GARTEUR (AD) AG 19 on PIV for large wind tunnels, assisted by the expertise of the Aerodynamics and Hydraulics Laboratory of the Delft University of Technology. NLR manufactured a test item that will be used by the Action Group members to compare recording and processing techniques for PIV data.

The feasibility of the use of Pressure Sensitive Paint (PSP) for surface pressure measurements in NLR's high speed wind tunnels is being investigated. A small-scale test set-up was prepared to investigate candidate materials. Preparations were made for NLR's participation in a proposed GARTEUR Action Group on PSP techniques.

The design and manufacture of a new generation of accurate model balances was continued. Two special purpose internal six-component balances were completed, and the manufacturing of two general purpose balances was started. Two semi-span model balances, for the LST and the HST respectively, were completed, including their calibration. Their first wind-on applications, for validation purposes, were started by the end of the year.

The semi-span model testing technique was subject of continued investigation. Comparisons of experimental and theoretical data were made, aiming at improvements to semi-span model correction methods. In addition, an analysis was started to determine the level of wall interference on semi-span models in the modified test section of the HST.

New measurement systems and techniques, such as PSI, PIV and PSP, differ widely from conventional systems by the large amounts of data they produce and the special data acquisition and processing techniques they require. In preparation of the implementation of these new techniques, work has been started to define requirements and concepts for a new generation of wind tunnel data acquisition and processing systems.

For the localization of acoustic sources in wind tunnel experiments, an acoustic antenna consisting of a line or plane array of microphones was developed. When positioned out of the flow, this array proved to provide a reliable acoustic imaging technique. The resolution is expected to be capable of being improved by positioning the array in the flow. The first steps towards in-flow applications were made.

3.2 Flight

Summary

The activities in the Flight Division in the area of *aircraft development* stabilized at the level of the past few years. The decrease in the support to flight test programmes for Fokker was almost counterbalanced by an increase in development work in the areas of flight guidance and control, flight systems and *human factors. Support to helicopter development programmes also tended to* increase.

The level of activities on *aircraft operations* continued to rise, as in the past few years. In the military field the increase in the number of vehicle types (transport aircraft, helicopters) for the Royal Netherlands Air Force leads to a further demand for support. In the civil field the continuous growth of the demand for air transport already saturates the present air traffic management system. Much more research and development is necessary to cope with this demand and the ever more stringent environmental restrictions, and to guarantee a safe, efficient and environmentally friendly air transport system in the future. The work is more and more accomplished in international collaboration under the auspices of Eurocontrol and the European Union.

Aircraft development activities concentrated on support in flight test programmes *of the Fokker 50, the 'Enforcer', the Fokker 70 and the Fokker 100.* The existing Measurement, Recording and Data Processing system (MRVS) was used in the flight trials of these aircraft. The development of a new MRVS with modern instrumentation capabilities and facilities for flight test purposes was continued. NLR took part in a joint research programme on the in-flight use of laser Doppler anemometry.

Within the field of *flying qualities and control systems* NLR took part in a cooperative study using NLR's Research Flight Simulator (RFS) to investigate the handling qualities of modern civil transport aircraft.

In a windshear study the main focus was on an experiment using the RFS to investigate the use of coloured windshear presentations.

Under contract to RLD, an investigation on identifying the prime causes of Controlled Flight Into Terrain accidents was initiated.

In the field of *man machine integration and human factors,* research was carried out to analyze, improve and optimize the role of humans (pilots and air traffic controllers) in operating future air transport systems.

As part of a National Technology Project, NLR carried out research into the use of voice recognition for control functions in fighter cockpits.

In the area of *aircraft operations* a flight test programme with NLR's Metro II research aircraft was carried out under contract to Eurocontrol to validate the installation of an Experimental Flight Management System (EFMS).

Several flight tests were carried out with the Metro II and the Cessna Citation II research aircraft at Amsterdam Airport Schiphol.

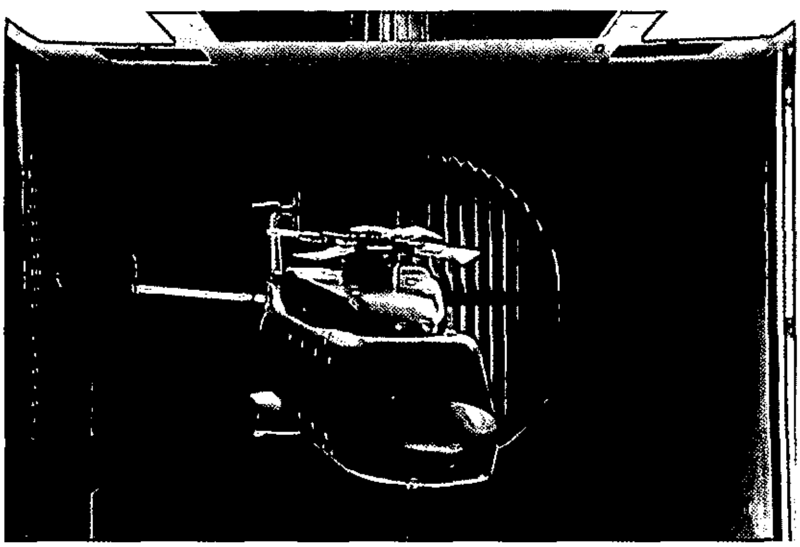
In the field of *air traffic management,* NLR supported Air Traffic Control The Netherlands (LVB) and Eurocontrol in such areas as aircraft and radar models, ATC simulation and automation and aeronautical telecommunication networks. Within the framework of the Programme for Harmonized Air Traffic Management Research in Eurocontrol (PHARE), NLR contributed to the development of systems and tools.

Under contract to Eurocontrol, NLR continued work in the joint development of an ATC Radar Tracker and Server (ARTAS) and facilities for its testing.

NLR provided management and assistance to several projects of Eurocontrol and participated in the activities of EU programmes.

NLR supported the Royal Netherlands Air Force (RNLAF) in operation training and during flight tests, air defence trials and in the analysis of aircraft accidents.

Within GARTEUR, NLR participated in the activities on *helicopter* flying qualities and helicopter performance and modelling. The RNLAF and the Royal Netherlands Army were assisted in the activities related to the procurement of armed helicopters, and contributions were made in the design and development phase of the NH90 programme for a future NATO helicopter.



NH90 model tested in the low-speed wind tunnel LST

In the field of *aircraft environmental research*, calculations of noise loads were made for civil airports and military airbases. Investigations of the air pollution caused by aircraft were carried out on national and international levels. The NLR methodology to determine third party risks around airports was used to carry out calculations for large airports and regional airports.

NLR started investigations on *policy analysis* related to the future developments of air transport.

With regard to *facilities and equipment*, the development of the National Simulation Facility (NSF) was continued by the installation of the visual system and the validation and integration of the F-16 Mid-Life Update (MLU) avionics simulation software. NLR continued the development of the RFS and the NLR ATC Research Simulator (NARSIM). The simulators were used in various experiments and demonstrations.

The data processing system for flight test data and the pressure calibration facility were upgraded.

Aircraft Development

Flight Testing and Flight Test Instrumentation

Evaluation and Certification of the Fokker 50, 70 and 100

The Measurement, Recording and Data Processing system MRVS was used in the flight trials of the Fokker 50, Fokker 70 and Fokker 100. A team of NLR personnel maintained the system and was responsible for its operation during the flight tests, which were conducted because of new developments or customer requirements.

Fokker 50

Flight tests with the Fokker 50 prototype were mainly concerned with a new digital autopilot system.

The flight test programme of the 'Enforcer', a maritime patrol version of the Fokker 50, was continued, supported by NLR-personnel operating, controlling and maintaining the flight test instrumentation systems on board of the two participating aircraft. The final phase of the flight tests was completed.

The Production Flight Test system was used for the factory acceptance of all new Fokker 50 aircraft.

Fokker 70

The flight test programme of the Fokker 70 continued. The flight test measurement system for this programme is based on the system used in an earlier Fokker 100 prototype but incorporates many newly developed items. Additional flight tests were carried out with the first Fokker 70 production aircraft, also equipped with an NLR flight test instrumentation system. After the basic airworthiness certification was acquired, flight tests for additional items such as the automatic landing system were continued. For these tests NLR provides the flight trajectory measurement system.

Fokker 100

NLR's flight test instrumentation system installed in the prototype Fokker 100 aircraft was used for the certification of a new main landing gear. Other tests were dedicated to the evaluation of ice detection sensors.

The Production Flight Test system was used for the factory acceptance of all new Fokker 100 aircraft.

MRVS-90

The MRVS-90 project, under contract to the Netherlands Agency for Aerospace Programs (NIVR) and in co-operation with Fokker Aircraft, was continued. It is aimed at modernizing the instrumentation capabilities and facilities for flight test purposes. A number of new systems were used on board of the Fokker 70 prototype. The development of the high-capacity avionic data acquisition system (ADAS) and of the subsystems for on-board instrumentation control and monitoring continued. The Position Reference System (PRS) based on the Global Positioning System (GPS), using a new multi-channel GPS receiver, entered its next development stage. Flight tests with NLR's research aircraft revealed a three-dimensional position accuracy better than the design specification of 30 cm.

Measurement and Analysis Techniques for In-Flight Research

As a follow-on to the result of a Garteur Exploratory Group on the subject, a joint NLR-DLR research programme was started on the in-flight use of laser Doppler anemometry. Several flights of NLR's Cessna Citation research aircraft were carried out using laser anemometers of NLR and DLR simultaneously.

For the accurate measurement of angle-of-attack and angle-of-sideslip during flight tests, a system using a number of flush mounted pressure vents in the nose of the aircraft was evaluated. This alternative to the classical nose-boom equipped with vanes proved to function well. After elaborate calibration, accuracies in the order of 0.5° were achieved.

Military Flight Test Support

Support to the Royal Netherlands Air Force

NLR assisted the Royal Netherlands Air Force during flight tests with F-16 aircraft and during air defence flight trials. New data acquisition equipment was put into use.

Flight Loads Monitoring Programmes

National and foreign military services were supported in their flight loads monitoring programmes by NLR's supervising the installation of equipment on board of their aircraft and performing safety analyses.

Flying Qualities and Flight Control Systems

Flying Qualities

In the framework of a GARTEUR collaboration, NLR, in co-operation with DLR, DRA and ONERA and co-funded by the Netherlands Agency for Aerospace Programs (NIVR), has carried out a study using the Research Flight Simulator (RFS) to investigate the handling qualities of a civil transport aircraft equipped with a glass cockpit, advanced Fly-By-Wire Flight Control Systems (FCS), a sidestick controller, a simulated Head Up Display (HUD) and an autothrottle. This research is aimed at the development of low-speed lateral/directional handling qualities design guidelines for future transport aircraft. Subjects evaluated the control characteristics of a particular aircraft/FCS combination by executing a precise localizer and glideslope intercept (and ILS tracking) using raw ILS data, under various atmospheric conditions. Somewhere between 1000 and 200 ft AGL (Above Ground Level) a lateral sidestep manoeuvre had to be executed after which the aircraft had to be landed on the runway precisely. One conventional and two newly designed *lateral/directional* FCS systems were investigated. Combined with the longitudinal FCS the pilot directly commanded a flight-path vector that was presented on the HUD. Sometimes an FCS failure would occur during the approach. Then the reversion from the primary lateral/directional FCS to and the handling of the aircraft with a less sophisticated backup Flight Control System was investigated. The longitudinal FCS characteristics were left unchanged throughout the experiment. The evaluations were performed by four test pilots. Both objective and subjective data, measured parameters, pilot questionnaires and debriefing comments, were collected. Prior to the principal investigation, a preparatory experiment was executed on DLR's fixed-base simulator at Braunschweig, Germany. This latter experiment was aimed at obtaining a preliminary pilot-in-the-loop evaluation of the newly designed flight control systems and at establishing a proper pilot task.

AFC/NFT (Active Flight Controls/National Fly-By-Wire Testbed)

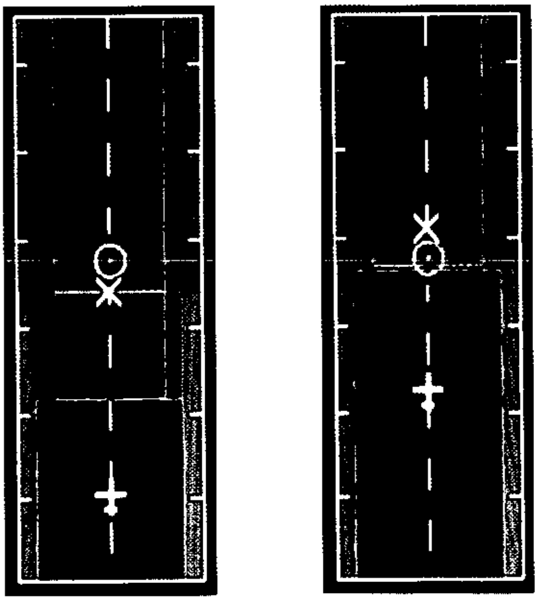
NLR is co-operating with the Delft University of Technology in the 'Active Flight Controls/National Fly-by-Wire Testbed' project. A proposal for the conversion of the Cessna Citation II research aircraft into the National Fly-By-Wire Testbed was prepared. Basic control laws were evaluated in a computer-based engineering environment for control systems.

Robust Flight Control

A GARTEUR Action Group 'Robust Flight Control in a Computational Aircraft Control Engineering Environment', supported by the NIVR, has been established. It will be managed by NLR for a period of two years until October 1996. Four universities, six research establishments and eight industrial enterprises from seven European countries work together to improve the development process of flight control software. The first objective of the Action Group is to identify, apply, assess and compare modern and classical controller design methods on the basis of a civil automatic landing benchmark problem and a military high angle of attack benchmark problem. The definition of both benchmarks has been initiated as well as the organisation of a design challenge which will be the carrier of the activities. The second objective is to develop an environment which supports the flight control software development process. The definition of the requirements and the architectural design for such an environment have been started.

TOPM (Take-Off Performance Monitor)

Research into Take-Off Performance Monitors (TOPMs) has been conducted under contract to NIVR. TOPM systems are aimed at improving crew situational awareness by presenting real-time performance information on the status of the take-off. They could enable the crew to take corrective actions in a timely manner should take-off conditions be adversely affected. The objective of the study was to examine the potential safety benefits offered by such systems. Results show the best system should incorporate current aircraft performance with predictions of both continued take-off and stopping ability.



Dynamic display of Take-Off Performance Monitoring (TOPM) system. Current positions of aircraft, between brown can-stop bars, and nominal and estimated rotate speed points, between blue can-go bars, are shown on the Navigation display. Left-hand and right-hand pictures show better than normal and worse than normal performance, respectively.

Windshear

In 1994 the windshear activities of GARTEUR Flight Mechanics Action Group (FM) AG 07 were harmonised with the activities in Phase-Ib of the Windshear Master Plan supported by the Netherlands Agency for Aerospace Programs (NIVR), the Netherlands Department of Civil Aviation (RLD), KLM Royal Dutch Airlines and the Royal Netherlands Meteorological Institute (KNMI). As a result an experiment was carried out on the NLR Research Flight Simulator (RFS). The effects of presenting coloured windshear icon information on an Electronic Flight Instrument System (EFIS) navigation display on situational awareness, pilot decision making and flight safety have been investigated. This icon information was generated by a scanning forward-looking windshear detection system. Special attention was given to the problem of integration of the aural and visual alerts of both the reactive and the forward-looking windshear detection system. The proposed integrated windshear warning concept was evaluated in combination with a predefined flight procedure. A special flight director go-around mode, incorporating alpha protection, was evaluated for performance. Six crews flew about 240 simulated straight-in approaches under moderate to severe and sometimes catastrophic windshear conditions.

Controlled Flight into Terrain

Accident Statistics indicate that Controlled Flight into Terrain (CFIT) is currently the largest single cause of air carrier accidents. Under contract to RLD, an investigation focused on identifying the prime causes of CFIT accidents was initiated. A comprehensive classification of causes has been developed, and a number of prevention strategies are being recommended. The results of this investigation are contributed to the activities of the Flight Safety Foundation/ ICAO International CFIT Task Force, of which NLR is an active member.

A related study, conducted under contract to the Netherlands Agency for Aerospace Programmes (NIVR), involves the development of algorithms and terrain displays for advanced collision avoidance systems. Both awareness and conflict resolution are being considered.

Verification of Flight Control and Display Concepts

Under contract to Fokker, NLR is involved in a design study for a short to medium range aircraft that is expected to fly in a 4D air Traffic Management environment. Fokker has proposed a number of flight control system concepts and information display concepts that should provide the pilot with a lower workload and better situational awareness. Preparations have been made to verify these concepts by flight simulation in a realistic ATM environment.

Mathematical Models of Aircraft

The determination of the aerodynamic model of the Fairchild Metro II research aircraft is a co-operative project of NLR and the Faculty of Aerospace Engineering of the Delft University of Technology. A Non-Stationary Measurement Method (NSM) and dedicated parameter identification techniques are used in this project. Earlier results suggested the dynamic fuel displacement during the manoeuvres could cause the large dispersion of some of the model coefficients. A flight test programme to verify this assumption was prepared.

The possibilities for the application of the Multi-Input Multi-Output method (MIMO) for aerodynamic modelling were studied in collaboration with the Faculty of Aerospace Engineering of the Delft University of Technology.

Application of Voice in the Cockpit

In a National Technology Project, NLR and the TNO Human Factors Research Institute are carrying out research into the possible use of voice recognition technology for control functions in military (fighter) cockpits. As part of this project, NLR identified eligible control functions in an F-16 Mid-Life Update cockpit and developed the associated command syntax structure. In Phase II of the project, a Marconi MR8 speech recognizer card was used for the implementation of the syntax and command word vocabulary. A PC-based demonstrator was developed for initial evaluation of the syntax and integration aspects such as the hierarchy and authority of the various voice control functions, timers, automatic node-setting and pilot feedback. The resulting concept is currently being implemented on the National Simulation Facility.

Tactical Recce System Replacement

A feasibility study was carried out for the Royal Netherlands Air Force into the replacement of the current F-16 Orpheus reconnaissance pod. The requirements included replacement of the current wet film cameras by Electro-Optical (EO) sensors with low and medium altitude recce capabilities in both the visible and infrared part of the spectrum and the introduction of a near-real-time datalink capability. Various pod/equipment options were studied for the accommodation of the EO sensors, the digital management and data recorder systems and the high-rate digital datalink units and antennas. In parallel, the requirements for associated ground stations were prepared. Time schedules and ROM costs were estimated for the national development of the new recce system to be introduced in 1999.

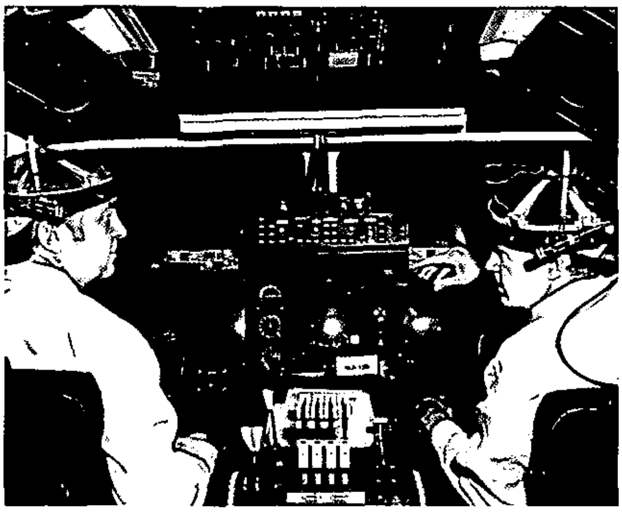
Man Machine Integration and Human Factors

Glass Cockpit Design for Airliners

A mission analysis was performed for short haul aircraft, reviewing the requirements of the future Air Traffic Management (ATM) operating environment. The capability to effectively fly and negotiate economic 4D trajectories is a key element, but cycle times and crew workload are important as well. The potential flexibility and high level of planning in the ATM environment introduce new standards and requirements for future crew interfaces. Prototype displays for 4D navigation functions were designed and implemented in the flight simulator for testing under the operational circumstances envisaged.

Two major cockpit concepts, based on different automation strategies were identified. The 'DRONE' concept refers to a future 'Datalink Routed Obedient Navigation Environment' as opposed to the 'PRIDE' concept that refers to a 'Pilot Routed Informed Decision Environment'. Both concepts were prototyped and implemented in the RFS to allow systematic comparative studies. This work is carried out in collaboration with the Ohio State University, USA, and the University of Leiden.

In support of the cockpit research, and in collaboration with the FAA and RLD, new datalink interfaces were designed that allow so-called 'gating' of uplinked trajectories into the FMS or even the Mode Control Panel. In human factors experiments with airline pilots collaborating, the effectiveness and acceptance of such technologies were evaluated. Early results confirm that technology additions to existing cockpit concepts require intensive reconsideration and more effective integration of the total crew concept including task and information sharing, cross check and operating procedures.



One of the crews, equipped with miniature video camaras for head tracking in NLR's Research Flight Simulator, participating in a collaboration with the FAA

The application of Enhanced and Synthetic displays was pursued in collaboration with industry and the DLR, which resulted in a project supported by the Commission of the European Communities.

An alternative interface to FMS systems was designed in an attempt to allow more timely interaction of the crew during high-time-pressure mission segments. The direct object principle, for instance trajectories manipulation on the navigation and other multi-function displays, is used. Prototypes were installed in preparation of validation experiments.

A cockpit human factors study that summarised critical human factors problems encountered when operating highly automated aircraft was performed. The results were published by the 'Air Safety Working Party' of the European Transport Safety Council (ETSC), an independent organisation of which NLR is an invited member. The complexity of flight modes, in-flight transitions and an uneven distribution of task loads during the mission pose major problems together with the occurrence of violations of major ergonomic design principles. The 'Glass cockpit' concept is poorly standardised, introducing potential confusion and human performance difficulties when crews have to make a transition to other aircraft.

ATC/ATM Controller Human Machine Interface

Studies and prototyping activities were performed in support of the design of advanced human interfaces for ATC controllers, using state-of-the-art technology. This effort was made with PHARE partners and resulted in a so-called 'reference' system for Eurocontrol advanced technology research. The system will serve as a baseline for comparison with and validation of more expanded versions that contain additional 'tools' aimed at increasing traffic throughput.

Three expanded working positions that included new capabilities such as looking-ahead functions for trajectory planning, graphical conflict problem identification and 'what if' resolution capability were developed. This work is performed in the context of the PHARE GHMI (Ground Human Machine Interface) project managed by NLR.

The exploration and validation of possible automation strategies for Air Traffic Control and Air Traffic Management was investigated with a research test bed developed by NLR on the basis of the Center Tracon Automation System (CTAS) of NASA Ames. The facility allows human factors research for new concepts by providing a flexible allocation of functions capability. Duties can be assigned to either machine (software) functionalities or human tasks. The actual allocation can be guided by traffic load considerations or controllers intent. A datalink is fully integrated and selectable as well. This work is performed in collaboration with the human factors division of NASA and the Catholic University of Washington.

Military Crew Station Design

The F-16 mock up was prepared and used for exploratory trials concerning 'visual sampling' strategies that pilots use while operating different Head Up Display formats under varying levels of task loading.

The F-16 Mid Life Update cockpit will be upgraded with colour displays. In collaboration with Lockheed, strategies were discussed to determine consistent colour application in fighter cockpits.

The 'Glass cockpit' under development for the Chinook helicopter was reviewed using CODEP (Cockpit Operability Design and Evaluation Procedure).

The design recommendations that were adopted by the RNLAF will be integrated in the flight deck design. The issues addressed concerned mode consistencies, transitions and modifications of the EFIS display layouts, and colour coding. The Glass cockpit of the Chinook is fundamentally different from civil flight decks, and careful consideration is required for designing adequate crew training methods for it.

Human Operator Training and Familiarisation

Training and simulation research is being carried out under two EUCLID projects, both involving considerable human factors aspects: RTP 11.1 on 'Simulation Based Training System Concepts' and RTP 11.2 on 'Simulation Techniques'. In both projects, the majority of the simulation industry is represented.

Flight trials were prepared that aim to obtain a so-called (pilot) performance template for a standardised set of manoeuvres. This template subsequently has to be reproduced accurately in and by the training devices. The planned flight trials include both fighter and helicopter platforms.

A training requirements study was supported for the Chinook helicopter.

A computer-based ATC Human Machine Interface familiarisation course was designed for introducing new concepts to air traffic controllers. The course will be implemented in the first PHARE test of 'Advanced Tools' and 'Ground Human Machine Interfaces'.

Operator Performance and Workload Measurement

Research on the development of a practical 'Workload toolbox' for flight deck applications was continued. Airline pilots participated in an experiment involving datalink cockpit interfaces exploiting several workload measurement techniques in one comprehensive scenario. The research contributed to the development of a set of measures that should enable a more systematic study of crew strategies, attentional state and interactions with advanced user interfaces. Based on the experiment, the physiological equipment of the NLR SWEAT (Standardised Workload Evaluation and Assessment Techniques) set was modified to interface more effectively with simulation and aircraft equipment. The commercially available analysis software was critically reviewed and improved.

Head/eye tracking equipment has been integrated in the design and evaluation cycle of display and control concepts.

A 'traffic awareness' questionnaire was developed as part of a set of 'situational awareness' indices. A mode awareness assessing procedure was initiated.

Human Factors Certification Aspects

NLR continued the process of integrating complex human factors background material and knowledge in a practical format to assist aircraft developers and users in their certification needs regarding human factors issues. This work is done under the name of CODEP (Cockpit Operability and Design Evaluation Procedure).

MMI Design Tools

NLR developed a Man Machine Interface package for the aviation environment named NADDES (NLR Advanced Display Design and Evaluation System). This package allows design conceptualisation on PCs and produces both specifications independent of hardware and software code for specific target systems.

Aircraft Operations

Research Aircraft

The Fairchild Metro II and the Cessna Citation II research aircraft performed combined approaches on converging runways of Amsterdam Airport Schiphol for the qualification of a new Air Traffic Control tool, the 'Converging Runway Display Aid' (CRDA).

Fairchild Metro II

Under contract to the Air Traffic Control authorities of the UK, France and the Netherlands and the Netherlands Department of Civil Aviation (RLD) a flight test programme was executed at Aberdeen Airport, UK, to demonstrate the capabilities of the 'Multi Mode Receiver'. A video movie was made of the use of this receiver for the execution of approaches based on either the Instrument Landing System (ILS), Microwave Landing System (MLS) or Differential GPS (DGPS). The tests were executed in view of the necessity of maintaining Category III landing capability on the wold's important airports, and are to be continued in the following years. The movie was made to support the position of France, the UK and the Netherlands at the ICAO European Regional Air Navigation Meeting in September 1994.

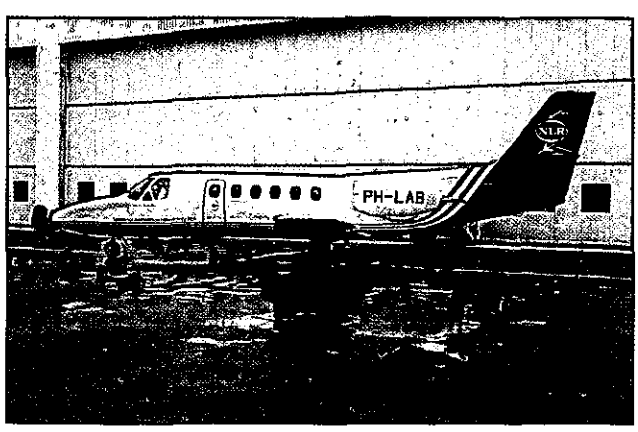
The tests with the Experimental Flight Management System (EFMS) and a datalink for digital communication with Air Traffic Control were continued; in co-operation with the French company CENA a flight test programme was carried out at Bretigny airfield under contract to Eurocontrol.

Remote sensing flights were made in a number of projects with the optical scanner CAESAR over different areas in the Netherlands; they included a number of repetitive flights over one test area in a period of several months, in the project 'Optimal Agrochemical Use at Farm Level'. A number of flights were made with the PHARS synthetic aperture radar, including a few for determining the sea bottom floor in shallow waters.

Cessna Citation II

The Cessna Citation II is owned and operated jointly with the Delft University of Technology.

A test programme was carried out with Laser Anemometers from NLR and DLR to test the applicability of the sensors for measuring velocity profiles in the boundary layer on a non-interfering basis, with promising results.



Prof.mr. J. Cohen, State Secretary of Education, baptized the PH-LAB, the Cessna Citation research aircraft, 'Prof. H.J. van der Maas'

A new method for investigating flutter phenomena has been tested. For this purpose special 'pressure tapes' have been attached to the wing of the Citation to measure high frequency pressure fluctuations, in combination with accelerometers.

Other Operations

Support to the Ministry of Transport

NLR's experience in the field of aircraft trajectory reconstruction was used to advise the Road and Hydraulic Engineering Division of the Ministry in a project for the upgrading of its motorway road profile measurement vehicle.

Air Traffic Management

Air Traffic Control

Research and development in Air Traffic Control has been carried out under contract to Air Traffic Control The Netherlands (LVB), and, mostly in co-operation with European industries and other research institutes, for Eurocontrol and the European Union (EU). Activity areas were: aircraft and radar models, surveillance (SSR mode S), ATC simulation and automation, controller working position, the aeronautical telecommunication network (ATN) and man-machine interface/ human factors.

The Center Tracon Automation System (CTAS) was further improved. A long-line experiment with NASA was performed, allowing the NASA flight simulator to 'land' at Amsterdam Airport Schiphol under automated Air Traffic Control using a datalink.

Support to Air Traffic Control The Netherlands (LVB)

The evaluation of area conflict detection, short term conflict detection and flight plan monitoring functions has resulted in validated specifications for the Amsterdam Advanced Automation (AAA) system. Large-scale evaluation of these functions was continued. Prototyping work was done for displays and input devices for this system. Research for automation support to the LVB for the period after the acceptance of the AAA system was continued, with emphasis on flight path monitoring, conflict probing and conflict detection.

NLR supported LVB and RLD in the procedural development and validation of converging runway operations aimed at increasing the runway landing capacity of Amsterdam Airport Schiphol. Several demonstration flights were made with the Metro II and Cessna Citation II research aircraft to prove the operational readiness of the Dependent Converging Instrument Approach (DCIA) procedure. A theoretical assessment of the collision risk was made for the case of two aircraft having to make a go-around under DCIA conditions.

NLR installed the software package SIMMOD (Simulator Model) for the estimation of capacity and punctuality at Amsterdam Airport Schiphol, and prepared it for operational use.

SICAS Panel of ICAO

On behalf of the LVB, NLR took part in activities of a number of international organizations. NLR is a member of the SSR Improvement and Collision Avoidance Systems (SICAS) Panel of ICAO. This panel is responsible for the development of standards for the Aeronautical Telecommunication Network, SSR mode S used for advanced surveillance and as a datalink and the airborne Traffic Alert and Collision Avoidance System (TCAS). Also on behalf of the LVB, NLR participated in the Aeronautical Telecommunications Network Panel (ATNP) of ICAO.

Support to Eurocontrol

Within the framework of the 'Programme for Harmonized Air traffic management Research in Eurocontrol' (PHARE) NLR contributed to the development of:

- An Experimental Flight Management System (EFMS);
- A Common Modular Simulator (CMS);
- A PHARE Aeronautical Telecommunication Network (PATN);
- An Airborne Human Machine Interface (AHMI);
- A Ground Human Machine Interface (GHMI);
- The PHARE Advanced Tools.

In addition NLR participates in the PHARE Demonstration 3, a Multi-Sector, Multi-ATC Centre demonstration of advanced ATM developed by PHARE partners and intended to be operational in the period 2000–2010. For this programme, draft operational specifications were produced.

NLR provides full-time assistance to the PHARE cell at Eurocontrol, Brussels.

In the framework of the Programme for Harmonized Air traffic management Research in Eurocontrol (PHARE) NLR contributes to the development of an Experimental Flight Management System (EFMS). Participants in the EFMS Development Group besides Eurocontrol are DRA of the UK, DLR of Germany and CENA of France. The contribution of NLR is in the field of datalink communication and pilot-EFMS interface.

The first flyable version of the EFMS including an experimental two-way VHF datalink was integrated in NLR's Metro research aircraft in 1993. In that configuration a 10-hour flight test programme for the assessment of the EFMS using manual flight control was conducted under contract to Eurocontrol. Later, the EFMS was used in an SSR mode S experiment in which the airborne segment was provided by NLR and the ground segment by CENA of France.

In parallel to these experiments the development of the EFMS continued. NLR participated in the drafting and reviewing of the user requirements and design documents of the next version, scheduled for 1995.

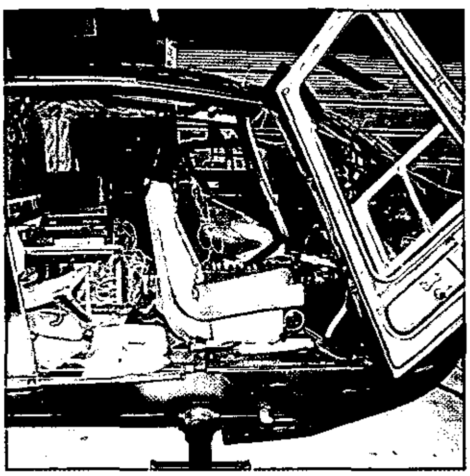
A flight test programme aimed at validating the installation of the EFMS in the Metro II research aircraft was successfully carried out near Groningen Airport Eelde. A further flight test programme aimed at providing a first experience of an actual 4-D trajectory negotiation over a mode-S digital datalink was carried out in co-operation with CENA near Paris.

NLR provided the project management and further assistance to PRAISE, the Preparation of an R & D Programme in support of EATMS, the European Air Traffic Management System. This project defines the necessary research for a successful start of EATMS.

Support to the European Union

In the EU's European Transport Programme (EURET), NLR continued participating in the activities related to the European Aeronautical Telecommunication Network (EURATN), which will comply to the draft ICAO Standards. The main objective is to realize an experimental air-to-ground and ground-to-ground data communication system. A large demonstration to delegates of the Commission and Eurocontrol was successful.

NLR participated in the SWIFT (Specification of a Controller Working Position in Future ATC) project, which was concluded with the development of a 'demonstrator'. This demonstrator, which contains some specific NARSIM features, will travel around Europe for display on selected locations. NLR's activities for the future European ATM sytems are directed towards optimal use of the limited airspace and airport capacity. These activities are expected to continue expanding in the next few years.



A BO105 helicopter of the Royal Netherlands Air Force with a flight test data acquisition system installed and operated by NLR staff

Helicopters

NLR participated in the activities of the GARTEUR Group of Responsables for Helicopters. Contributions were made to the GARTEUR Action Groups (HC) AG 06 and 09, 'Mathematical Modelling for the Prediction of Helicopter Flying Qualities', (HC) AG 07, 'Helicopter Performance Modelling', (HC) AG 08, 'Helicopter Vibration Prediction and Methodology', and (HC) AG 10, 'The Prediction of Dynamic Stall and Blade Torsion'.

In co-operation with Fokker and DAF Special Products, NLR takes part in the Design and Development phase of the NH90 programme for a future NATO helicopter. Wind tunnel tests were conducted in the LST using a model designed and manufactured by NLR.

The Royal Netherlands Air Force (RNLAF) and the Royal Netherlands Army were assisted extensively in the activities related to their armed helicopter procurement programme. Flight tests were carried out to prove the safe operation of the Stability Augmentation System on a BO105 helicopter in a modified configuration.

A flight test programme for the Royal Netherlands Navy (RNLN) was carried out with a Lynx helicopter with new composite main rotor blades.

Aircraft Environmental Research

Calculations of Noise Loads

Noise loads were calculated for the actual situations at the large civil airports and at several military airbases in the Netherlands. In addition, calculations were made for growth scenarios at Amsterdam Airport Schiphol, several military airbases and airfields used by general aviation. Most of the calculations were made under contract to the Department of Civil Aviation, the Ministry of Defence and Amsterdam Airport Schiphol.

Noise Monitoring

Under contract to the Ministry of Housing, Physical Planning and the Environment, NLR took care of the management of the noise monitoring networks near the airbases of Geilenkirchen and Brüggen in Germany. Amsterdam Airport Schiphol was assisted in the design and realization of a noise monitoring network.

Calculation of Air Pollution

An investigation into the total air pollution caused by aircraft in the Netherlands was carried out. Under contract to the national government, NLR took part in international consultations on air pollution by aircraft. The environmental effects of commercial aviation will increase in importance in the coming years, and NLR's activities in this area are expected to grow also.

Policy Analysis

In 1994 NLR started offering a new service to the international aviation community: policy analysis. Under contract to the Department of Civil Aviation, NLR participated in a policy analysis of air pollution caused by aircraft. NLR also contributed to a study into the effectiveness of government subsidy with respect to the development of aircraft gas turbines with low emissions and low energy use.

Accident Investigations

NLR supported the Royal Netherlands Air Force (RNLAF) in the investigations of accidents with RNLAF fighter aircraft, transport aircraft and a helicopter. NLR staff took part in the investigation teams, in particular to carry out investigations into possible technical or operational causes of the accident.

NLR supported the Netherlands Bureau for Civil Accident and Incident Investigation in the analysis of accidents and incidents. An accident with a commuter aircraft was investigated by NLR at the request of the Norwegian Aircraft Accident Investigation Board.

Risk Analyses for Airports

The method developed by NLR for the determination of third party risks associated with aircraft accidents around airports was used to carry out a large number of calculations of the third party risk implications of development options for Amsterdam Airport Schiphol. NLR was contracted by the UK Civil Aviation Authority to carry out a third party risk analysis for London Heathrow International Airport. The growing awareness of third party risk around airports led to numerous presentations on the NLR methodology and results, given at the request of civil aviation authorities and airport authorities from other countries.

Under contract to the Netherlands Department of Civil Aviation, the NLR methodology and the analysis software were extended to support the calculation of third party risk associated with the commuter and general aviation categories of aircraft, in order to enable risk analyses to be made for regional airports. In addition, a number of enhancements of the methodology and software were carried out to enable the calculation of third party risk inside the airport boundaries and to support detailed analyses of the geographical distribution of societal risk.

Facilities and Equipment

Avionics Research Testbed (ART)

To be able to conduct the flight testing of the Experimental Flight Management System (EFMS), an SSR Mode S transponder and a digital Data Link Processor Unit (DLPU) were installed in the Metro II research aircraft.

For the participation of NLR in the European Automatic Dependent Surveillance project (EADS), preparations for the installation of satellite communication equipment in the Cessna Citation II research aircraft were started.

Air traffic controller working position of the NLR ATC Research Simulator (NARSIM)

NLR ATC Research Simulator (NARSIM)

The development of the NLR ATC Research Simulator (NARSIM) was continued. The NARSIM configuration has been extended with a third Air Traffic Controller working position featuring a large colour display, two touch input devices and track balls. The accompanying display computer is compatible with the X-Windows system. A high-performance workstation has been acquired for the development of user interfaces.

Research Flight Simulator (RFS)

Modifications were made to the Research Flight Simulator to enable various experiments to be conducted. For research on the benefits of the datalink, the RFS has been connected to the Air Traffic Control (ATC) simulator of the US Federal Aviation Administration in Atlantic City. The programmable Research Flight Management System (RFMS) has been extended for further Human Factors research on datalink applications. The RFMS now supports full flights, and additional functions such as gating ATC commands to the Mode Control Panel have been implemented.

A software code generator has been developed to enable the RFS to use displays defined by the NLR Avionics Display Development and Evaluation System (NADDES). Preparations were made to install a tracker ball and a touch pad for enhanced pilot input functions, replacing the Command and Display Units of the FMS.

National Simulation Facility (NSF)

NLR has continued the development of the flexible and versatile National Simulation Facility (NSF) as an extension to its existing flight simulation facilities. The visual system procured from Evans & Sutherland was installed and integrated with the host computer and the platform motion system. The dome was prepared using new coating application procedures resulting in a seamless dome interior. The VistaView head-tracked projection system was rigorously tested for withstanding the high-performance motion system dynamics, and subsequently accepted.

The software program simulating the F-16 MLU avionics was validated by Lockheed engineers, integrated with the simulator executive and connected to the various hardware systems. A dedicated F-16 cockpit interface node was procured (from the Dutch firm CH&SS) which acts as a translator for the host computer commands sent through a fibre-optic reflective memory link to all cockpit instruments, displays, panels and controls. Integration of this system took place early December.

The tactical environment simulation will be handled by the CAE ITEMS software package, the most advanced system available today. It also enables the NSF to be networked with other, heterogeneous simulator facilities through the IEEE-standard for Distributed Interactive Simulation.

The first 'flight' with the NSF took place on 31 December, in accordance with the planning, and was concluded with several flawless landings which showed the correct interrelation of all cueing means: the motion, visual, and audio systems and software models.

Delivery of a G-cueing system was awarded to a consortium of Sogitec Industries and Fokker Control Systems. In 1996 the system will be added to the NSF for the simulation of sustained acceleration and forces.

F-16 Mock-up

The F-16 mock-up was used extensively as the primary means of testing and validating the complex F-16 avionics simulation software and all other NSF software models. The mock-up was used in a demonstration to show the feasibility of using the pilot's voice to control certain F-16 avionics and communication system modes, using a voice analyser and recognition system developed by NLR and TNO.

National Fly-by-wire Testbed (NFT)

A preliminary project plan was drawn up for the conversion of the Citation II research aircraft into a testbed suitable for research into Active Flight Controls.

Facilities for Measurement and Processing of Flight Test Data

The tests of a new highly dynamic five-hole pressure probe were concluded. The availability of sensors for in-flight analysis of the exhaust emission of aircraft engines was studied.

A new recording device for flight test instrumentation systems for data streams up to 2.2 Mbit/s and based on standard video recording techniques was tested in severe environmental conditions before it was used in an F-16 fighter aircraft.

The Helicopter Data Acquisition System (HEDAS) was provided with a new device for the pilot to control the system.

A downward looking video system was developed for independently verifying the accuracies of positioning systems to be used during autoland flight tests. Accuracies are in the 5-cm class when the aircraft is flying at 15 feet above the ground.

The modernization and upgrading of the data processing system for flight test data was started. A new dual-processor computer was acquired with new I/O interfaces. A fair amount of the existing software packages have been converted to the new machine. The next stage will be the interfacing of the recording media such as high density digital data recordings of the Ampex DCRSi type.

Measurement Equipment for Human Factors Research

The system for physiological measurements was improved and was successfully used in experiments. A new eye/head-tracker system was acquired and was subjected to an acceptance test programme.

Measurement System Configuration Data Base

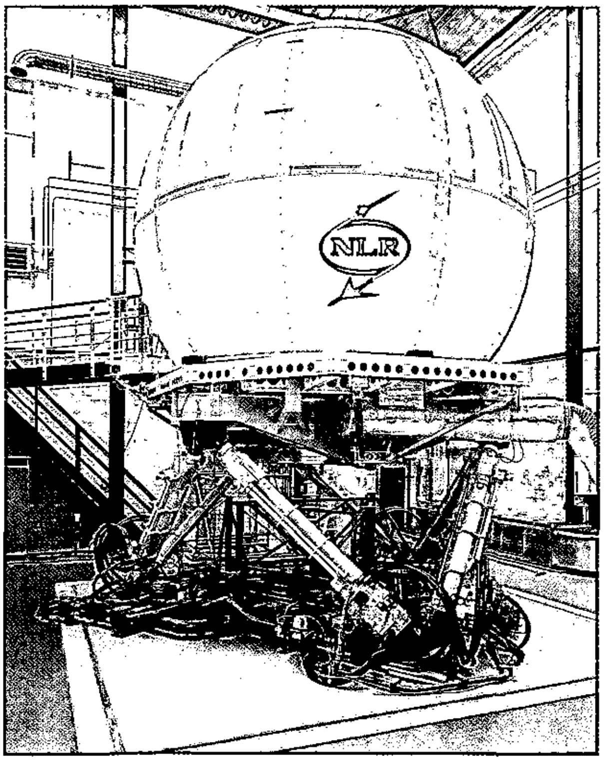
This data base, containing all information on the configuration and calibration data of current and earlier flight test instrumentation systems was converted to a new computer and another Data Base Management System.

Calibration and Test Equipment

The integration and test facility for flight test instrumentation providing programmable IRIG PCM, ARINC 429 and MIL-STD 1553 data streams was further developed and used for laboratory testing of flight test instrumentation packages.

The pressure calibration facility (VACAL), accredited by the Netherlands Calibration Organization NKO, successfully participated in an inter-laboratory comparison of the Western European Calibration Co-ordination (WECC). The quality manual of VACAL was updated to the EN 45001 Standard and the ISO/IES Guide 25. Technical developments included the design and scheduling of a major update of the pressure calibration hardware and the ordering of the necessary equipment.

A thorough overhaul of the test and maintenance facility for flight test data acquisition equipment was started. This work was carried out partly under contract to the Aydin Vector company.



The National Simulation Facility, with an F-16 Mid Life Update cockpit in the dome of the visual system

3.3 Structures and Materials

Summary

The activities continued to be strongly focused on the application of composites and the characterization of fibre metal laminates as candidate materials for damage tolerant structures.

Support to aircraft operators is being gradually expanded. Load and usage monitoring is applied to an increasing number of aircraft, including aircraft of foreign operators. Cost-effective maintenance of high-temperature parts in aero-engines is becoming another important area for support by NLR.

The consequences of nonlinear response characteristics, inherent to aircraft with active controls, for methods for the determination of gust loads were studied.

In the area of advanced structures, the cost-effective application of composites in primary parts of the airframe is being studied in close collaboration with Fokker.

Development of a methodology for the prediction of structural response continues to address particular aspects such as acoustic transmission, damage tolerance and crashworthiness.

Crack initiation and growth are being studied for multiple site damage configurations in traditional aluminium alloy lap joints. A unique test facility has been assembled to allow representative damage tolerance testing of curved panel structures at low cost.

Work in progress towards more complete understanding of damage processes in fibre metal laminates has resulted in a preliminary model for fibre failure at blunt notches.

The successful development of a crash tube to augment the energy dissipation of helicopter landing gear in crash situations was carried into the validation phase. A novel idea for improved crashworthiness in the event of water impact that is based on the concept of a stretchable skin was further developed.

The results of NLR work covering a 25-year period on the engineering properties of aerospace aluminium alloys have been compiled.

Attempts to gradually replace traditional surface treatment processes that have undesirable environmental effects or health hazards has led to a GARTEUR programme on cadmium-free protective coatings.

Aircraft Loads

Modern transport aircraft feature active control systems with inherently non-linear response characteristics. The design criteria for continuous turbulence (Power Spectral Density, or PSD, design gust cases) contained in present Airworthiness Requirements are not directly applicable to non-linear aircraft. Under contract to the Netherlands Department of Civil Aviation (RLD), methods proposed in the literature to determine continuous gust design loads for such aircraft are compared. A proposal for a concerted evaluation of these methods in an international co-operation in an AGARD Working Group has been made.

Following an accident in which the main spar of an agricultural aircraft failed by fatigue, load measurements were carried out in a similar aircraft during crop-dusting operations during the 1994 season. The measured load experience per hour was comparable to measured data obtained by NASA in the US but somewhat more severe than design assumptions.

The consequences of proposed changes in the Airworthiness Requirements with regard to dynamic manoeuvre load conditions are being studied. In addition, a new method to determine design gust fatigue load spectra on the basis of a continuous gust model is under development.

Under contract to the Netherlands Agency for Aerospace Programs (NIVR), measurements of tail loads on a Fokker 100 operated by KLM were continued. The measurements will continue until a data base covering 2000 flights has been obtained. This data base will provide statistical information about the tail load experience in actual service.

The Fatigue Load Monitoring programme of F-16 aircraft of the Royal Netherlands Air Force (RNLAF) has been continued. Three aircraft within each squadron are equipped with a four-channel digital solid state recorder measuring the wing root bending moment and three additional load quantities. The measurements are used to determine average spectra per mission type and per squadron. Data from the RNLAF Computer Aided Maintenance System (CAMS) are used to determine the mission mixture flown by each individual aircraft in the fleet. Thus, the load experience can be determined, and therefore the fatigue life each individual aircraft has consumed.

NLR is carrying out load and usage monitoring programmes for other fixed-wing aircraft and helicopters operated by the RNLAF, the Royal Netherlands Navy and foreign Armed Forces.

Dynamic Analysis of Structures

Under contract to NIVR, the development of a method for the prediction of noise transmission through a fuselage wall continued. Different methods were used to model the dynamic behaviour of the exterior fuselage structure in combination with cabin panelling and the cavity in between. Modelling of structural details such as cabin panel connectors and glass wool insulation was studied in the European collaboration programme Basic Research in Internal Noise (BRAIN). The method developed enables different structural wall concepts to be ranked for design studies. Also, the description of damping in the analysis method was improved and methods to increase the damping by applying tuned dampers or special adhesive layers were investigated.

Strength and Stiffness of Structures

Under contract to NIVR, a feasibility study was finalised on the application of optimization methods in the preliminary design phase. A preliminary program, Aircraft Design and Analysis System (ADAS), was developed in co-operation with the Faculty of Aerospace Engineering of the Delft University of Technology. The modular finite element code B2000 used by NLR was added, to take into account the structural aspects. A Fokker 50 aircraft was modelled to demonstrate the ADAS features. In a GARTEUR co-operative programme, several approaches to multilevel optimization were investigated allowing a selection of methods to be implemented in the ADAS preliminary design programme.

Under contract to NIVR, an investigation of final panel failure and damage behaviour in an impact-damaged panel was continued. To be able to translate

damage behaviour measured in small coupons to real structures, an intermediate level of so-called structure-relevant specimens is being developed under the EUCLID CEPA 3 Research and Technology Project 3.1. Tests on a first series of these specimens showed promising results.
To improve the strength after impact of composite sheet material, the use of fibres perpendicular to the sheet is being investigated.

Tools are developed to analyse the static strength and buckling behaviour of composite spars. Analytical results for different access hole geometries in the web were verified experimentally. Degradation of spar performance owing to impact damage or hot/wet environment is being established experimentally.

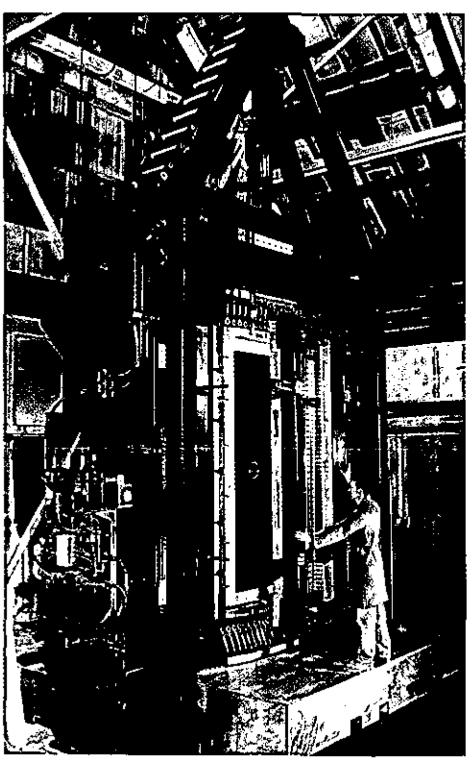
Tests on sub-components representative of composite stabilizer structures are being done to establish a feasible validation and certification process for composite primary structures.

A composite crash tube to absorb a specified amount of energy was developed for a helicopter landing gear under contract to DAF Special Products.

The improvement of the crashworthiness of civil transport aircraft is being studied in the BRITE-EURAM research project AE 2002. A stretchable composite skin concept, the so-called tensor skin, is being developed for the improvement of the water impact behaviour of helicopters. This concept may also improve the bird impact resistance of leading edges of wings and stabilizers.

Damage Tolerance of Materials and Structures

The structural safety associated with the damage tolerance of lap joints in ageing aircraft is addressed in a programme under contract to the RLD, co-sponsored by the US Federal Aviation Administration (FAA). Crack initiation and crack growth at multiple sites in a lap joint under biaxial loading were investigated in specimens representative of Fokker aircraft fuselages. Also, test specimens used by the FAA in uniaxial tests were subjected to biaxial loading. These tests have provided a better understanding of Multiple Site Damage (MSD). The ageing aircraft problem is also studied in a GARTEUR Action Group. Research focused on the analysis and testing of the residual strength of curved stiffened panels was begun. A unique test set-up has been designed and built to test curved, stiffened fuselage panels under biaxial loading and internal pressure.



Test rig for curved fuselage panel structures including frames. Circumferential loads are generated by differential air pressure. A hydraulic system provides longitudinal pressurization loads superimposed by fuselage bending effects

The crack growth rate in metal structures is largely determined by the strain condition near the crack tip. NIVR has granted a contract to investigate this effect in detail. This investigation must lead to models that can be applied in feasible engineering methods for crack growth prediction. Initial results obtained with an extremely fine-meshed model of the crack tip zone revealed a plastic constraint effect on the stress distribution that is very different from current assumptions.

Advanced crack growth models are being implemented in the standard damage tolerance analysis program NASGRO. This activity is performed under contract to the European Space Agency (ESA) as part of a collaboration programme of ESA with the US National Aeronautics and Space Administration (NASA). Also under contract to ESA, the growth of cracks in bolts has been tested and analysed in great detail.

The durability test on the stabilizer and fin of the Fokker 100 aircraft was finalised after testing for 315,000 simulated flights, representing the load experience of 360,000 actual flights. A number of residual strength tests were performed. The investigation on the stabilizer and fin will be concluded with a tear-down inspection.

Evaluation of aluminium alloy/fibre laminates continued under NIVR funding. Two types of laminate have been developed, ARALL and GLARE, both commercially available. Aramid fibres are used in ARALL laminates and glass fibres in GLARE laminates.

Fibre metal laminates have fatigue crack growth properties far superior to monolithic aluminium. However, other mechanical properties, such as fatigue crack initiation, residual strength and blunt notch strength are only slightly better, if at all. This necessitates the development of prediction methods for these properties. As part of an ongoing NIVR programme, NLR completed an experimental investigation into the residual strength of ARALL laminates with cracks at the thickness transition of bonded-on doublers, and an investigation into the blunt notch strength of ARALL. On the basis of the results of a full-scale test on an ARALL3 lower wing skin panel, a research programme was defined, in co-operation with Fokker and the Faculty of Aerospace Engineering of the Delft University of Technology. This programme was finalized in 1994. NLR's contribution to the programme consisted of three items: (i) the experimental determination of the fatigue crack initiation period at open holes under flight simulation loading conditions, (ii) a study into the load bearing capability of doubler run-out structures containing fatigue damage and (iii) the calculation of the residual stress distribution around holes in fibre metal laminates. All three investigations were done for both ARALL and GLARE laminates. NLR contributed to the ARALL 'Effect of Defects' programme by performing compression tests on stiffened ARALL panels with artificial delaminations. The panels were made by Fokker.

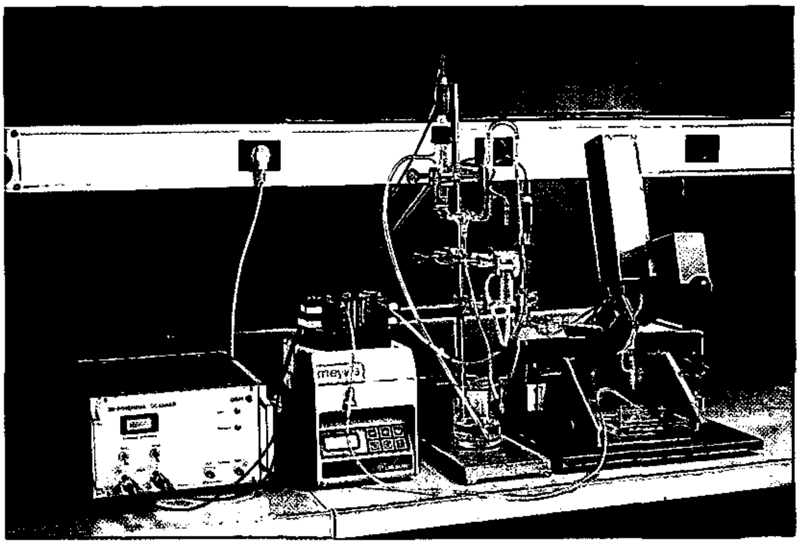
An investigation of the improvement of damage tolerance in hybrid composites was begun in the framework of EUCLID CEPA 3 RTP.1, 'Impact and Damage Tolerance'. NLR's contribution concentrates on the optimization of protective surface layers of composites.

Work funded by the Ministry of Defence under the WEAG TA 31 programme on Life Cycle Concepts for Aero-Engine Components was continued. The main activities were specimen manufacture, which has been completed, and mechanical testing. Most of the Low Cycle Fatigue (LCF) and Compact Tension (CT) fatigue crack growth tests have been completed, as have fracture toughness tests.

Materials Characterization

An investigation of the damage tolerant aluminium-lithium plate alloy 8090-T8171, which was part of the GARTEUR (SM) AG 07 programme, has been completed. Comparison of the mechanical properties, fracture toughness and fatigue crack growth properties of 8090-T8171 with those of other plate alloys, including the industry standard damage tolerant alloy 2024-T351, showed that from an engineering property viewpoint there would appear to be significant advantages in using 8090-T8171.

The compression failure behaviour of composites continues to be studied in the BRITE/EURAM programme ICOMP, with the aim of developing composites with improved compression strength.



Equipment for corrosion testing now includes a scanner that measures the electrostatic potential distribution in a contact-free manner, along both flat and curved surfaces. The method reveals local corrosion at fasteners or heat-affected zones such as welds

An NIVR programme to develop a cure model for a carbon/epoxy prepreg was begun. The model will include the effects of cure time and temperature on the chemical reaction kinetics and the viscosity profile of the resin during the cure. An investigation on another prepreg system concerns the effect of variations in the cure cycle (cure temperature and heating rate) on some physical and mechanical properties.

An NIVR-sponsored GARTEUR programme on cadmium-free protective coatings was begun. This programme includes comparisons of rapid electrochemical test methods and standard corrosion testing, including outdoor exposure.

As were previous years, 1994 was a busy year for service failures. A number of failures of cadmium-plated steel components were caused by hydrogen embrittlement, which is generally due to inadequate baking after plating. Several overtemperature analyses for aircraft gas turbine components were done. This work included developing a method for determining overtemperatures from the coarsening of microstructural precipitates.

An investigation for the RNLAF on the effect of countersink edge corrosion on fatigue crack initiation at fastener holes and on fatigue life was completed. For fairly thick specimens any changes in fatigue origin locations did not affect the fatigue life. However, the fatigue lives of thinner (6.3 mm thick) specimens were significantly affected.

Another investigation for the RNLAF was done to determine the effect of alkaline solvents on the condition of cadmium-plated high strength steel bolts.

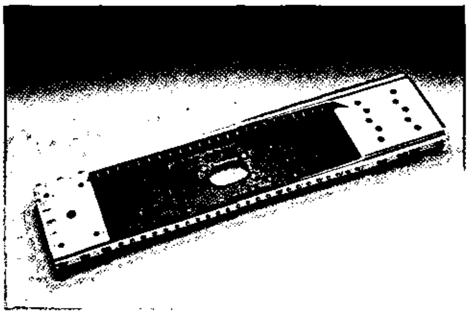
Engine Materials

Plasma-sprayed porous seals that can be directly applied to compressor casings were evaluated for the RNLAF. These seals are intended to replace soldered-in strip seals worn away during service.

An extensive evaluation of the 'Retirement for Cause' lifing procedure was carried out for the RNLAF. This evaluation will continue in 1995.

The burner rig testing of improved NiCoCrAlY and CoNiCrAlY coatings, part of the COST 501 Round II project, was completed. The tests were carried out at 900°C (hot corrosion testing) and 1100°C (oxidation testing).

Facilities and Equipment



Specimen of thin-walled composite C-spar. To minimize cut-outs in skin panels the sparweb contains inspection holes. Testing includes hot/wet conditions

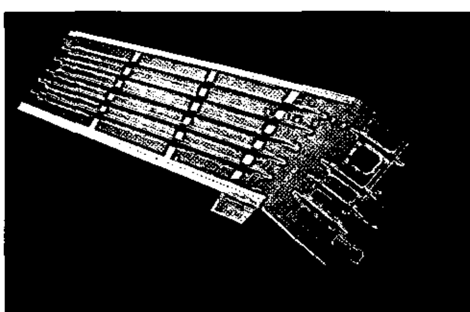
Special test rigs were constructed for validation testing of different composite spar web configurations, including cut-outs and repairs, and of stiffened composite skin panels as parts of a box structure.

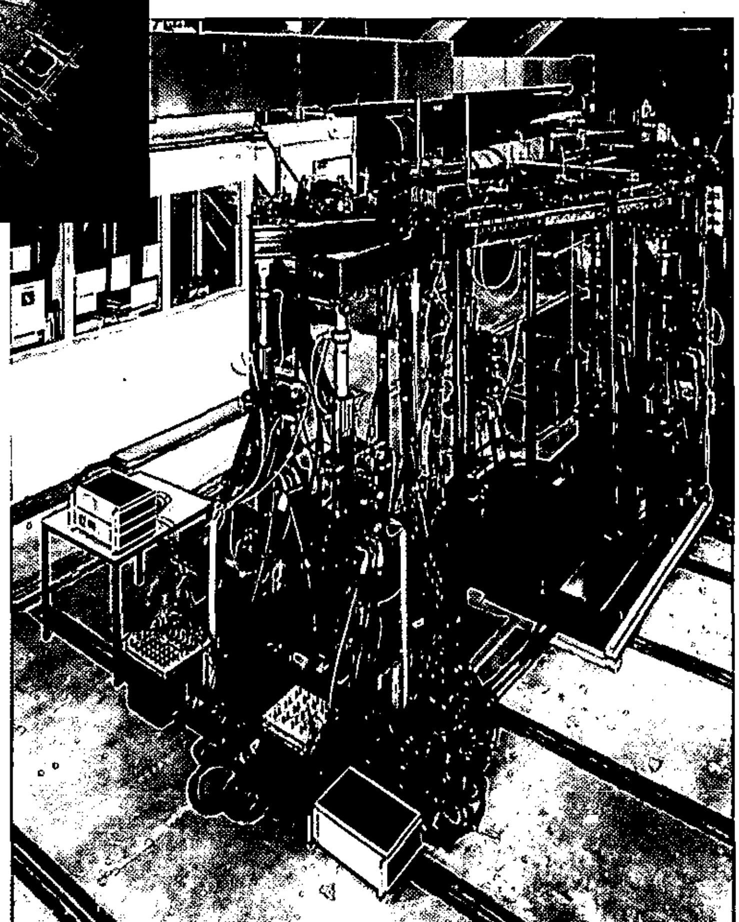
In support of in situ studies of composite failure mechanics, using an electron microscope, a fine measuring grid was generated on a coated specimen surface by means of electron beam lithography.

To enable automated testing in fundamental and applied studies of corrosion, two pieces of electrochemical equipment were installed: a potentiostat/galvanostat and a potential scanner.

The implementation of a system for digital image analysis required considerable effort. Procedures for shape and size analysis of microscope images have become feasible by the development of software upgrades, although deformation analysis by grid measurements still suffers from a lack of speed and accuracy.

Composite manufacturing methods included resin injection moulding, a technique that allows dry weaves to be placed and formed into complicated shapes that cannot easily be obtained by wet-laminating pre-impregnated material. Also, stitching of lay-ups to increase delamination resistance can now be performed on dry stacks, which are subsequently impregnated.





Test set-up for torsion-bending loading of stiffened skin panels (see inset) as part of a design validation and certification process

3.4 Space

Summary

Space activities were executed both in the area of space technology and in that of user support programmes. The technology-oriented activities were focused on thermal control, test and simulation facilities, space robotics, microgravity facilities and remote sensing. The user support activities were concentrated on the demonstration of the Dutch Utilization Centre and the definition of a national data infrastructure for the scientific and operational use of earth observation data. The total volume of contract research and development activities increased slightly. This increase was mainly owed to international customers.

The contribution of NLR in the development of a modular Test and Verification Equipment (TVE) for the European Space Agency (ESA) was continued.

NLR continued its participation in the development of the Italian-Dutch X-ray satellite SAX (Satellite per Astronomia a Raggi X).

A two-phase flow experiment was carried out successfully on board of a Space Shuttle. The experiment was a joint effort with NLR as main contractor. Studies were started on the thermal control of the laser head of the Atmospheric Lidar, on a condenser with a low pressure drop, and on flow meters.

The Baseline Selection Phase for the Slosh Test Orbital Facility (STOF) was continued. STOF is a micro-satellite for the investigation of forces exerted by a liquid in a tank, to be launched from the Space Shuttle.

The study on Modular Payload Systems for microgravity experiments was continued. The study on a COntainer Based Automated Microscope (COBAM) for cell biology in space was also continued. A prototype of a Smart Camera was installed at the European Space Research and Technology Centre (ESTEC).

The Dutch Utilization Centre (DUC) concept was demonstrated during a three-day mission simulation. During the mission a crew of three 'astronauts' executed two experiments in the 'Space Segment', using a Glovebox and the High Performance Capillary Electrophoresis instrument. The DUC infrastructure was also used during the Spacelab IML-2 (International Microgravity Laboratory) mission, to support the Van der Waals-Zeeman laboratory of the University of Amsterdam, in an experiment in the Critical Point Facility. Through DUC, corrective actions could be taken during the flight.

A study was started on the tele-operation of robots, in preparation of the operations of the European Robot Arm (ERA). A proposal was made for the development of the Mission Preparation and Training Equipment for ERA.
The study on automatic execution of microgravity experiments in the Automation and Robotics for Microgravity Applications DEmonstrator (ARMADE) project was continued.

The feasibility study for a Netherlands Earth Observation Network (NEONET) was continued. This study will define a national infrastructure for the Netherlands scientific and operational user community.

NLR was contracted for the processing and photographic restitution of Landsat Thematic Mapper imagery. The images produced will be the basis for photo interpretation work of the CORINE Land Cover programme to assess the land use in five East European countries. NLR participated in a consortium which analyses the constraints and opportunities for cost-effective implementation of earth observation data in developing countries.

A study was performed on the development of a Meteorological Datafusion WorkStation (MDWS), for the extraction of data from meteorological satellites. For the EUCLID RTP 9.1 study 'Technology concept and harmonisation', NLR acts as national representative in an international consortium.

Testing and Simulation

The development of the modular Test and Verification Equipment (TVE) for ESA was continued. This TVE has to support the integration and testing of the various components of the Attitude and Orbit Control System (AOCS) and the verification of the correct functioning of the control loops during various stages of integration, both without and with hardware in the loop. The satellite rotational dynamics and in-orbit environments are simulated in real-time in the host computer of the TVE. The main parts of the TVE are a specially designed Front End and a standard UNIX workstation running the test software. The design of the Front End hardware and software has been completed, and the integration and testing of the hardware was started. The test software has been designed as an application of PROSIM, an application-independent tool developed for the National Simulation Facility (NSF). The system is targeted for testing the AOCS of the European X-ray Multi-Mirror Mission (XMM). The project is carried out in co-operation with FSS and with Adelsy of Switzerland, and partly funded by NIVR.

Two-Phase Flow

The Two-Phase Experiment (TPX), prepared in the framework of ESA's In-orbit Technology Demonstration Programme, was launched on board of NASA's Space Shuttle Discovery on 4 February 1994. The experiment was carried out in a so-called Get Away Special container, mounted to the Shuttle Cargo Bay. After a start command given by the Shuttle crew, the experiment ran autonomously for 40 hours until the battery was exhausted. By then 90% of the on-board computer was filled with flight data of the TPX heat transport loop. The fluid circuit included capillary evaporators and an accumulator developed by SABCA, vapour quality sensors developed by NLR and Bradford Engineering (BE), a condenser developed by FSS, a three-way valve developed by BE and data acquisition electronics developed by SPE. The main tasks of NLR were: thermal modelling, mission planning, providing control electronics and software, performing system tests and project management. Analysis of the flight data has shown that the experiment was successful, although the in-orbit thermal environment of the experiment differed from the ideal thermal radiation environment, due to the position within the cargo bay. The project was carried out under contract to ESA and was partly funded by NIVR.

In a team with prime contractor BAe, BE and the Russian firm Lavochkin, NLR participates in the development of a breadboard model of the thermal control system for the laser head of the Atmospheric Lidar ATLID. The temperature of the laser head is kept at 5 ± 1 degrees using a capillary evaporator and a two-phase thermal control system. NLR is responsible for the thermal modelling and the thermal control analysis.

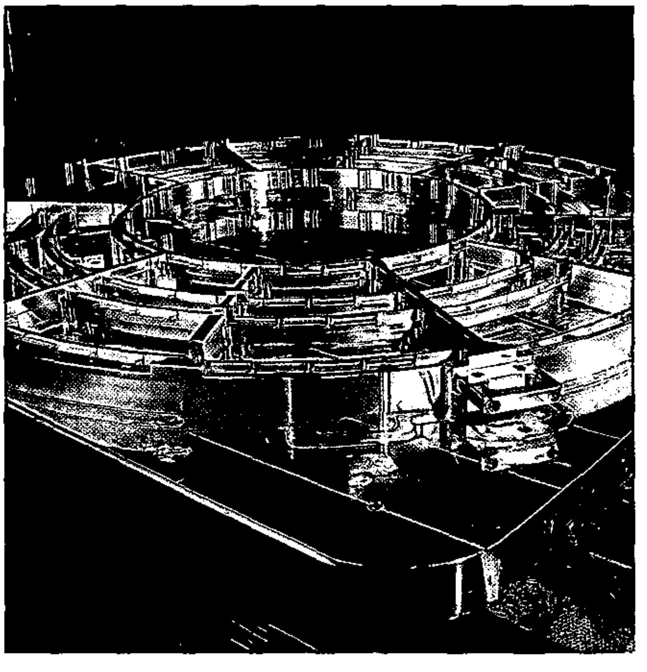
Under contract to ESA, NLR started a pre-qualification study on the development of a condenser with a low pressure drop, in co-operation with DASA-ERNO and the Swiss firm BE-SPPS. After a literature survey of available condenser concepts and means to improve condenser efficiency, a preferable concept will be proposed. Sample condensers will be made and tested. In this study NLR is responsible for project management, thermo-hydraulic computations, tests and evaluation.

Under contract to ESA, NLR has started a study on liquid flow meters for use in space. A comparison will be made of available flow meters for use on earth, which after minor modifications may be used in thermal control systems and propulsion systems in space. The resulting concept will be manufactured and tested. The study is performed in co-operation with Bradford Engineering and SABCA. NLR will be responsible for project management, concept study and concept selection, modifications development, test plan and test execution.

Under contract to DASA-Dornier, NLR participates in a concept study for a flexible thermal link, to be used in two-phase thermal control systems of moving structures.

Grating Element Support Structure

For the Space Research Organization Netherlands (SRON), an engineering and qualification model is made of the Grating Element Support Structure (GESS) for the AXAF (Advanced X-ray Astronomy Facility) Telescope. GESS is a complicated mechanical structure for mounting individual modules in four circles behind mirror shells of the telescope. Because the structure is lightweight, it requires special mechanical support equipment during the production phase. As the project may be extended with a second or even a third structure, special attention is given to the reproducibility of the work.



Engineering and qualification model of the Grating Element Support Structure for the Advanced X-ray Astronomy Facility telescope

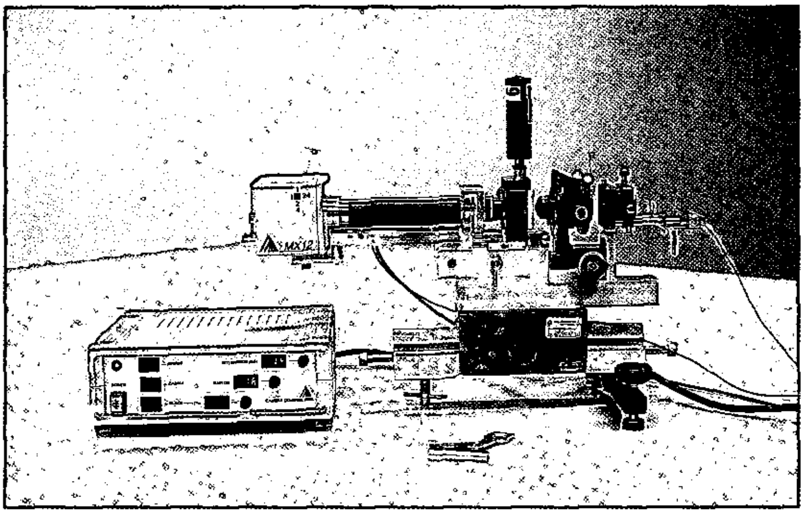
Microgravity Technology/Payloads

The Baseline Selection Phase for the Slosh Test Orbital Facility (STOF) project, carried out under contract to ESA, was continued with a Preliminary Design Phase. STOF is a micro-satellite, to be launched from the Space Shuttle, for the investigation of forces exerted upon a manoeuvring spacecraft by a liquid in a partially filled tank. An Investigators Working Group meeting was organized in San Antonio, USA, which resulted in the participation of NASA in the project. Studies were made on the configuration of the tank, the determination of the fluid surface, and on suitable accelerometers and gyroscopes, among other subjects. The Sloshsat Motion Simulator was developed. The project is executed in co-operation with FSS.

Under contract to Alenia, the study on Modular Payload Systems for microgravity experiments was continued with a Phase A1 study on a Single Rack module for the Fluid Science Laboratory proposed for Columbus.

NLR and FSS continued the study on a COntainer Based Automated Microscope (COBAM) for ESA, to be used for cell-biology studies in space. Various concepts were developed, two of which will be demonstrated in a breadboard set-up.

The concept for a smart telescience camera was tested and provided with remote control of all image acquisition parameters. A prototype was installed at ESTEC.



Prototype smart telescience camera

Telescience and Utilisation

NLR has continued co-ordinating the Dutch activities in the development of a Dutch Utilization Centre (DUC). Partners in the DUC consortium are NLR, FSS, BSO, Bradford Engineering, Comprimo and ITC. The user support concept was demonstrated during the Columbus Attached Pressurized Module mission simulation. In this simulation, a ground segment and a space segment were realized at NLR, together with the necessary communication equipment. During a three-day 'mission' a crew of three 'astronauts' executed two representative experiments, supported by the Primary Investigators and staff in the ground segment.

The second key activity was the operational and technical support to a team of the Van der Waals-Zeeman laboratory, during the Spacelab IML-2 mission in July 1994. This laboratory executed an experiment in the Critical Point Facility (CPF) of Spacelab. A communication link was set up between the Remote CPF Science Team at NLR-Amsterdam, the Primary Investigator at the Science Team in Huntsville, USA, and Spacelab. Results of the experiment could be studied in real-time by the remote science team, enabling adjustments to be made to the test programme in space. Prior to the Spacelab flight the whole team participated in training and mission simulations, organized by NASA.

Both DUC activities were executed under contract to ESA and NIVR and were partly funded by NLR's own research programme (see also Chapter 4: Capita Selecta).

Under contract to BSO and ESA, NLR contributes to the development of the Advanced Crew Terminal, a dedicated Personal Computer, and to the demonstration and evaluation in a realistic environment.

Satellite Subsystems

NLR continued its participation in the development of the Italian-Dutch X-ray satellite SAX under contract to FSS and NIVR. FSS is subcontractor for the Attitude and Orbit Control (AOCS) of this satellite. The Basic and Extended Attitude Control modules were delivered to Alenia of Italy. Updated versions, satisfying requirements changes and incorporating refinements were developed and tested (see also Chapter 3.5, Informatics).

Under contract to NIVR a study is being made of the definition of a future European Military Satellite Communication system, Eumilsatcom.

Space Robotics

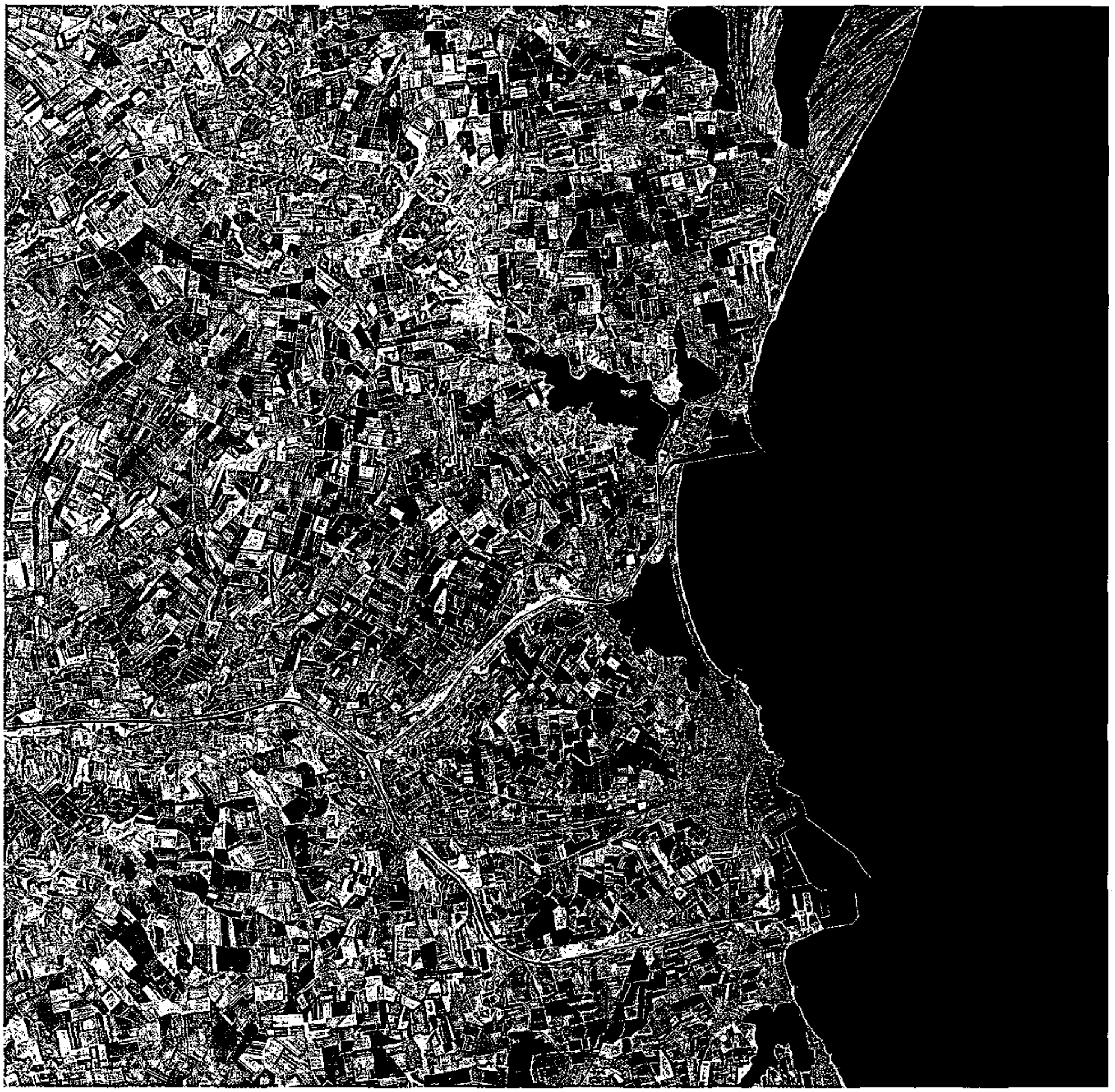
Under contract to NIVR and in co-operation with FSS, a study has been started on the tele-operation of space robots. The main purpose of the study is to derive integrated and coherent concepts for mission preparation, astronaut training, ground processing and flight operations of the European Robot Arm (ERA), including concepts for the necessary tools and facilities. Details of the study concerned the concepts of Exception Handling by the on-board computer, the Camera and Lighting Unit, simulation models and the ERA operations. At the end of the year a proposal was made for the development of the Mission Preparation and Training Equipment, as part of the overall ERA proposal to ESA.

Under contract to NIVR, a study is being performed on an Automation and Robotics for Microgravity Applications DEmonstrator (ARMADE). The purpose of this study is the development and demonstration of technologies for automation and robotics, to be used in microgravity facilities. For ESA, ARMADE will be incorporated in the Columbus Automation Testbed. This testbed will be provided with a realistic payload model, to demonstrate the ARMADE concept and to enable tele-operation of an automated instrument to be compared with with crew-operated implementation. The project is performed in co-operation with FSS, Comprimo, SPE and ICT.

Remote Sensing

The first phase of the feasibility study for a Netherlands Earth Observation Network (NEONET) was completed. The second phase, which is carried out in co-operation with the Royal Netherlands Meteorological Institute (KNMI) and the Survey Department of the Ministry of Transport, under contract to the Netherlands Remote Sensing Board (BCRS) and SRON, has started. It comprises the realization of a prototype earth observation meta-information system on Internet. In addition, prototype data infrastructures related to atmospheric chemistry and water quality management will be designed. NEONET will be part of an international network, giving Dutch users access to a wide range of earth observation data products and allowing Dutch service providers to make their products and services available to a large international user community.

NLR was contracted by the Commission of the European Communities (CEC) to perform geometric corrections to Landsat Thematic Mapper satellite images of five East-European countries: Poland, the Czech Republic, the Slovak Republic, Rumania and Bulgaria. In 1994 a Task Force of the European Environment Agency of the European Union extended its activities in building up the European-wide CORINE database. This has to provide geomorphological information in order to improve knowledge and enable policy making in environmental issues on a European scale. A total of 800 map sheets were produced, for which 70 Thematic Mapper scenes were processed.



Remote sensing image of a coastal area of Romenia, processed for the European Union

For the CEC, NLR participated in a consortium to analyse the constraints and opportunities for cost-effective implementation of earth observation data in developing countries. Based on the experience it gained in projects for the UN Food and Agriculture Organization, NLR carried out an information analysis in the Philippines and in Indonesia, of which the results highlight a number of interesting opportunities. One such opportunity is closely related to work that has been carried out for NIVR on an end-to-end mission concept for forest monitoring. This mission concept consists of several items of which the space segment part was studied in 1994. Elements of the space segment include P-band SAR instrumentation and small satellites. A pre-feasibility study into these two items was carried out, in which RESPAS user requirements were taken as a baseline.

In preparation of future EUMETSAT projects a pilot- study is performed on the development of a Meteorological Datafusion WorkStation, a robust operational system for the extraction of data from the METEOSAT and NOAA meteorological satellites. The required products will be obtained by means of recipes that describe the necessary processing routines. The execution of the recipes will be controlled by a scheduler. Data compression will be performed for data transfer and storage. The study is performed under contract to NIVR.

The work on EUCLID RTP 9.1 'Technology concepts and harmonisation', which is part of CEPA 9 (Advanced Technologies for Surveyance Satellites) was continued. For this study, NLR acts as national representative. The work on a preliminary design of an optical sensor was finished. Simulations were performed to study the atmospheric influences on the optical sensor. The study on cloud statistics and cloud information was started. The results will be used for the optimisation of the data take selection. Under contracts to BCRS and the West European Union (WEU), flights were performed with NLR's Metro II research aircraft fitted with the optical sensor CAESAR (CCD Airborne Experimental Scanner for Applications in Remote Sensing) and the microwave sensor PHARS (Phased Array Synthetic Aperture Radar).

NLR continued acting as National Point of Contact (NPOC) for the distribution of Landsat, ERS-1 and NOAA remote sensing data for Eurimage, and, on behalf of SPOT-Image, for the distribution of SPOT data within the Netherlands.

Facilities and Equipment

The two-phase ammonia loop has been used for the testing of two-phase components, i.e. the quality sensor and various evaporators. The loop has been prepared for experiments on condensers.

The Test and Simulation Assembly (TSA) has been used to support the integration and testing of the Application Software of the SAX Attitude Control Computer in a real-time simulation environment. Modules of the new generation Front End for the TSA were developed and tested.

The robot system installed in the Space Division Robotics Laboratory has been integrated with a Columbus double instrument rack. A force sensor was installed. The system is being integrated with the CAE program RobCad.

In the context of the National Dutch User Support Organisation, a PC-based hardware/software and communications infrastructure has been defined and implemented. The equipment has been used during the DAMS project and during the Spacelab IML-2 mission.

The RESEDA-system has been used for CORINE, among other projects. The in-house developed user interface FIRST has proved to be very useful.

3.5 Informatics

Summary

In the area of robot control, NLR contributed to the determination of the requirements and to the design of the control algorithms for the European Robot Arm ERA. A study into the possibilities of the development of a real-time dynamics simulation model for ERA based on the non-real-time ESF (ERA Simulation Facility) has been performed. The development of the real-time simulator was started.

The ISNaS information system for flow calculations based on the Navier-Stokes equations supports process control in the development and application of Computational Fluid Dynamics (CFD) software. The toolkit of ISNaS was extended.

The support of process control in the development and application of software other than for CFD appeared to require similar tools to those available in ISNaS. It appeared possible to generate a Software Platform for a Network Environment (SPINE) by which the network is presented to the user as one single virtual computer.

The efficiency of the multiblock flow solver Soleqs for compressible viscous flow was improved by applying the multigrid technique. In a collaboration, NLR has started the development of efficient parallel linear solvers for Poisson equations, to be used on a distributed memory parallel computer. For Large Eddy Simulations on non-uniform tensor grids, new filters are examined that commute with differentiation up to any given order of the filter width.

A mathematical model for determining the probability of a (near) collision between two aircraft approaching parallel runways has been developed.

NLR participates in projects in the areas of artificial intelligence methods for planning and tasking, and in the modelling of the command and control process.

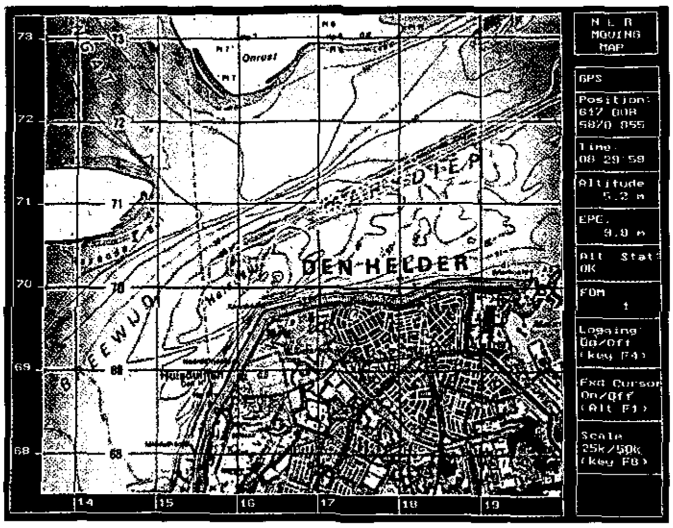
The MSS/C production systems were subjected to a field evaluation by the European participating air forces. An upgrade for the current NLR map scanning system was defined. The feasibility of a mission preparation system for transport helicopters was investigated. A solution based on re-use of existing components of MSS/C was preferred by the RNLAF.

NLR has designed a system to support the assessing of skills of students in procedural approach training, with assistance from Air Traffic Control instructors.

NLR provided information on safety and certification aspects of software to the Netherlands Department of Civil Aviation.

NLR provided the specifications of the User Requirements and the description of a generic Crew Assistant.

In the field of avionics, NLR undertook major research efforts in the areas of modular avionics and airborne electronics, a phased-array airborne Synthetic Aperture Radar, an avionics suite for the F-16 Mid Life Update programme and the NH90 programme. A moving map based on GPS in a helicopter, and a controlled reception pattern antenna for GPS were demonstrated.



Moving map display showing the city of Den Helder and Marsdiep

NLR was the main contractor for the supply of the wind tunnel data acquisition system for the European Transonic Windtunnel (ETW). This system, and an upgrade of the data acquisition system of the German Dutch Wind Tunnel (DNW) were completed.

A major contribution was given to the electronic subsystem of the Get Away Special container for the Two Phase flow experiment, launched on the Space Shuttle.

NLR's Infrastructure for Computer Aided Engineering of Electronics was extended and upgraded.

Plans were established and the acquisition process completed for a major upgrade of NLR's EMC laboratory.

The use of the computer facilities, in particular the servers, showed considerable growth. The hardware of NLR's computer network includes an NEC SX-3 supercomputer, several UNIX servers and a non-UNIX mainframe. A communication network based on TCP/IP protocols connects these facilities with workstations, X-terminals, PCs and other terminal equipment all over NLR. Wind tunnels, simulators and other facilities are also connected to the network. A design for a major upgrade of the computer network was completed.

Robotics

NLR contributed to the determination of the requirements and to the design of the control algorithms for the European Robot Arm (ERA), which is currently being developed by Fokker Space & Systems (FSS). These algorithms are to be implemented in the ERA Control Computer as part of the on-board software. Exteroceptive control concepts and algorithms for ERA proximity control and ERA compliant motion control have been evaluated.

Research with respect to force/position control of constrained manipulators with flexible joints continued. Simulation programs were developed to evaluate the results.

In co-operation with FSS, an evaluation has been made of the conceptual design of the Man-Machine Interface for extra-vehicular activities with the European Robot Arm (ERA). Also, the functional design of the Exception Handling system, or Failure Detection, Isolation and Recovery system, for the ERA has been established. A study on the applicability of continuity checks and consistency checks for failure detection has been performed. With these checks, serious, acute failures have to be detected in space, whereas degraded performance of the system has to be detected on the ground.

A study into the possibilities of the development of a real-time dynamics simulation model for ERA based on the non-real-time ERA simulator ESF (ERA Simulation Facility) has been performed. Based on the outcome of the study the development of the real-time simulator has started.

NLR participated in the User's Committee of the Stichting Technische Wetenschappen for the project The Role of Flexibility in the Manual Control of a Space Manipulator.

Computational Fluid Dynamics Environment

In preceding years, the ISNaS information system for flow calculations based on the Navier-Stokes equations was developed for the support of process control in development and application of Computational Fluid Dynamics (CFD) according to the ISO-9001 standard. The ISNaS toolkit GENUINE for automatic generation of user interfaces was extended with a facility for the automatic generation of user interfaces that support graphics-based input and output. Also for ISNaS, a UNIX-based data file management system was designed and realized. This system supports functional integration of computer networks into one virtual computer as far as file handling is concerned.

ISNaS proved to be applicable for cost-effective enhancement of existing CFD software in the case of the Japanese α-FLOW system for flow simulation. Preparations to use ISNaS for this on a large scale were made.

In collaboration with NEC, a vizualization-based input facility has been developed, with the help of GENUINE, for a real time vizualization system for CFD. The vizualization-based input facility supports the input preparation for the flow simulation and enables computational steering of the simulation process.

Software Platform in a Network Environment

To support process control in the development and application of software in other areas than CFD, similar tools appeared to be required to those available in ISNaS. Tools were therefore abstracted from ISNaS, generating a Software Platform for a Network Environment (SPINE) by which the network is presented to the user as one single virtual computer. SPINE contains a software system (Toolmaster) that enables simple centralised maintenance of information about the location of all software on the various servers. SPINE was used to integrate software development tools in use at NLR, and implemented on various servers in the network, into the Integrated NLR Software Engineering Toolkit.

Computer Aided Control Engineering Environment

The first version of the ISMuS working environment for Computer-Aided Control Engineering (CACE) has been realized, using SPINE as a framework. ISMuS supports modelling of dynamical systems and designing of controllers for dynamical systems as well as performing simulation studies for the evaluation of controlled dynamical systems. These functions have been realized by functional integration of three commercially available software packages (MATLAB, PVWAVE, MAPLE) and the simulation package PROSIM developed by NLR. PROSIM is the Programme and Real-time Operations SIMulation support tool derived from the simulation program of the National Simulation Facility (NSF). PROSIM has been placed under configuration control in ISMuS and has been made available to other projects at NLR.

NLR contributed to the development of the EUROSIM Mk 0.1 facility, an engineering simulator under development at Fokker Space & Systems. NLR is responsible for the Software User Manual and for the independent system test, including the system test plan and the demonstration model.

Mathematical and Computational Aspects of Flow Solvers

In the ENSOLV flow solver for the numerical simulation of three-dimensional viscous flow around complete aircraft configurations based on the thin-layer Reynolds-averaged Navier-Stokes equations, the Johnson-King turbulence model was implemented and tested in order to improve the results of the flow solver for boundary-layers with shock-induced separation. The numerical accuracy in boundary layers was improved.

The efficiency of the multiblock flow solver Soleqs has been improved by applying the multigrid technique. Simulation of steady flow about a clean wing has been designed and implemented, and reached the test phase. The clean-wing application was used as a benchmark for shared-memory computer architectures. A single-airfoil application and a multi-element application were used as benchmarks for distributed memory architectures. Simulation of time-dependent flows has been added as a feature of Soleqs. This feature was used to investigate the level of time-accuracy for efficient time-integration methods. The feature has been tested for simple configurations.

In collaboration with NEC, NLR has started the development of efficient parallel linear solvers for Poisson equations, to be used on the distributed memory parallel Cenju-3 computer. Parallelization is based on decomposition of the computational domain into cube-like subdomains. These subdomains are distributed among the processors. An iterative solution method for the linear equations has been chosen. In order to accelerate the convergence of the solution process, a two-step preconditioning technique has been developed. First, the linear subsystems of equations in each subdomain are solved by applying a fast method (a combination of an iterative method and multigrid). Then, a coarse-grid operator is applied on the complete computational domain to smoothen the various local solutions on the subdomains in order to further improve convergence. Communication is by message passing.

Research has been performed for the correct modelling of Large Eddy Simulations. For Large Eddy Simulations on non-uniform tensor grids new filters are examined that commute with differentiation up to any given order of the filter width. Using these filters, the modelling error which arises form the fact that filtering and differentiation do not in general commute, can be neglected.

Earth Observation

For EUMETSAT, data compression methods have been investigated for use under the operational conditions of the future Meteosat Second Generation program to enable the transmission of large quantities of data to the end users.

A prototype earth observation data and information service has been realized based on the multimedia tools Mosaic/Netscape and HTTP (HyperText Transfer Protocol) and Internet. As a spin-off, a preliminary version of the WWW (World Wide Web) Home Page of NLR has been published.

NLR participated as an invited expert in a workshop on satellite observations for cloud detection and characterisation, organized by the Joint Research Centre.

Safety

In order to increase the capacity of Amsterdam Airport Schiphol, the simultaneous use of the parallel runways 19R and 01R for landing is being considered. A mathematical model has been developed and implemented for determining the probability of a (near) collision between two aircraft approaching the runways 19R and 01R simultaneously and independently.

A new accident location model has been developed for regional airports. This model consists of a two-dimensional probability distribution that is used to determine the probability of an accident at a specific location. With the available accident data, first the form of the model has been determined, next parameters have been estimated, and then the model has been qualified. Finally, a sensitivity analysis has been performed.

A literature survey has been made for a second-order statistical wind model. This model is required for describing the influence of wind on the separation of landing aircraft on converging runways.

NLR participated in two meetings of working group A of the ICAO RGCS panel on aircraft separation in an Automatic Dependent Surveillance (ADS) environment and Airspace Planning Methodology. As input for the first meeting, a working paper was issued on lateral separation between parallel routes in an ADS environment.

Investigations into the applicability of Human Reliability techniques concentrated on the question to what extent aircraft dynamics has to be taken into account in the analysis techniques. In a simulation environment, pilot behaviour will be modelled as a function of aircraft dynamics.

An invited speaker of NLR participated in the workshop 'Human reliability Models: Theoretical and Practical Challenges' in Sweden.

NLR participated in a Committee on Human Reliability, along with the Delft University of Technology, KEMA, Marine Safety Rotterdam BV, the Ministry of Public Health, Regional Development and the Environment, the Ministry of Social Affairs and Employment and the nuclear power plant of Borssele. Two workshops were attended.

Validation of new Air Traffic Management systems is recognized as a very important element in the introduction of these systems. Various definitions of validation are used in practice. These definitions, and the approaches, methods and techniques applied have been summarized and evaluated as a preparation for forthcoming European projects.

Environment

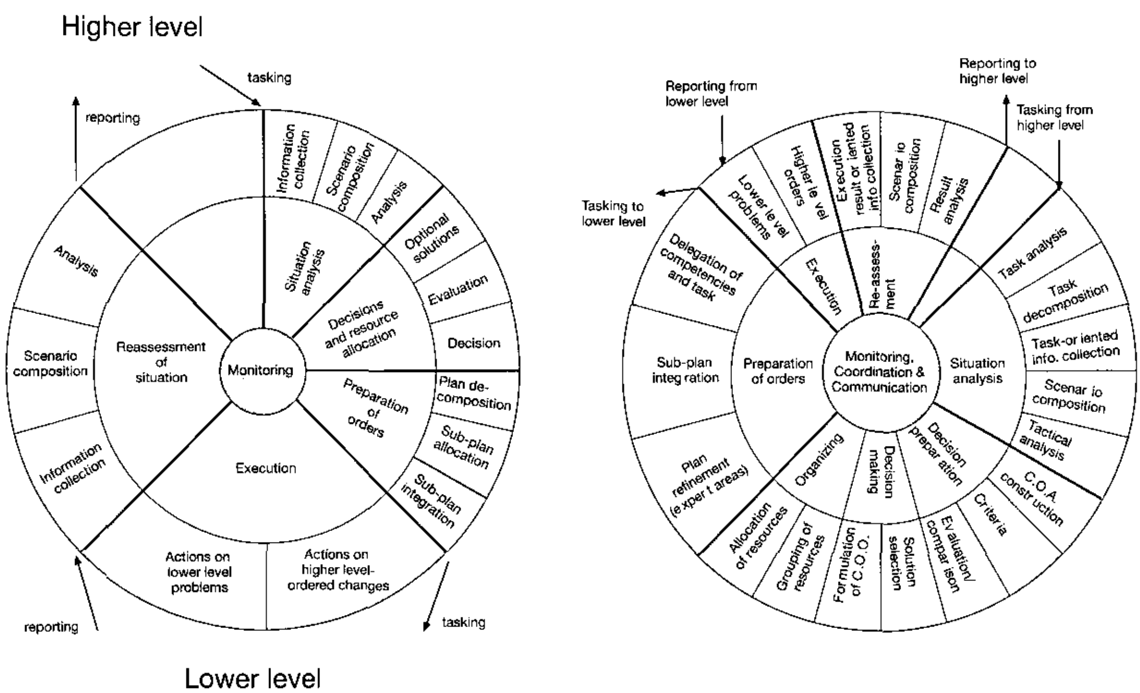
Under contract to the Aeronautical Inspection Directorate of the Directorate General of Civil Aviation, a start has been made with the development of a method for noise load prediction. With the known flight trajectories of the approaching and departing aircraft, the effective noise on the ground can be calculated. Based on the calculated noise load after a few months, this model will enable predictions to be made of the noise load over a year, taking into account effects of seasons. Research on the reliability, accuracy and sensitivity of the method for calculating noise load was defined.

Command, Control, Communication and Intelligence Systems

NLR has continued work in the EUCLID RTP 6.1 'Advanced Information Processing for a Command and Control workstation'. The goal of this programme, carried out by 18 participants from seven countries, is to accelerate the application of artificial intelligence (AI) and advanced software engineering methods, such as agent-based and object-oriented approaches, in Command, Control, Communications and Intelligence (C^3I) systems.

NLR is participating in the area of artificial intelligence methods for planning and tasking, and in the modelling of the command and control process. The basis for the latter activity was laid in the period between 1975 and 1985, in which the Royal Netherlands Air Force (RNLAF) and NLR co-operated in the initial modelling of the command and control process and in the development of operational systems and prototypes for operations support, intelligence processing and mission preparation. The model was further detailed in an IEPG Expert Group on time-critical aspects in command and control, to better reflect the applicability to any of the levels in the command and control process, and to any of the land, naval and air domains. The resulting generic model for command and control was used as a basis for support in the planning and decision making process in the Mission Support System/CAMPAL (MSS/C). The iteration and interaction between modelling and development has proved to be beneficial to both these activities.

In the context of EUCLID RTP 6.1, the generic model for command and control was further refined to serve as a basis for the understanding of C^3I procedures and decision making in the nations participating in the programme. The model has been validated by military experts in the land, naval and air domain in the seven participating countries.

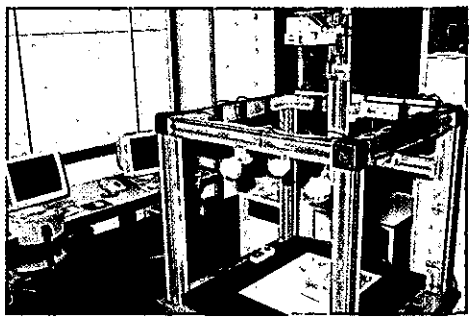


Models of Command and Control, reflecting multiple levels of air, land and naval operations: The NLR/RNLAF model for IEPG and MSS/C (above, left) and the Euclid RTP 6.1 model (above, right)

In the definition of test scenarios for validating the new Artificial Intelligence (AI) and software engineering methods in the C^3I workstation, NLR has defined elements in the air domain as part of a variety of new scenarios derived from changing military tasks and operating environments. With respect to advanced information processing to support planning and tasking, NLR focuses on real-time execution and updating of AI planning, and reasoning with uncertain and incomplete information. State-of-the-art planning and control methods that fulfil the most important military planning and tasking requirements were selected.

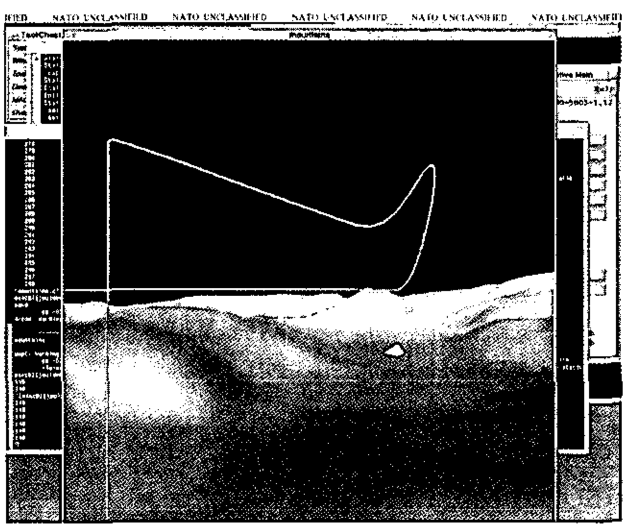
Mission Support System/CAMPAL (MSS/C)

The MSS/C production systems were given a field evaluation by the European Participating Air Forces (EPAF) in a period of Operational Test and Evaluation. Preceding this operational test, air force staff were trained in the use of the software and maintenance of the hardware. Requested technical assistance was given to air forces in the preparation of the hardware facilities and data sets to be used during the tests. Test results were analysed and remaining problems were solved. In discussions with the main contractor Lockheed Fort Worth and the air forces, requirements were updated to reflect the changing tasks of the EPAF. The requirements were subsequently analysed and some of them were tagged for future work. The feasibility of implementation of critical requirements was investigated, resulting in proposals for system upgrades. One of the upgrade areas is the improvement of the resolution of the electronic maps. An upgrade for the current NLR map scanning system was defined.



Map scanning station

Upon request of the RNLAF, the feasibility of a mission preparation system for transport helicopters was investigated. The RNLAF selected a solution based on re-use of existing software components of MSS/C. In anticipation of future requirements, graphics support for mission rehearsal was prototyped, as an add-on to the current MSS/C system.



Graphics support for mission rehearsal showing the flight path and attitude of an F-16 aircraft over 3-D terrain

Multisensor Data Fusion

Two studies were carried out into the feasibility of fusing imperfect information from various sensors, using artificial intelligence methods. The first study was carried out for the West European Union (WEU) in the context of a military Earth Observation system for verification, crisis monitoring, and environmental monitoring. NLR was responsible for the data fusion study, under contract to DASA. Subcontractors to NLR were British Aerospace for the WEU ground infrastructure, and the British National Remote Sensing Centre for some of the remote sensing aspects related to specific types of sensors.
Under contract to the Royal Netherlands Navy, an investigation was carried out in the same technology field, focused on real-time artificial intelligence methods.

The second phase of the TA-10 project on advanced information processing for multisensor data fusion has started. In this project, NLR co-operates with

Thomson-CSF, Matra-CAP Systèmes, Signaal, Inter Access and Physics and Electronics Laboratory TNO to develop a near-real-time multisensor data fusion demonstrator, leading to applications of these technologies in military production projects in the 2000–2010 time frame.

Multi-radar Aircraft Tracking System for Eurocontrol

Work on the development of the core capability of an advanced radar data processing system for Eurocontrol was continued. The goal of the ATC Radar Tracker and Server (ARTAS) system is to provide a basis for a harmonized and integrated ATC system in a large and expandable geographical area. Under contract to Thomson-CSF, NLR is responsible for the tracker subsystem, which will process multiple radar surveillance data. The production of the operational version is based on previous research by NLR on advanced probabilistic tracking methods that enable all available radar information to be used, have the capability to discern certain types of aircraft manoeuvres and are robust with respect to track interrupts, track jumps and false radar information. A release of the Ada version of the prototype tracker was made available. Additional functions were designed and coded, and testing has started. A pre-release of a tracker production version was made available to Thomson CSF, to be integrated into the ARTAS system for demonstration purposes. The tools for analysis of tracker requests were adapted to serve the integration testing phase.

Information System for Schiphol Runway Use

For Air Traffic Control The Netherlands (LVB), NLR has designed and developed software for establishing preferable runways at Amsterdam Airport Schiphol for arriving and departing aircraft. Depending on runway availability and meteorological conditions, the software determines the most preferred runway combination at any particular time. It uses models in which crosswinds and tailwinds are important parameters. Output of the system are daily reports on preferable theoretical runway use per quarter of the day. These can then be compared with recorded actual runway use. In this way, the implicit knowledge currently used by air traffic controllers in assigning runways can be analysed. LVB is aiming at the verification of the correctness of actual runway allocations. A prototype system was developed for demonstration purposes. This system simulates a fast time environment by showing preferred runway combinations.

Computer-based Training

In co-operation with Netherlands Air Traffic Control instructors, NLR designed a system to support them in assessing skills of students in procedural approach training. This PASA (Procedural Approach Student Achievement) system consists of software that simulates the Terminal Manoeuvring Area and records all actions of student controllers during a Procedural Approach Training (PAT) exercise. An inventory of information to be recorded was made. The results were included in a preliminary System/Segment Specification. In a preliminary System/Segment Design Document, a functional analysis was made of the PASA system, and it was described how the actions of students can be registered. Furthermore, preliminary versions of the Software Requirement Specification and Interface Requirements Specification were delivered. A prototype to show the applicability of electronic flight strips was developed.

Software Certification

For the Netherlands Department of Civil Aviation, NLR concluded a comparative study of current standards used by industry for software engineering, as a partial fulfilment of software safety requirements and guidelines for certification. NLR provided advice to the Royal Netherlands Air Force with respect to software certification issues in platforms purchased by the RNLAF.

On-board Decision Support

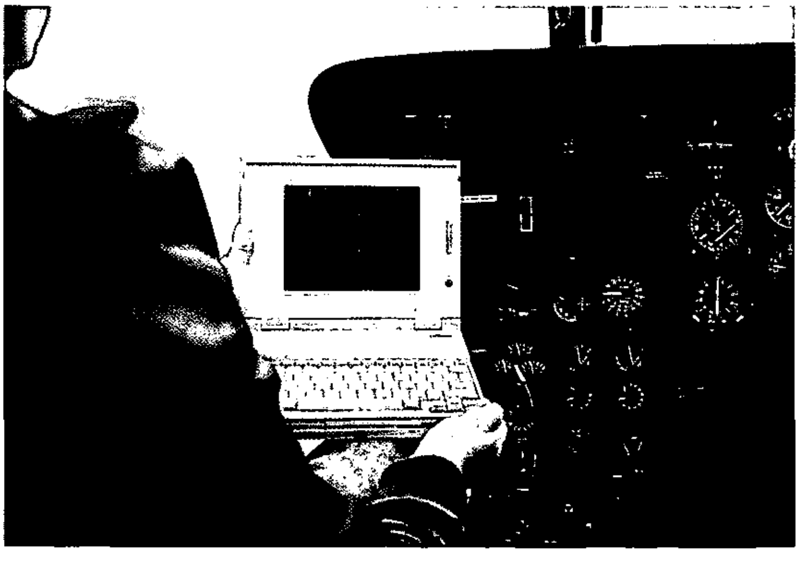
NLR is Single Lead Industrial Entity for the EUCLID Research and Technology Project 6.5 'Crew Assistant' being carried out. Besides NLR, the consortium consists of DASA of Germany, Alenia of Italy and Boğaziçi University of Turkey. In this project, the initial phase of a 'Crew Assistant' demonstration programme, the first set-up of a 'Crew Assistant' architecture applicable to many platforms is defined. The project includes delivering the following products: (1) the specifications of the user requirements, (2) the description of a generic 'Crew Assistant', (3) the results of a survey of Advanced Information Processing technology suitable for the Crew Assistant and (4) the System/Segment Specifications for a Crew Assistant demonstration. The project is on schedule, and the first steps to initialize the follow-on project, to realize the functional and mission realistic demonstrations, have been made.

Electronic Systems for Airborne Applications

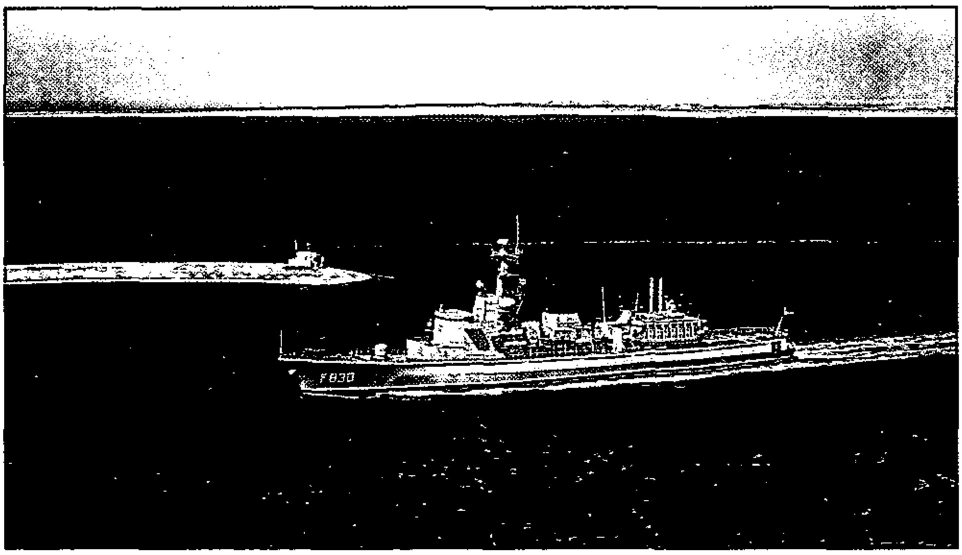
NLR is heavily involved in EUCLID programme CEPA 4, RTP 4.1 'Modular Avionics Harmonization Study'. This study, headed by DASA, is a collaborative study of six European nations in which a total of 27 companies participate. NLR's major contributions are in the field of data buses, networking, digital sensor data processing and cooling.

The research and development in the area of electronic moving maps for navigation purposes was concluded by test flights in a helicopter. The demonstration system is composed of a Precision Light Weight Military GPS Receiver (PLGR) and a notebook personal computer containing a digital map data base and a colour display. The digital map data can be derived either by digitizing standard maps or from satellite data covering remote areas of which no adequate maps exist.

The adaptive, controlled GPS-antenna developed under contract to the Royal Dutch Navy, was tested on board of HMS frigate 'Tjerk Hiddes'. The antenna was designed to cope with the severe electromagnetic environment of a military battle ship, while maintaining its abilities for reception of satellite signals in the presence of intentionally jamming. The tests proved that the design meets expectations.



Test of Moving Map in BO 105C helicopter of the national police (Rijkspolitie)



HMS frigate 'Tjerk Hiddes' with adaptive controlled GPS antenna

Data Link Processor Unit (DLPU)

The upgrade under contract to Eurocontrol of the twelve Data Link Processor Units (DLPUs) for new software was completed. All twelve units obtained their airworthiness certificate. Meanwhile, work for the adaptation of the DLPUs to operate with the so-called dual transponder has begun under a new contract obtained from Eurocontrol.

F-16 Mid Life Update

Within the framework of the co-development programme for the F-16 Mid Life Update (MLU), five members of the NLR staff were detached at Lockheed Fort Worth Company (LFWC) in Texas, USA, under contract to LFWC. Four of them were working with the Avionics System Requirements and Verification Team of the LFWC's F-16 MLU design team, the fifth one participates in the activities of the Systems Integration Laboratory.

Also under contract to LFWC, NLR is preparing co-development activities, on its own premises, regarding pilot vehicle interface research, cockpit lighting/ night vision goggles compatibility and full-mission MLU cockpit evaluation. To this end the National Flight Simulator (NSF), equipped with the MLU cockpit, will be used.

PHARUS

The Phased Array Universal Synthetic Aperture Radar (PHARUS) project consists of the definition and construction of a fully polarimetric airborne Synthetic Aperture Radar, to be flown on the Citation II research aircraft. The development, under contract to NIVR, is a co-operative project of the Physics and Electronics Laboratory TNO, the Delft University of Technology and NLR. In 1994 the main elements of PHARUS were developed.

Radar image of an area including the *city of Amersfoort, with a resolution* of 6m x 6m, taken with the PHARS sensor on an NLR research aircraft

Electronic Systems for Space Applications

NLR headed the international Two Phase Flow experiment, under contract to ESTEC, for an investigation of a vapour/liquid two phase thermal control system on board of a Space Shuttle. NLR was responsible for the electronic control and data gathering subsystem, among other things. The experiment was launched early February 1994. The equipment operated satisfactorily.

For manned space applications NLR has been involved in several activities of ESTEC and NIVR regarding spaceborne mass memories (as part of data management systems). Under contract to Matra-Marconi Space, NLR performed studies on the space qualifiability of commercially available CD-ROM and Winchester disk drives.

Multimedia Applications

A contribution was made in the field of tele-education, based on multimedia and signal processing techniques and using standard telephone lines. The multimedia telecommunication system developed by NLR as a spin-off was successfully applied in an experiment during the International Microgravity Laboratory (IML-2) Spacelab Mission. The system provided direct communication to the principal investigator in Huntsville, USA, and his scientific support team at NLR, Amsterdam, enhanced by text, graphics and still video.

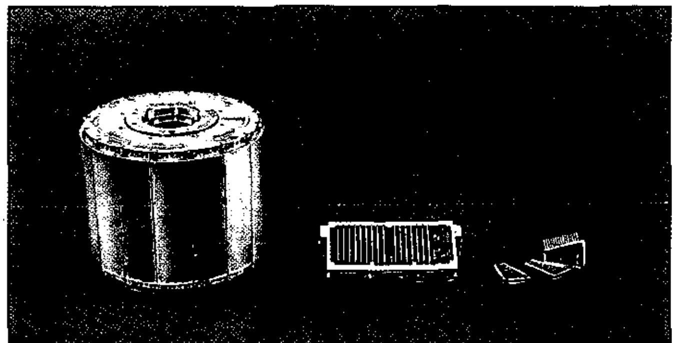
Ground Stations

A low-cost combined METEOSAT/NOAA high resolution receiver has been acquired, installed and put into operation. It serves in a research activity to define a low-cost, PC-based, regional ground station, a mini-ARTEMIS (Africa Real Time Environmental Monitoring using Imaging Satellites) system. ARTEMIS is an operational remote sensing data processing system, developed by NLR for the Food and Agricultural Organization (FAO) of the United Nations in Rome, Italy. Its user products are disseminated to other, predominantly African, users. A study has been made to expand the amount of user products and to request and disseminate these products by electronic mail.

Signal Conditioning, Wind Tunnel Instrumentation

For both the European Transonic Windtunnel (ETW) and the German-Dutch Wind Tunnel (DNW), measurement equipment for their windtunnel data acquisition systems was developed, produced and delivered.

For pressure and strength measurements on powered model propeller blades, a Rotating Amplifier System, a shaft-mounted set of instrumentation amplifiers, was designed and produced. The design is based on NLR's instrumentation amplifier for wind tunnel measurements. Because of the limited space available and the high G-forces at rotation (600 G), the design was miniaturized and based on hybrid technology for electronics.



Rotating Amplifier System for wind tunnel measurements on powered model propeller blades

Computer Aided Design of Electronics

The NLR Infrastructure for CAE of Electronics was expanded with one workstation. The existing workstations were replaced by more powerful ones. The software package was expanded with new capabilities. For mechanical design, the Autocad software is used. The Autocad workstation was coupled to the IBM/CATIA CAD/CAM system of NLR for mechanical parts.

Environmental Testing, Calibration

To cope with the new requirements for EMI test levels such as in RTCA - Do 160C, a market survey for test amplifiers and measurement equipment was executed. Several units were ordered. The new equipment is planned to be operative in the second quarter of 1995. With this upgrade the EMC laboratory will be capable of providing a field strength of 200 V/m in the frequency range of 10 kHz – 18 GHz.

For both the EMC laboratory and the Vibration and Shock Test (VST) laboratory, preparations are under way for obtaining accreditation from STERLAB, as part of NLR's activities in quality assurance. In these laboratories, many tests were carried out on various equipment under contract to military and civil users. The calibration laboratory for electromagnetic quantities was certified again by the Netherlands Calibration Organization (NKO), part of the NKO/STERIN/STERLAB organization.

Computer Facilities

The hardware facilities of NLR's computer network include an NEC SX-3 supercomputer, several UNIX servers and a non-UNIX mainframe. A communication network based on the TCP/IP protocols connects these facilities with workstations, X-terminals, PCs and other terminal equipment all over NLR. Wind tunnels, simulators and other facilities are also connected to the network, which is connected to networks of major customers and to national and international networks as well. The number of stations connected to NLR's network increased from 470 to 650.

A design for a major upgrade of the computer network, to accommodate the rapid growth of the number of stations, was completed. Implementation was started of a 34 Mbps ATM (Asynchronous Transfer Mode) link replacing the present 2 Mbps link between the two sites of NLR. The network will be segmented, to provide users with a high communication performance. To prepare for future enhancements, a start is made with a design of a growth path to an ATM infrastructure.

To enhance the functionality for users of the interface to the outside world, FTP, Gopher and Mosaic clients and servers were installed. In the near future, NetNews will become available. Via FTP and Mosaic, a gateway from the outside world to NLR has been created.

The use of the computer facilities, in particular the servers, showed considerable growth. Two servers for research in the area of parallel processing were integrated in the network. A special server for software development was made operational. The file server provides a file system with virtually unlimited size. After 1.5 years of operational service it manages 700,000 files with a total size of 70 GB. The combined file server and tape robot is used to create backups during nights and weekends automatically. Over 100 workstations and PC servers distributed over NLR use this facility.

To control the rapidly growing computer and network infrastructure and to decrease operating cost, the maintenance of the infrastructure received a great deal of attention. A start was made with the creation of a centralized system for operational workstation support. Support of PCs is by central PC servers. An organizational structure for centralized support and maintenance of the PC infrastructure was created. Storage facilities and several tools were made available via the PC servers. A uniform validation and accounting infrastructure was created for the NLR computer network.

3.6 Engineering and Technical Services

Wind Tunnel Models and Model Equipment

Many new wind tunnel models, model parts and related equipment were designed and manufactured, and several existing models were modified. The variety of these models was large: they included aircraft models, propeller blade models, helicopter models, rotor models, non-aerospace models, space vehicle models, jet exhaust flow simulation models and re-ingestion models. Because of the complexity of many of these models, NLR's IBM/CATIA CAD/CAM system has been used intensively.

Models have been manufactured for various customers, often as a part of an international project.

Work was done on:

- The design and manufacturing of a rotating hub (scale 1:10) and the manufacturing of a Tail Rotor model for the NH90 helicopter;
- The manufacturing of carbon fibre reinforced propeller blades for several models for BRITE/EURAM programmes;
- Several models for programmes of NIVR;
- The design of a Fokker 100 model to be used in the cryogenic European Transonic Windtunnel (ETW);
- The design and manufacturing of the housing of a Rotating Amplifier System (RAS) for the Tilt Rotor model.

Strain Gauge Balances

Several strain gauge balances were developed and manufactured. Not only additions to, or replacements of the existing universal NLR balances were made, but also dedicated model balances for NLR and for customers. Finite Element Methods were increasingly used in the design phase. The manufacturing of a new accurate semi-span model balance was finished, and the balance has had its first successful use in the HST. A new balance for non-aerospace research in the LST has been manufactured. Two new internal six-component sting balances were mechanically finished and beginning to be instrumented. Two dedicated balances were designed and manufactured for ARD/Apollo models. One rotor balance for a Tilt Rotor model has been manufactured and delivered to NASA; manufacturing of a second balance was started.

Various Structures

Along with specialized models and balances, several structures of very different nature were designed or manufactured, some being very complex. They included:

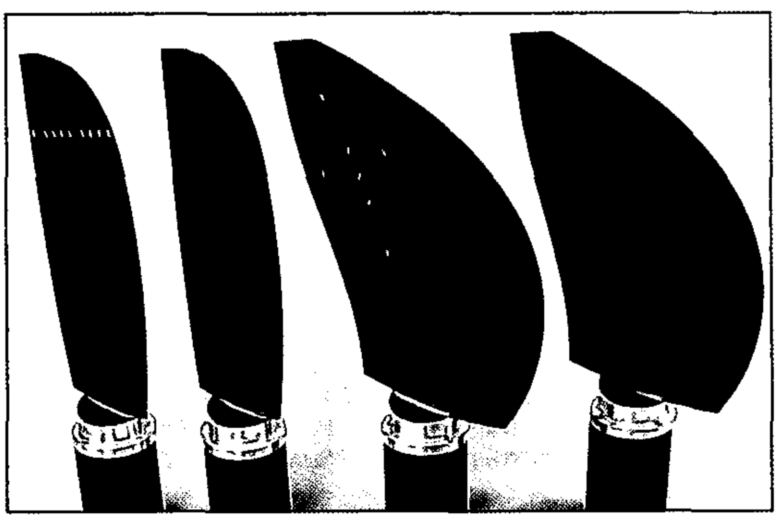
- tunnel equipment: a new pressure rake equipped with five-hole probes of very small diameter;
- test rigs: a test box for composite skin research, a biaxial full scale fuselage panel test rig;

- equipment for the Cessna Citation research aircraft;
- radar equipment in an external store;
- a Grating Element Support Structure for space application;
- a prototype of a miniature boundary layer traversing probe;
- flight test equipment for Fokker and RNLAF aircraft;
- a multi-purpose floor section for DNW.

Development of New Techniques

New techniques were developed and put into practice, to enable highly specialized products to be manufactured. Experience has been gained with the machining of special materials for cryogenic applications. Finite Element Methods have been used in designing all kinds of structures. For the instrumentation of carbon fibre reinforced model propellers, new techniques for accommodating large quantities of dynamic pressure sensors, pressure tubes and holes, and strain gauges in propeller blades have been applied.

Reduction of manufacturing costs and delivery times were given constant attention. Much effort was put into improving quality assurance, especially in manufacturing wind tunnel models.



Carbon fibre reinforced propeller blades with embedded instrumentation: two Low Speed Propeller blades (above, left) and two High Speed Propeller blades (above, right)

4.1 The Assessment of Third Party Risk due to Aircraft Accidents in the Vicinity of Airports

Introduction

Airports are hubs in the air transport system. Consequently, their presence causes a convergence of air traffic over the area surrounding the airport. The population living in the vicinity of an airport are therefore involuntary exposed to the risk of aircraft accidents. Although the probability of an accident per flight is very small (typically in the order of one in one million), accidents tend to happen during the take-off and landing phases of flight and hence close to airports. In addition, the small probability of an accident per movement is multiplied by a large number of movements (typically several hundreds of thousands) to arrive at the probability of an accident per year. This probability is of course much greater than the well known and very small probability of being involved in an aircraft accident as a passenger.

An increase in airport capacity usually involves changes to runway lay-outs, route structures and traffic distributions. This affects the local risk levels around the airport. Therefore, third party risk is a pivotal issue in making decisions on airport development. Consequently, objective and accurate risk information is required to provide guidance to the local and national government, the population around the airport and the airport authorities.

Amsterdam Airport Schiphol is planning a major expansion, involving more than doubling its current capacity by adding a fifth runway. Such an endeavour requires an environmental impact analysis which also involves the issue of third party risk. Until recently, however, adequate methods for the assessment of third party risk did not exist. Therefore, NLR was contracted by the Netherlands government to develop a comprehensive method for the assessment of third party risk around airports. The method was applied by NLR to Amsterdam Airport Schiphol as well as for the public inquiry into the London Heathrow expansion plans.

Definitions of Risk

For third party risk analysis two dedicated measures of risk are often used: individual risk and societal risk.

Individual risk is defined as:
the probability (per year) that a person permanently residing at a particular location in the area around the airport is killed as a direct consequence of an aircraft accident.

Societal risk is defined as:
the probability (per year) that more than N people are killed as a direct consequence of a single aircraft accident.

Individual risks depend on the exact location in the area, but are independent of anyone actually staying there. The societal risk applies to the entire area around the airport and hence is not location-specific within the area. Societal risk only exists when people are actually staying in the area around the airport. In an unpopulated area, individual risk levels may vary from location to location, but societal risk is zero by definition.

In order calculate risk in terms of the risk measures defined above, NLR developed the methodology and models described below.

Methodology

The method developed to calculate the third party risk around airports consists of three main elements. First, the *probability of an aircraft accident* in the vicinity of the airport is determined. This probability depends on the probability of an accident per aircraft movement and the number of movements (landings and take-offs) carried out per year. The probability of an accident per movement, the accident rate, is derived from historical data on numbers of movements and numbers of accidents during these movements. The development of the accident rate over time is

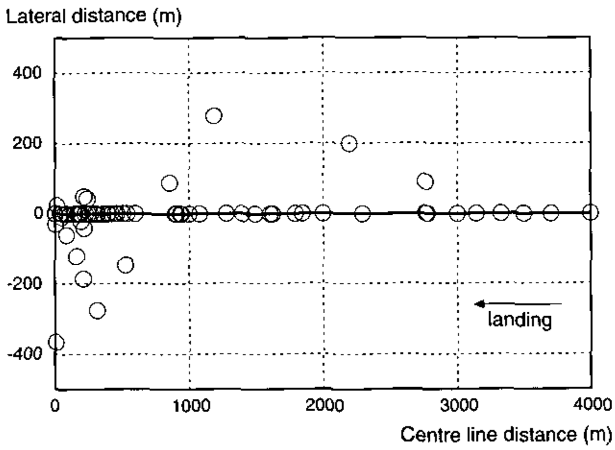


Fig. 1 - Sample of the landing accident location data

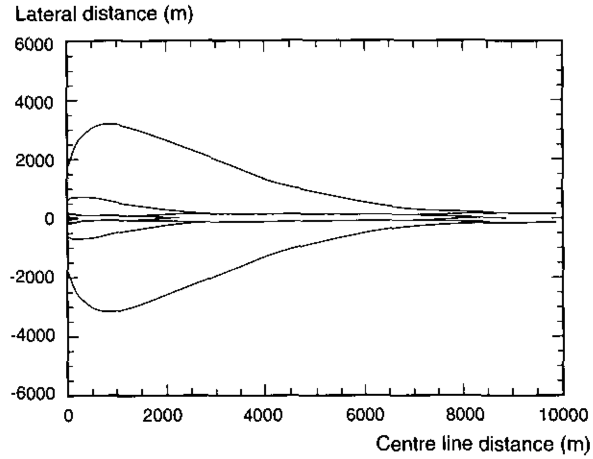


Fig. 2 - The accident location probability model for a straight landing route

modelled by a statistical function, which can subsequently be used for extrapolations to estimate future accident rates. Since large differences in safety levels exist between different types of operation and different regions of the world, a careful data domain definition is required to render airport-specific results. The accident rate, combined with the number of movements in a particular year provides the probability of an accident in that year.

The local probability of an accident is strongly dependent on the position of that location relative to runways and traffic routes. *This dependence is represented in an accident location probability model*, which is the second main element of the third party risk assessment methodology. The accident location probability model is based on historical data on accident locations (see Fig. 1). The distribution of accident locations relative to arrival and departure routes is modelled through two-dimensional statistical functions (see Fig. 2). By combining the accident location probability model with the accident probability, the local probability of an accident can be calculated for any location in the area around the airport.

A person residing in the vicinity of an airport is not only at risk when an aircraft accident occurs at this person's exact location, but also when an accident occurs in this person's close proximity. The accident consequences may have lethal effects at considerable distances from the impact location. The dimensions of the accident area are not only dependent on aircraft and impact parameters but also on the local type of terrain and obstacles. The effects of the aircraft and impact parameters and the type of terrain on the size of the accident consequence area as well as the lethality of the consequences are defined in the *consequence model*, the third main element of the third party risk assessment methodology.

By combining the three main elements described above, individual risk and societal risk can be calculated. To calculate the individual risk level for a particular location (x,y), the probability of an accident must be determined for an area surrounding (x,y) defined by all locations of which the accident area overlaps location (x,y). This probability in combination with the lethality of the accident consequences yields the individual risk at location (x,y).

Societal risk is determined by calculating the probability of more than N casualties occurring in case of an accident, for each location in the area around the airport, using the consequence model and information on the local population density. This probability is multiplied by the local probability of an accident, which renders the local probability per year of more than N casualties. By summing this probability for all locations around the airport one finds the probability per year of more than N casualties for the entire area around the airport, the societal risk.

Input Data

After adequate airport-specific models have been established, several types of scenario data describing the airport under investigation, the area around the airport and the traffic at the airport must be provided to enable the calculation of third party risk.

Traffic Distribution

The distribution of traffic over the area around the airport is determined by the local route structure and the traffic volumes per route. The complex geometry of the route structure and the number of movements per year for each route must be specified as input data. Because different accident rates and different aircraft weights are associated with particular categories of traffic, and different categories of traffic may not be evenly distributed over the available routes, movement numbers must be specified per category, per route. The movement data must be further specified into separate day and night movements. The reason for this is that societal risk (as opposed to individual risk) depends on the geographical distribution of the accident probability relative to the geographical distribution of the population. The distribution of the population around the airport is different for business hours (day) and non-business hours (night).

Airport Area Description

In order to calculate individual and societal risk, the local type of terrain must be known. For the calculation of societal risk, the local population density must be known as well. The population density used can be based on information on the number of houses per unit of area. In addition, local concentrations of people such as in schools, hospitals, public buildings and industrial complexes should be taken into account. Separate day and night population density information must be used for societal risk calculations.

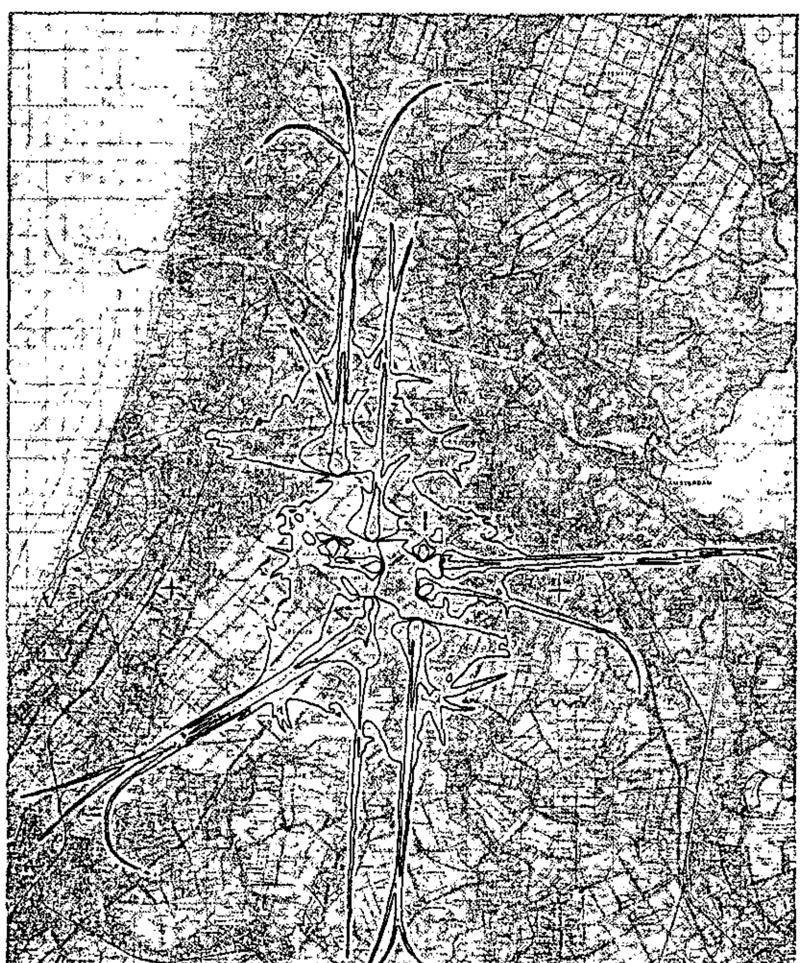


Fig. 3 - Calculated individual risk contours for Amsterdam Airport Schiphol with a fifth runway, in 2015

Results

Individual Risk

After local individual risks have been calculated for the entire area around an airport, risk contours can be generated and plotted on a geographical map, not unlike noise contours. Figure 3 shows individual risk contours for Amsterdam Airport Schiphol for the year 2015 involving a planned fifth runway and twice the current traffic volume. Individual risk levels indicated by the contours are 10^{-5}, 10^{-6} and 10^{-7}. The highest risk levels (10^{-5}) occur in a relatively small area close to the runway thresholds.

Individual risk contours are often used for zoning purposes. If maximum allowable risk levels have been defined, the contours can be used to determine whether houses can be built at a particular location and whether a particular airport development option results in local exceedings of maximum allowable risk levels in populated areas. If so, either the plan must be changed, the buildings must be removed or risk reduction measures must be applied.

Since high individual risk levels are only a problem if they coincide with population concentrations, a derived risk indicator used in the Schiphol analysis is found by counting the number of houses within a risk contour, i.e. counting the number of houses exposed to a risk level exceeding a particular individual risk value. By performing these calculations for all airport development options and comparing the results, an objective evaluation of development options can be made. In evaluating different ways of increasing the future capacity of Schiphol, a number of runway configuration options have been defined. Two options involve the construction of a fifth runway, which may either be parallel to the nearest existing runway (option 5P) or rotated relative the nearest existing runway (option 5G). A third option is to accommodate the projected future traffic volume on the currently available runways (option 4S1). In order to evaluate these options

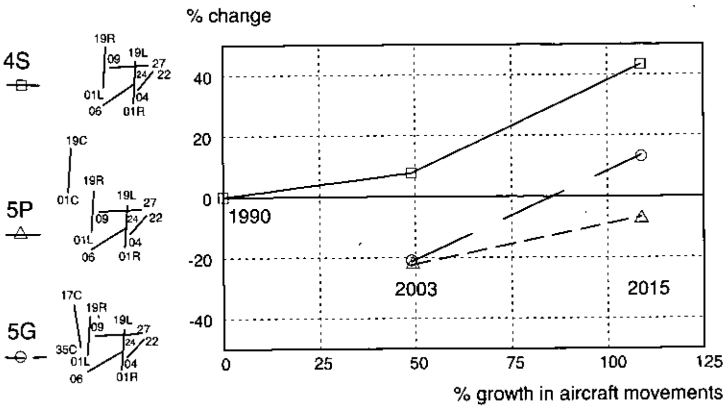


Fig. 4 - Three airport development options (left) and the corresponding changes in the number of houses exposed to an individual risk level exceeding 10^{-6} in 2003 and 2015 compared to 1990

in terms of risk, the development in risk around the airport was determined for each option as indicated by the number of houses exposed to an individual risk level exceeding 10^{-6}. The vertical axis in Figure 4 shows the percentage change in the number of houses exposed to risk levels exceeding 10^{-6} relative to the current situation. The horizontal axis represents the percentage increase in annual traffic for the years 2003 and 2015 relative to the current annual traffic. As is shown in the figure, the options involving a fifth runway perform better, with the parallel fifth runway option even resulting in a slight decrease in risk relative to the current situation in spite of an almost 100% increase in traffic. The improvement is due to the fact that an additional runway allows a better distribution of traffic over the area around the airport.

Societal Risk

Societal risk is a measure which is more difficult to use than individual risk. Figure 5 shows a societal risk curve for Amsterdam Airport Schiphol. The logarithmic horizontal axis represents the number of third party casualties (N) involved in a single accident. The logarithmic vertical axis represents the probability per year (F) that an accident will occur which involves more than N casualties.

A derived application of societal risk is the identification of locations where a particularly large probability exists of an accident involving

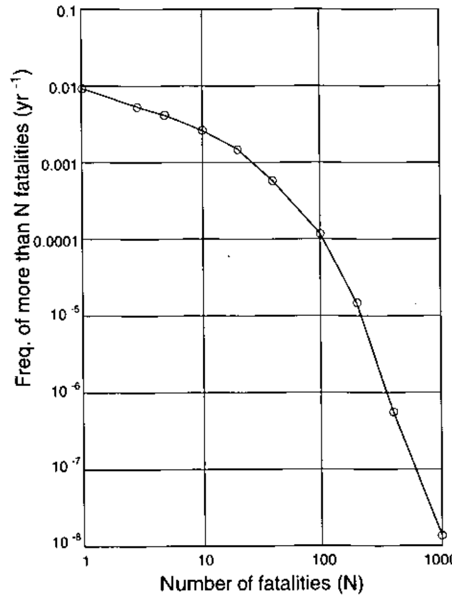


Fig. 5 - Example of a societal risk curve for Amsterdam Airport Schiphol

a large number of casualties through the calculation of societal risk per grid cell. Such information can be used for contingency planning purposes.

Uncertainty in Risk Information

Risk analysis using statistical models inevitably involves uncertainty. Because the results of a risk analysis may have far-reaching (and costly) consequences for airport development, uncertainty in the accident rates, the accident location model and the accident consequence model were calculated and combined to allow the calculation of 95% confidence intervals for individual risk and societal risk. Figure 6 shows an example of the 95% confidence area in addition to the nominal risk value (the best estimate) for a 10^{-5} and a 10^{-6} contour associated with a single take-off route with 20,000 annual movements. Since risk levels for different airport development options are calculated using the same models, however, conclusions concerning *differences* between airport development options in terms of risk are usually based on the nominal (best estimate) results of the risk analysis.

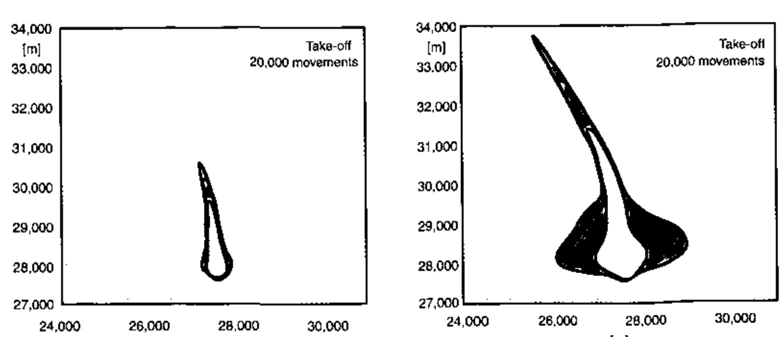
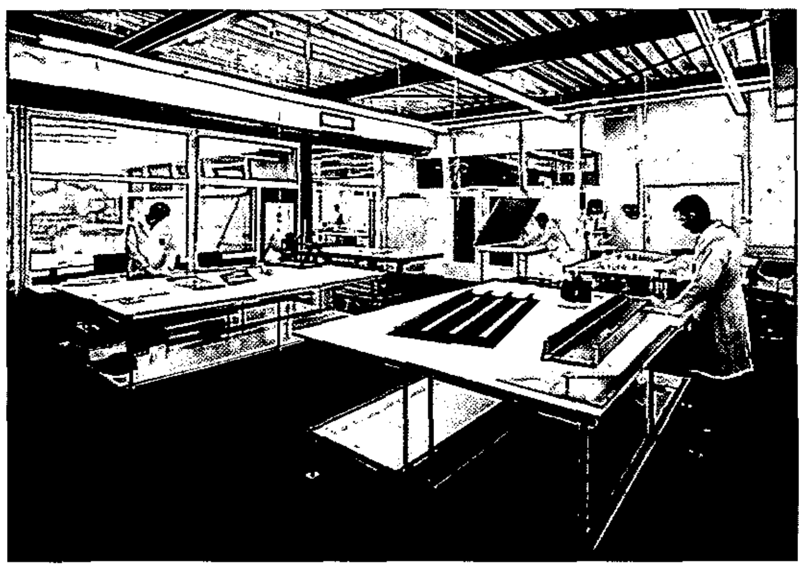


Fig. 6 - Nominal risk contours and 95% confidence intervals for a risk of 10^{-5} (right) and 10^{-6} (far right)

4.2 Fabrication and Concept Development of Composites

Since the mid-1970s, NLR has contributed to the development of technology for the application of composites in civil aircraft, in close co-operation with Fokker. First, studies were undertaken at both the material and the structural level, and experiments were conducted on specimens fabricated by Fokker. In the mid-1980s, a workshop with a clean room and an autoclave for the fabrication of composite specimens was inaugurated at NLR. Since then, new fabrication techniques were mastered. Currently, fabrication is no longer limited to that of specimens needed for experimental programmes, but is also used in the development of innovative structural concepts for new applications.



Composites Workshop

Aircraft Technology Programme

During the past few years NLR has participated in the Aircraft Technology Programme of the Netherlands Agency for Aerospace Programs (NIVR). In close co-operation with Fokker, technology has been developed to accomplish 'technology readiness' of the design methodology for composite empennage and wing structures, and for other areas where composites may be used in the near future. NLR's roles have been, and still are, to support the development of design methods and to fabricate and test structural components.

Stiffened skin panels for wing and stabilizer structures have been designed, using an optimization code developed by NLR, fabricated and tested. Emphasis in the design and testing has been on stability and damage tolerance.

Several configurations based on the damage tolerant 'soft skin panel concept' have been evaluated, including a skin with low stiffness to which blade- or I-shaped stiffeners were bonded in a secondary production cycle.

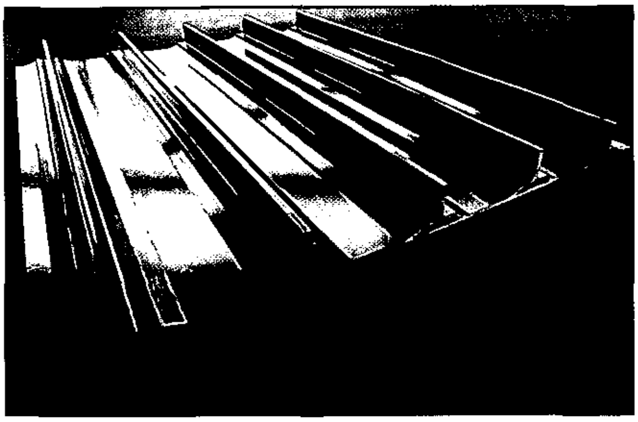
Spars for stabilizer structures were fabricated and subjected to tests combining bending and shear. Local buckling is the critical failure mode of these spars. Access holes in the spar webs may also introduce early failure, and design calculations were carried out to predict the failure load for this case.

The developments have now reached the stage where large assembled parts of a horizontal stabilizer are being built by Fokker. Sections up to 4 metre long will be tested at NLR, in a large test set-up built similar to that used for testing the Fokker 100 empennage.

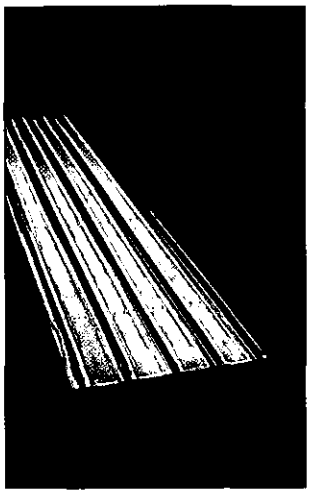
Damage Tolerance

The introduction of composites in civil aircraft structures requires solving potential damage tolerance problems. The development of a design methodology for primary aircraft structures and the complicated certification process that is required before such structures can be introduced are subjects of several research projects at NLR. Fibre-reinforced materials are anisotropic and inhomogeneous, and the common fabrication process results in a material that is composed of a number of thin plies which are stacked together with rather weak interfaces between them. When impacts take place on such composite structures during fabrication or in service, for instance as the result of dropping a tool, delaminations may occur inside. Such delaminations in layered material may not be visible but do reduce the strength of the structure, and some could be fatal in heavy flight conditions.

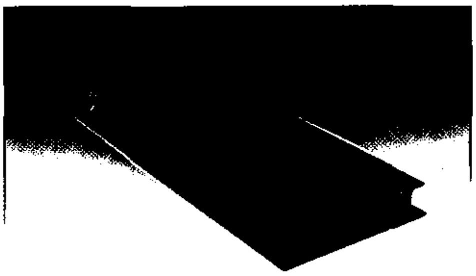
Heavy blade-stiffened wing panel

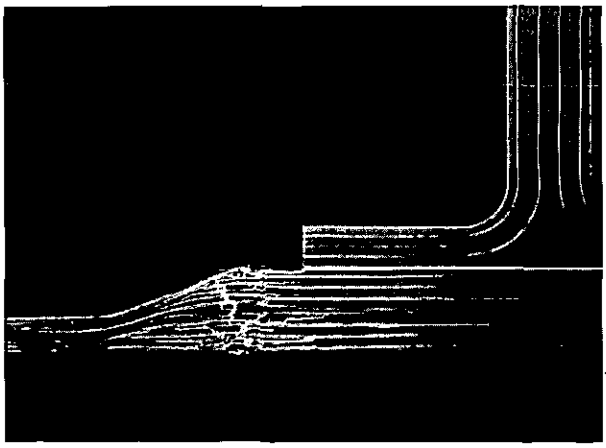


Light blade-stiffened panel for stabilizer



Intermediate I-stiffened wing panel





Cross section of a stiffened composite panel with impact damage

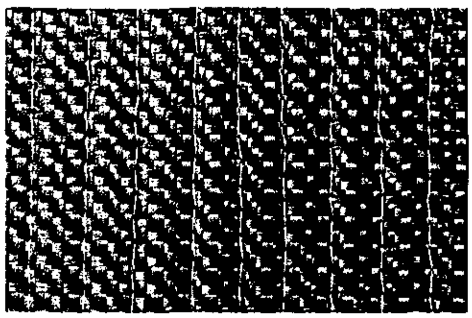
Three-Dimensional Composites

Solutions to the damage tolerance problem have to be found in new combinations of materials, structural configurations and fabrication techniques. NLR carries out investigations into this. Improved damage tolerance may be achieved by applying three-dimensional composites. In the case of plate structures, these are made of layers with fibres oriented in the plane of the plates, but the interfaces between the plies are reinforced by stitching the layers together with threads of structural fibres (glass, aramid, or Dyneema). Stitching of pre-impregnated layers is not possible when the fibres are embedded in matrix material, because the fibres would break when the needle passes through the layers during the stitching process. The regular pre-preg/autoclave technique therefore cannot be used. The fibre material must first be stitched, then placed into the mould, and only after that can the matrix material (epoxy resin) be added. This can be done with the Resin Transfer Moulding (RTM) process, for which NLR's composites workshop has been equipped. A research programme which includes the fabrication of several 3-D composite plates was started. The effects of the stitching density and the laminate composition on the damage tolerance of these plates will be established experimentally.

Crashworthiness

A design methodology for composite aircraft structures is being developed in close co-operation with Fokker. Structural concepts have been determined for several applications. Research by NLR is aimed at the development of design and analysis tools, at improving the performance of the structure, and at understanding the failure mechanisms. A new area of research is that of crashworthiness. During the past decade it has become clear that many aircraft accidents are potentially survivable, provided that 'crashworthiness' is designed into the aircraft structure. Especially composite structures can be improved by the development of new structural concepts.

Crashworthiness has become a major topic in the design of helicopters, both civil and military. Crashworthiness requirements to helicopters consist of a complex set of specifications. The most stringent requirement is imposed on the survivability of the occupants in case of a vertical downward



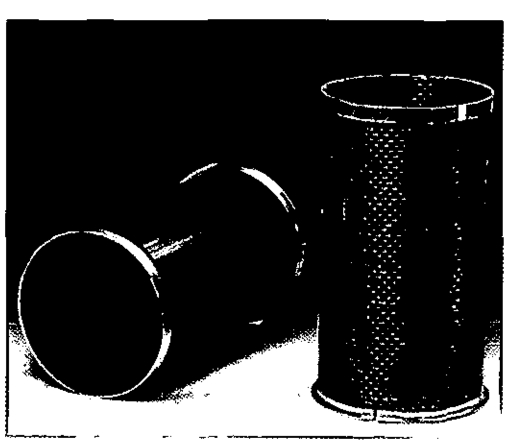
Stitched 3-D composite preform

impact. Injury of the spine must then be prevented, by reducing the shock load imposed on the occupant. This can be achieved by designing the bottom part of the helicopter such that, in case of a crash, it collapses in a controlled way while absorbing a substantial amount of energy. The objective is to slow down the occupant as regularly as possibly, using the maximum braking distance available.

In a helicopter, there is room to absorb energy in the landing gear, the bottom (subfloor) part of the structure, and in the seats for the occupants. NLR is involved in the development of concepts for all three components.

Crash Tube

A composite crash tube which is to be incorporated in the nose landing gear of a helicopter has been developed. In case of landings at vertical speeds above a certain value, the tube is loaded in axial compression and crushes in a predictable way, thereby absorbing the required amount of energy. The development phase of the crash tube was completed in 1994, and the certification phase was started.



Crash tubes

Crashworthy Seats

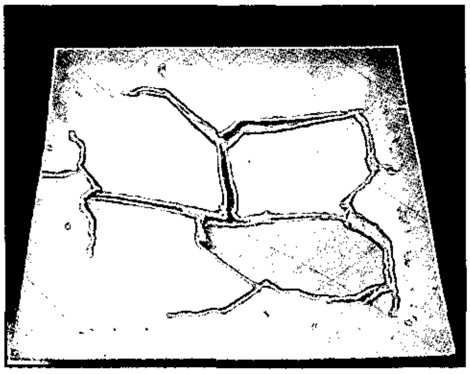
The technology to design crashworthy seats has become a subject for research because several helicopter producers have said that such seats will be required. Crashworthy pilot seats for military helicopters are commercially available, but seats for civil helicopters and seats for troops in transport helicopters still need to be developed. These should be lighter, smaller, and less expensive than pilot seats, as their requirements are less severe. A prototype seat was developed for Agusta, with a crushable composite tube inside the legs of the seat and composite used in the seat bucket. Production of the seats is being discussed with manufacturers in the Netherlands.

Concept Development

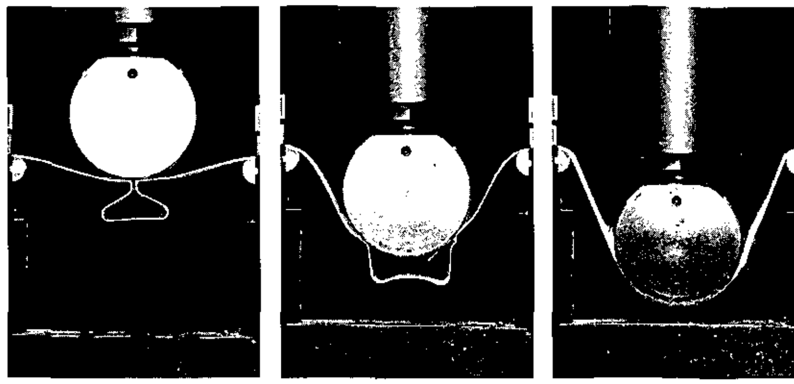
Structural concepts are developed in a number of cycles of design, fabrication, testing and analysis. The development process requires efficient co-operation between the various disciplines, and a low cycle time. At NLR these requirements are met, because all disciplines are available and collocated. An example of a structural concept developed is the so-called tensor-skin concept.

The design of helicopters for crashworthiness at impact on water has only recently become a subject for further study, and requirements have not yet been defined. In the mean time structural solutions must be found, because the energy absorption mechanisms incorporated so far in the landing gear and the subfloor structure are probably not very effective in case the helicopter crashes on water. To withstand the water pressure, the bottom skin must deflect considerably, to transfer the pressure loads to the substructure. However, the traditional fibre-reinforced composites are very brittle, so a bottom skin panel breaks before it deflects very much. At NLR a concept has been developed to produce a skin panel capable of being considerably deflected under pressure before failure, thereby showing a quasi-plastic behaviour similar to metal structures.

In several cycles of concept development, starting with small specimens, a combination of a structural configuration and material properties was found that allows the composite plate to deflect by stretching the built-in folds, until the plate is fully stretched and transfers



Composite skin panel failed by transverse pressure



Unfolding and stretching of the tensor-skin

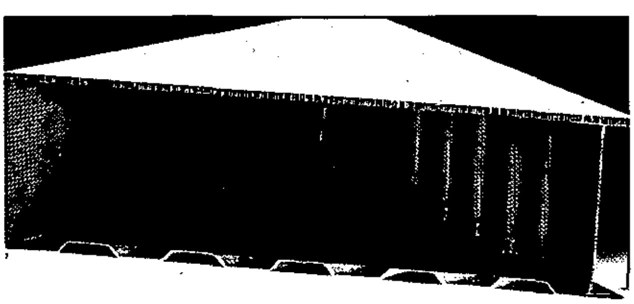
the transverse load by membrane tension. The material needed is the polyethylene fibre (DSM's Dyneema), embedded in epoxy, which is able to survive the stretching of the folds while the matrix material breaks. Because of these properties the concept was named 'tensor-skin concept'.

After a second development cycle, in which square plates were built and tested, a structural helicopter component was fabricated: a sandwich panel. The faces of the panel are made of regular composite material and break at small deflections, but the corrugated core is the element that unfolds and stretches, and yields the residual strength in case of a water impact.

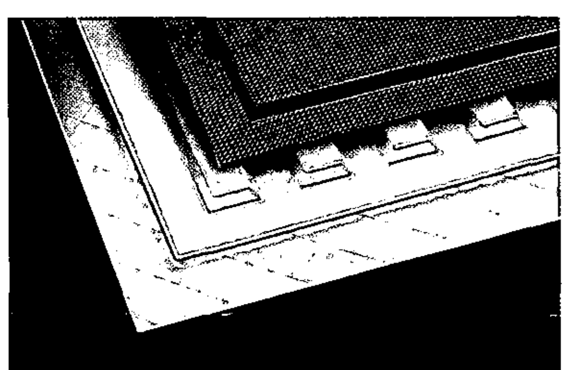
tooling concepts to produce sine-wave spars, and the development of a production method for thermoplastic parts.

The sine-wave spar is a structural design that can often be found in the subfloor structure of helicopters. It performs well under both operational loads, bending, and under crash loads, crushing. If a hybrid material such as carbon-aramid/epoxy is selected, it also has good post-crash integrity.

Sine-wave spars, however, are difficult to fabricate, and therefore expensive. To find economic solutions for the fabrication of sine-wave spars, two different tooling techniques



Generic helicopter subfloor structure with tensor-skin panel



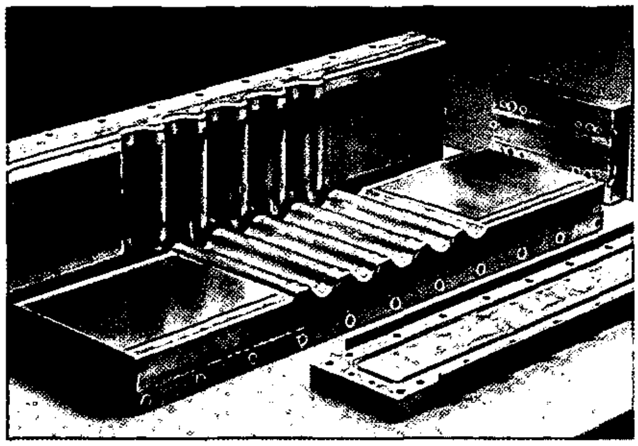
Elements of sandwich panel with corrugated core

The development described above is now going to be part of a new BRITE/EURAM programme on crashworthiness of composite aircraft structures.

Fabrication Methods

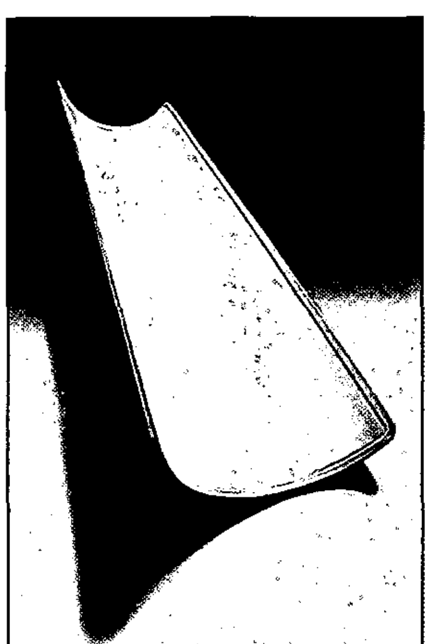
In addition to participating in the development of structural concepts, NLR develops new or enhanced fabrication methods for composites. Three such developments are described below: the developments of two

were developed: one for the Resin Transfer Moulding (RTM) process, and one for the autoclave process. In the RTM process, 'dry' fibre layers are put in a cavity formed by the mould, which is subsequently filled with liquid resin. The product is cured at an elevated temperature. The advantages of this method are: low material cost, low storage cost as no refrigerators are needed to store prepreg material, little waste and well controllable dimensions.



Tooling for RTM fabrication of a sine-wave spar

Another technique is the autoclave technique, using prepreg materials. Because of the complex shape of the sine-wave spar, this technique is difficult to use. However, a tooling concept has been developed that uses rubber coated moulds, which provide enough flexibility to guarantee a high product quality, whereas only little additional material is required as the tool itself is used to provide vacuum.



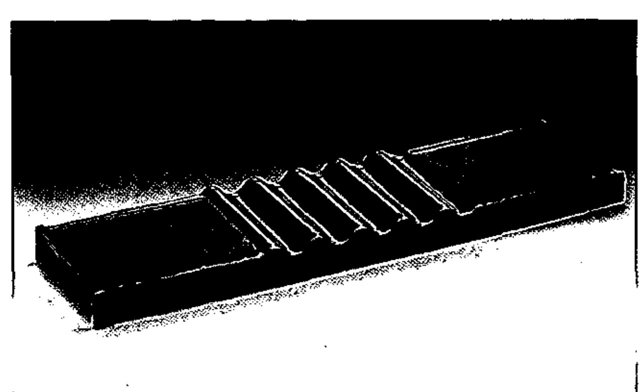
Radome

Thermoplastic materials require a different fabrication technique than do the thermoset materials discussed so far. Thermoplastic raw material comes in plates of fibres embedded in a matrix like a prepreg, but is not soft and pliable at room temperature. It has a fixed shape that can be changed only at a high temperature in a mould, and has to be kept in that shape until it has cooled down again. The difficulty here is to draw the original flat plate into the mould at high temperature. Advantages of thermoplastic materials are the fact that they can be recycled, and that complex shapes can be made in short cycles.

An affordable fabrication process has been developed for Fokker, to be used for the fabrication of the main undercarriage door of the Fokker 50. It is called a diaphragm forming process, as thermoplastic plates are drawn onto the mould by placing them under a diaphragm, and applying a vacuum. This takes place in the autoclave, where special infrared heating panels were fitted to accelerate the heating.

One of a Kind Products

The composites workshop of NLR is well suited to make one-of-a kind products for special purposes. In the framework of the national PHARUS (Phased Array Universal SAR) programme, a Dyneema/polyethylene radome was developed that will be fitted on an external radar on one of NLR's research aircraft. The dielectric properties of the Dyneema fibre and polyethylene matrix material allow radar beams to pass almost unhindered. To prevent deformation of the radome, the fabrication process has been improved.



Rubber mould for autoclave technique

4.3 User Support and Remote Science Operations from the Dutch Utilisation Centre

Introduction

In March 1989, the European Space Agency (ESA) set up an international team, in which NLR participated, in Cologne (Germany) to establish better concepts for the utilisation of the relatively expensive research facilities on board of spacecraft. This team worked together on the concept of a scientific User Support Organisation. A key element in this concept is the establishment of utilisation centres relatively close to the scientific user groups, offering utilisation support services and providing easy access to the facilities on board of the Space Station. Several ESA member states have adopted and implemented the concept of Utilisation Centres.

The Dutch Utilisation Centre

In addition to participating in the ESA-team, NLR played an active role in the establishment of the Dutch Utilisation Centre (DUC) at NLR. The DUC provides microgravity users (and other scientists interested in performing experiments on board of spacecraft) with mainly technical support. Various tools have been developed to facilitate for example:

- communication between crew member (astronaut) and Principal Investigator (PI);
- on-line real-time processing of scientific data;
- remote experiment operation by the ground-based PI.

In 1994, the use of the DUC has been demonstrated twice. In May the DUC was used successfully in a realistic manned mission demonstration, simulating activities of ground-based Principal Investigators and Space Station crew. In July a physicist performed a critical point experiment during a mission of the International Microgravity Laboratory. In this experiment the DUC provided on-line support to the remote science team.

A Manned Mission Demonstration at NLR

The Space Station crew simulation session at NLR was an extension of ESA's earlier mission simulation activities. After some events simulating one day out of the life of an astronaut, a longer period was called for, with an increased level of experiment realism and with higher payload operations complexity. In addition, a crew support concept was investigated using different control and monitoring modes for space and ground segment. Furthermore, the extended simulation event enabled the functionality of a so-called remote user support centre implemented in the DUC to be evaluated. The DUC provided ground support for payload integration, preparation, repair and maintenance of a breadboard Biology Facility which housed two multi-user payload facilities: the Glovebox and the High Performance Capillary Electrophoresis (HPCE) instrument. Identical man-machine interfaces for crew and ground terminals were implemented, according to an existing design of the Crew Portable Computer (Crew PC) and Ground PC. The demonstration set up was made by a Dutch consortium of industries and institutes headed by NLR.

Demonstration Set-up

A three-day mission demonstration was set up at NLR, with crew (astronaut) tasks performed by staff of the participating institutes/laboratories.

The set-up comprised two different sites: a 'space segment', where the experiment and facility hardware were located and where the simulation crew performed their activities, and a 'ground segment', the DUC, where Principal Investigators (PIs) and support personnel monitored and operated the experiments and communicated with the crew.

An overview of the 'Space Segment' is given in Figure 1.

Communication

The communication of voice, data and video images between a (simulated) space segment and ground segment was based on a realistic communication set-up.

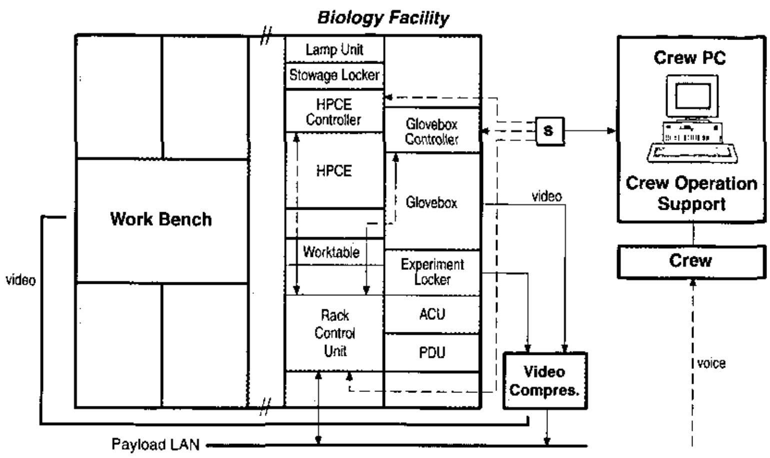


Fig. 1 - Set-up of the 'space segment'

The payload data communication was based on a standard path service protocol on Ethernet. The ESA Packet Utilisation Standard was used to identify payload and video data packages.

Voice communication was implemented on the NLR telephone network in a conference mode, using headsets and hands-free telephones.

A closed circuit television system from space segment to DUC-site was installed for visitors and observers.

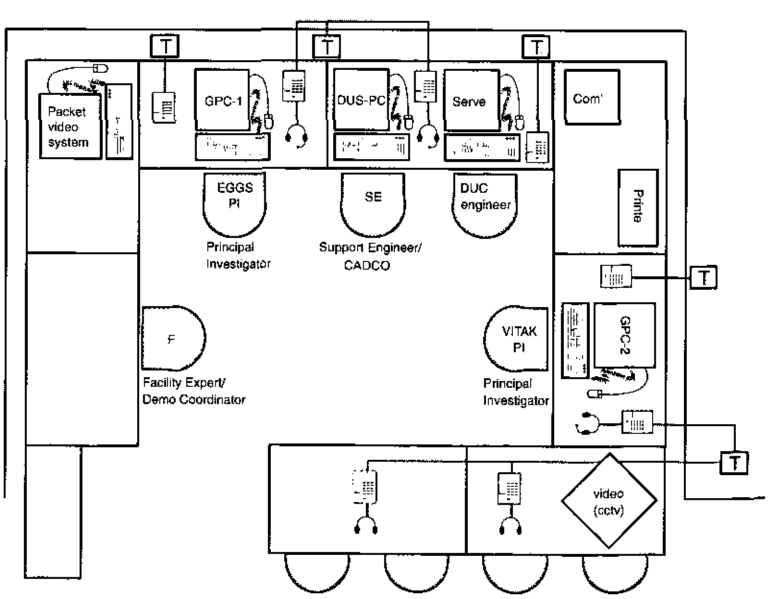


Fig. 2 - Set-up of the 'ground segment' (DUC)

Two Experiments

Two PIs were active during the demonstration, performing two different experiments: a Toad Egg experiment (EGGS), and a Vitamin K experiment (VITAK).

Dr. G.A. Ubbels of the Hubrecht Laboratory for Development Biology performed an experiment involving the fertilisation of toad eggs and the observation of their development. For this experiment the astronaut had to perform specific tasks: handling living toads, filling experiment modules and positioning the modules in special video observation stands, built in the Experiment Locker. The EGGS experiment was focused on the observation of the eggs' development by the PI on the ground.

Dr. C. Vermeer of the Biochemical Department of the University of Limburg performed an experiment related to the study of bone demineralisation in microgravity. For this experiment, urine samples of the crew were prepared and analysed with the High Performance Capillary Electrophoresis facility (HPCE).

The Ground Segment

Experiment and facility operations were performed from three functional positions at the DUC-site. The PI, the originator of the experiment, performed on-line operation and monitoring of the experiment. A Support Engineer, assigned to assist the PI, was responsible for crew communication and on-line support to the PI. A Facility Expert was responsible for support to dedicated on-board facility operations and maintenance.

The DUC lay-out (see Fig. 2) was built around two Ground PCs. Additional systems included a DUC User Support system (DUS-PC) operated by the Support Engineer for off-line experiment analysis, a Server Station monitored and operated by the DUC engineer, and a Video PC. The server dealt with the DUC internal data distribution, while the DUS-PC provided special applications for experiment data processing. The Video PC was dedicated to the presentation of Toad-Egg experiment video images. A Packet Video System allowed video images to be transmitted to the ground segment.

The Space Segment

The space segment comprised the breadboard Biology Facility, some general purpose facilities, such as the Portable Workbench, and the Crew PC. The Biology Facility houses two multi-user facilities that were used to perform the experiments, the High Performance Capillary Electrophoresis facility and the Glovebox, and one experiment-dedicated facility, the Experiment Locker. Figure 3 provides an overview of the Biology Facility and the Crew PC. Major activities of the crew in the space segment are the operation of the experiments and facilities as part of the execution of the experiments. The Crew PC is the crew's major tool for performing these tasks.

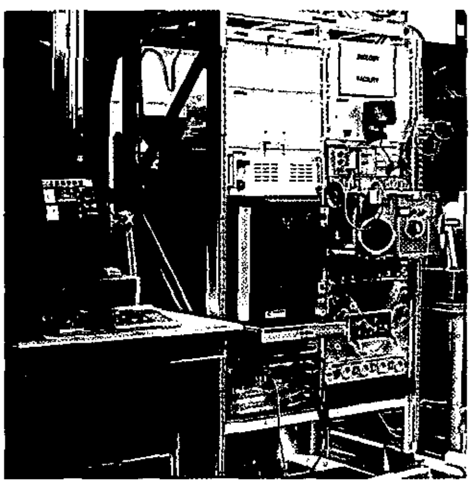


Fig. 3 - Breadboard Biology Facility and Crew Portable Computer

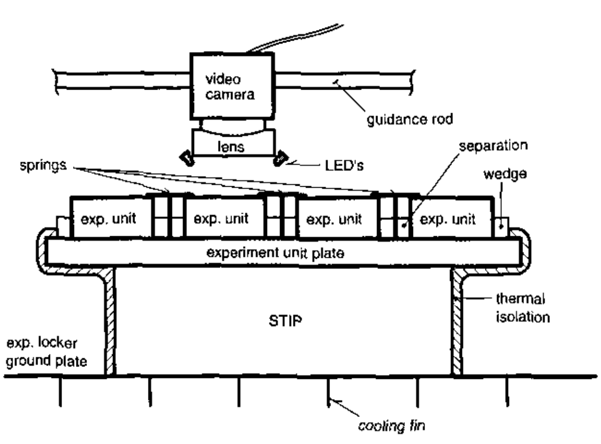


Fig. 4 - Experiment locker overview

The Crew PC

The Crew PC is the interface between the astronaut and the on-board systems. It is based on commercially available products, but includes a number of dedicated crew support tools. The Crew PC was used as the main crew workstation. A Crew Procedure Execution Support system assisted the crew in the step-by-step execution of on-board procedures. At each step, the required support could be obtained from a Document Filing System that provided direct access to text information, engineering drawings, explanatory photographs or video clips.

Virtual Control Panels were used to enable payload control by crew and ground and to read-out payload status by parameter values via the PC. A Multi-media Tele-Support system provided support to the operations by synchronising the user interfaces in the space and ground segments. In this way it was possible for the PI and the crew to communicate by means of annotations and drawings, and for the PI to monitor the crew activities. Annotations could be made in a way similar to pen computers using a 'normal' pen writing directly on a transparent screen overlay digitizer.

Capillary Electrophoresis Operations

By capillary electrophoresis, different components in a fluid can be separated. The High Performance Capillary Electrophoresis (HPCE) system implemented in the Biology Facility was based on a commercially available 1-g system. In the mission demonstration, the HPCE was used for the analysis of crew urine samples on the concentration of creatinine, reflecting the process of bone demineralisation. Sample preparation tasks were performed by the crew. The PI could take over the control and monitoring of the HPCE using the Ground PC.

Glovebox Operations

The Glovebox system implemented in the Biology Facility was a model based on the Shuttle Middeck Locker type. Three video cameras were installed to enable monitoring of operations in the Glovebox work area.

The control and monitoring of the Glovebox can be performed not only by the crew, via the Glovebox front panel and the Crew PC, but also by operators on the ground via the Ground PC.

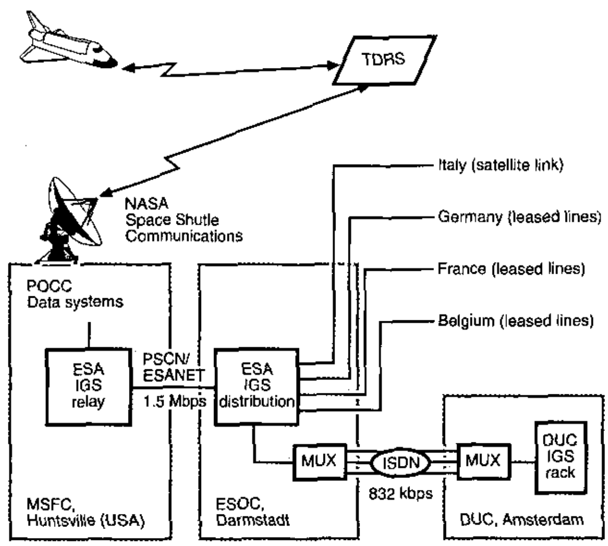


Fig. 5 - Overview of the communications.

(1) Data from Space Shuttle to Marshall Space Flight Centre (MSFC), Huntsville:
The Telemetry and Data Relay Satellite (TDRS) system of geosynchronous satellites allowed the orbiter to have line-of-sight transmission capability with at least one of the TDRS satellites at most times.

(2) Data from MSFC to ESOC, Darmstadt:
ESA had installed a single physical link to ESOC, Darmstadt, with all the different data streams of the remote centres integrated.
A transatlantic data connection was provided by ESA.

(3) Data from ESOC to DUC, Amsterdam:
To transfer data between ESOC and DUC, seven ISDN channels were used. The ISDN connection was used only when necessary, keeping the communications costs for DUC low.

Most of the Glovebox operations during the mission demonstration were focused on maintenance and in-flight payload integration.

Experiment Locker Operations

The Experiment Locker (see Fig. 4) provided a temperature-controlled environment for the Toad Eggs modules. A video system was implemented that allowed observation of the eggs in the modules. The crew could move the camera over the various modules such that different eggs could be selected for detailed observation. The video images were transmitted to the dedicated Video PC in the DUC.

Support in Critical Point Experiment

In July 1994, the Van der Waals-Zeeman laboratory and NLR/DUC were working together to prepare the DUC for Space Station user operations and to enhance the scientific return of an experiment of the Van der Waals-Zeeman Laboratory. This experiment was conducted in the Critical Point Facility (CPF) carried by Spacelab in the second International Microgravity Laboratory (IML-2) mission. During this mission an international team of experts, some from the Netherlands, worked together to study basic scientific issues under microgravity conditions. The DUC was one of five European user centres involved in remote support or operation of European facilities and experiments on board of the IML-2. In remote science operations such as these, scientists have access to their experiment data from another location than the Payload Operations Control Centre (POCC) in Huntsville, USA. The European remote science operations were carried out under numerous agreements between NASA, ESA and the participating Remote Centres, assuring technical, operational and programmatic compliance with services provided by NASA.

The end-to-end communication layout for the concept is depicted in Figure 5.

The Critical Point Facility (CPF)

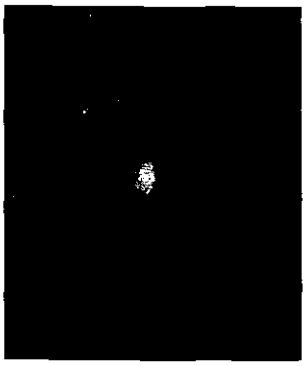
The CPF is a multi-user facility of ESA, offering investigators opportunities to conduct research on critical point phenomena in a microgravity environment in Spacelab. The critical point of a fluid is the point (characterized by one fixed temperature, pressure and density) where the distinction between the gas phase and the liquid phase just disappears. Fluids cannot be sustained in this temperature region in a surrounding where gravity exists, for example on earth.

The inherent instability in such systems, even in microgravity, and the long time to achieve equilibrium, requires any temperature changes to be carried out in very small increments, resulting in long duration experiments. Experiment runs of 40 to 60 hours are normal, and require missions such as provided by the Space Shuttle and Spacelab.

The Van der Waals-Zeeman Critical Point Experiment

Dr. Michels of the Van der Waals-Zeeman Laboratory used the CPF to study the processes of heat transport in a pure fluid (SF_6) near its critical point, and their fundamental relation to the density profile. The measuring technique was based on the observation of the propagation of a plane thermal disturbance into a homogenous sample with the help of interferometry and the scattering of laser light sent through the liquid. The measurements were done at different temperatures close to the critical temperature.

The experiment started 2 days and 4 hours after the launch of the Space Shuttle, and lasted 56 hours. During this time, full support from the DUC was available.



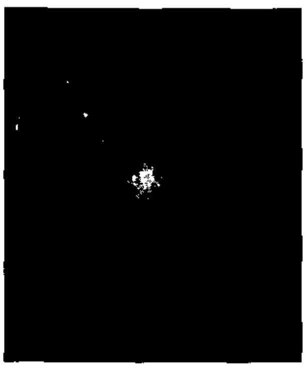


Fig. 6 - Interferograms, typical still video images made available by the DUC to the remote science team during their spaceborne experiment

Set-up of the DUC

At the DUC all experiment data from the CPF were received and stored. The most important data streams were extracted from the incoming data and immediately processed for (near) real time analysis:

- the still video information, giving every six seconds an updated interferogram of the sample cell (see Fig. 6);
- the data from the experiment computer including temperature data and light scattering data.

These processed data were observed and verified by the remote science team at the DUC in Amsterdam. They discussed their findings over a voice connection with Dr. Michels, who was at the POCC in Huntsville. The DUC used the NASA Voice Distributed System for the communication with the POCC. This voice matrix system groups all voice loops used to conduct a space mission. Electronic data could be transferred by means of an Ethernet connection between the POCC and the DUC.

In addition to the experiment data, mission-specific data were received at the DUC. A terminal of the Orbiter Mission Information System with data concerning the actual status of the mission and offering the possibility to request replay of experiment data (e.g. data that was taped on board during periods of Loss of Signal) was made available to the remote scientists.

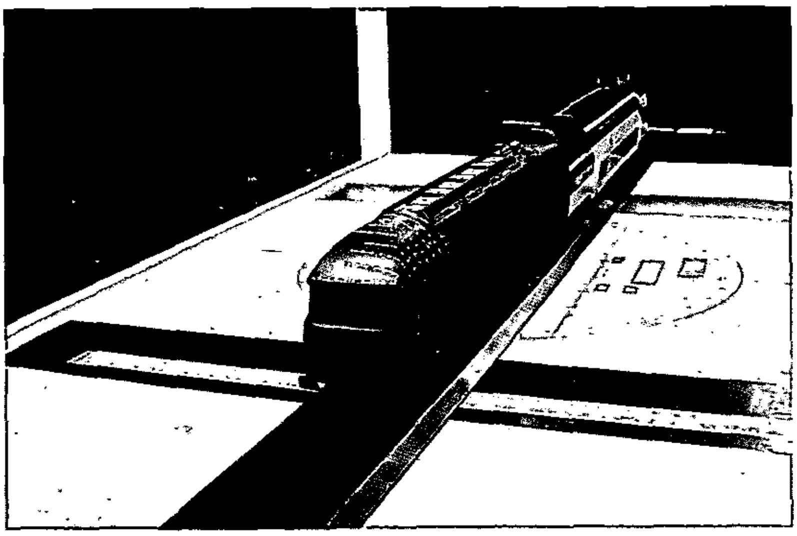
The advantage of the set up at the DUC over Huntsville was the possibility for the remote support team to have all the scientific data available in digital form (as opposed to the PI team in Huntsville, who had to work with analog slow-scan video). Furthermore, the DUC offered the possibility to the scientists to work in an environment provided with all books, computers and whatever else they needed at hand.

Another advantage of the DUC was the capability of correlating the different measurement systems of the CPF.

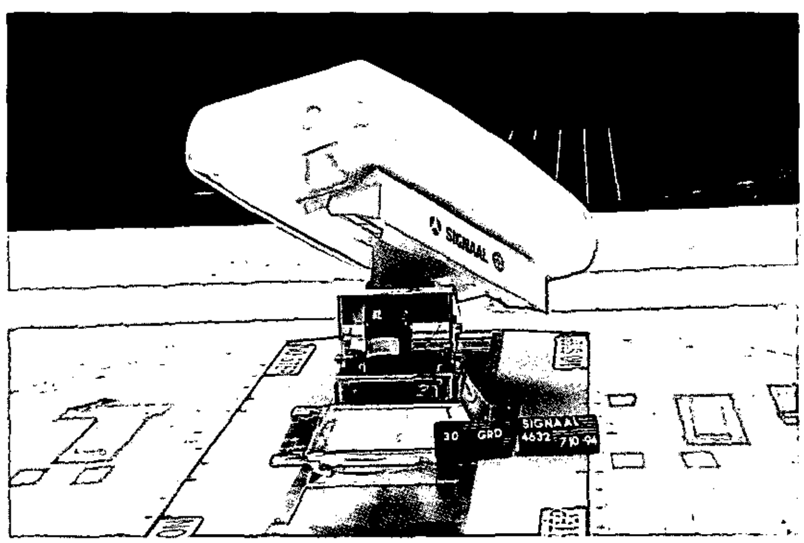
Conclusions

The manned mission demonstration using the DUC appeared to be very realistic. Payload utilisation, stowage locations, integrated experiment operations, time-lines, and operational procedures could be tested very well. The demonstration yielded many recommendations for improvements on payloads, crew and ground procedures, crew interfaces, and communication.

During the IML-2 flight all data from the Critical Point Facility were received by the DUC, enabling the remote science team to analyse the data in real time or near real time. The PI team in Huntsville could be provided with a sound basis for real time decisions concerning the execution of the experiment, so that the valuable experiment time was used to the largest possible extent.



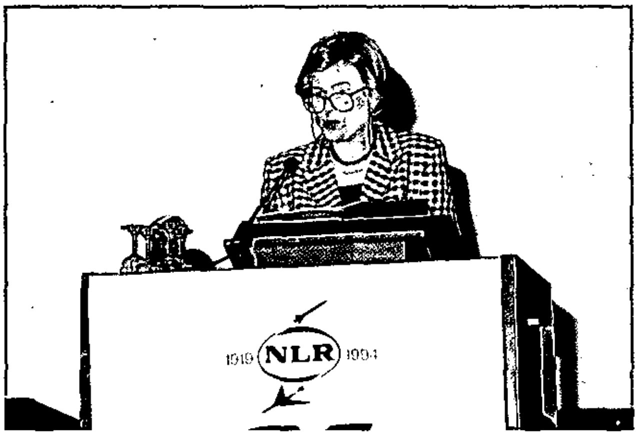
Models of existing and future railway materiel of the Netherlands Railways were tested in the LST to determine, among other things, the temperature rise at several positions due to the flow of air heated by the engines



A model of a radar antenna of Signaal was tested in the LST, tilted and rotating, mounted on a six-component balance

Internal and External Relations

Many visitors showed their interest in NLR's activities. NLR participated in several Airshows and exhibitions, and organized several events.



Mrs. J.R.H. Maij-Weggen, then minister of Transport, speaking at the celebration of the 75th anniversary of NLR

Visitors from the Netherlands

- Prof. Dr. D. van Norren, Director of the National Aerospace Medical Centre
- Mr. B.J.A. van Schaik and Dr. R.J. van Duinen, members of the Board of Fokker
- Mrs. N.A. van den Nieuwboer-Langenkamp, Burgomaster of Bredenwiede
- Mrs. Prof. Dr. A.J.M. Roobeek, member of the Board of the Foundation National Aerospace Laboratory

Foreign Visitors

- Mr. A. Bondreau; Director for International Affairs of the Arnold Engineering Development Center, USA
- Mr. Hamaki Inokuchi and Mr. Toshikazu Motoda of the National Aerospace Laboratory, Tokyo, Japan
- Mr. E. van der Linde, Technical Scientific Attaché in the USA
- Mr. David J. Mabey, Counsellor Defense Research and Development of the Canadian Embassy
- Prof. E. Mezquida and Mr. E. Campos of the Instituto Nacional de Técnica Aeroespacial of Spain
- Mr. J.P. Daniel of Aerospatiale
- Mrs. H.M. Bucher PhD, Chief Crew Station R & D Branch, Ames Research Center, U.S. Army Aviation Systems Command
- Mr. P. Schwab and Mr. R. Notestine of F-16 International Industries

Excursions

- Students of the Association 'Hendrik W. Bode', of the Eindhoven University of Technology
- Members of the Academie de l'Air et de l'Espace, Toulouse, France
- Staff of the Airbase 'De Harskamp'
- Members of the Study Society 'Sipke Wynia' of the Haarlem College
- Students of the Study Society for Technical Physics 'Ångström' of the Rijswijk College
- Staff of the Royal Netherlands Meteorological Institute (KNMI)
- Users of Lynx Helicopters
- Students of the Student Society 'Abacus' of the University of Twente
- Students of the Politechnico di Torino, Italy
- Members of the Society of Defence Engineers
- Members of the 'Panel on Physics and Electronics' having a meeting at the Physics and Electronics Laboratory TNO

- Students of the Student Society 'Mohres leren' of the University of Twente
- Members of the Technical Staff of the Netherlands Railways
- Members of the Dutch Society of Engineers NIRIA
- Participants of the General Assembly of the International Astronomical Union that took place in the Hague
- The financial staff of NIVR, staff of KPMG and civil servants of the Ministry of Economic Affairs
- Members of the Transport Committee of the European Parliament
- Members of the Student Society for Mathematics, Astronomy and Informatics 'De Leidsche Flesch'
- European Aerospace Students of the association Euravia
- Members of the College of Research Co-ordinators of the Ministry of Transport
- Civil servants of the Environmental Department of the Province of Groningen

Exhibitions

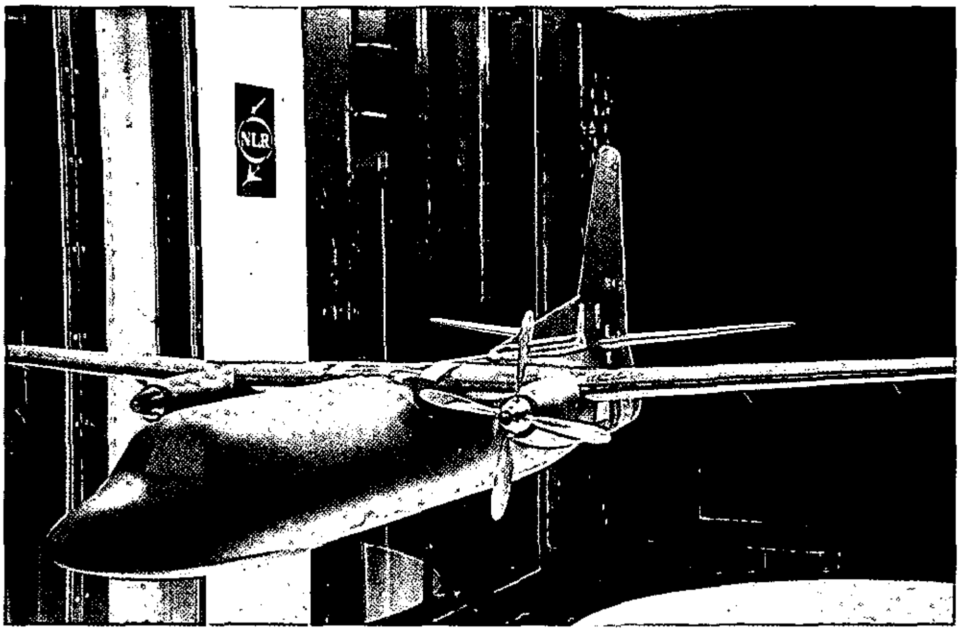
- For the third time NLR took part in the Asian Aerospace Air Show held in Singapore. During trade days a lot of business visitors showed interest. After the Paris Air Show, Singapore attracts the second biggest number of international participants.
- At the exhibition 'Het Instrument' in Utrecht, NLR showed its capabilities in the field of Electromagnetic Compatibility.
- NLR was present on an EU Information Market on European R & D activities held in the Rai Congress Centre, Amsterdam.
- The ITEC (International Training Conference and Exhibition) was held in the Hague. In the stand of the Netherlands Industrial Simulator Platform, NLR showed its simulation facilities in a video film and slide show specially focused on the National Simulation Facility.
- NLR contributed to the stand of the Gas Turbine Association (VGT) during the ASME Conference and Exhibition held in the Hague. Nearly 6000 visitors were registered.
- His Royal Higness Prince Willem Alexander opened the Exhibition 'The Netherlands 75 Years in Aeronautics' held at the Aviodome museum at the occasion of the 75th anniversaries of NLR, KLM and Fokker.
- At the 'Open Day' of the Royal Air Force held at Leeuwarden Airbase, NLR showed exposition panels.
- NLR participated in the Static Show of the Air Tattoo 1994 at Fairford Airbase in the UK. Many visitors showed interest in technical details of NLR's Metro II research aircraft.
- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) during the Farnborough Airshow 1994. A delegation of the Dutch Parliament showed special interest in NLR's Defence activities.
- The 'First International Airborne Remote Sensing Conference and Exhibition' took place in Strassbourg. NLR participated in the Static show and the exhibition.
- In the Hague the NIID organised a Symposium 'Priorities under Fire' and Euclid held an international Euclid symposium. During these events, 36 industries showed their activities for defence in an exhibition. NLR demonstrated the Mission Support System MSS/Campal.
- At Gatwick Airport NLR participated in The Airport Regions Conference.

Events

- Well-attended New Year receptions for the staff, held in Amsterdam and Noordoostpolder.
- The annual lunch of members of the Works Council with members of the Board of the Foundation NLR.

- Meetings at Amsterdam and Noordoostpolder for acquainting new employees with activities and procedures.
- The Second Progress Meeting of Euclid RTP 9.1.
- The 7th European Symposium of the Society of Flight Test Engineers held in the Aviodome, with an exhibition and an excursion.
- Dr. J. Cohen (State Secretary of Education and Science) unveiled the name 'Prof. J.H. van der Maas' on the new Cessna Citation II research aircraft PH LAB, which is operated by NLR and the Delft University of Technology. The event took place in the NLR hangar at Schiphol.
- The celebration of the 75th Anniversary of NLR in the RAI Congress Centre in Amsterdam. The celebration consisted of an official meeting for NLR personnel and pensioners, followed by a reception and a symposium for business relations.
- At the occasion of its 55th anniversary the NLR Staff Association organized a party for all members.

Dr. J.E. Andriessen, then minister of Economic Affairs, at the Symposium held at the occasion of the 75th anniversary of NLR



Fokker model provided with an
internal balance and mounted on a
sting in the LST

6 Scientific Committee NLR/NIVR

The Scientific Committee provided advice:

- To the Board of the Foundation NLR, on:
  - the results of the work NLR carried out under the Programme for basic research and development of facilities of NLR;
  - the preliminary Work Plan for 1995;
  - the Programme for basic research and development of facilities for 1996;
- To the Boards of Directors of NLR and NIVR, on:
  - the results of the work carried out by NLR in 1993 under the 'General Research Programme with a view to aircraft development in the near future' (ARP) of NIVR;
  - the reports NLR submitted to the Committee to be considered for suitability as scientific publications;
- To the Board of NIVR, on:
  - the subjects qualifying for a contract of NIVR in the framework of the ARP in 1994 or 1995.

Membership of the Scientific Committee

The composition of the Scientific Committee changed in 1994 by the resignations of Prof.ir. P. Jongenburger and Prof.dr.ir. J.A. Steketee. Both have been members of the Scientific Committee for many years. Their successors were expected to be appointed in the first half of 1995. At the end of 1994 the Scientific Committee was composed as follows:

Prof.dr.ir. P.J. Zandbergen, *chairman*
Prof.ir. C.J. Hoogendoorn
Prof.ir. T. de Jong
Ir. P.G. Vermeulen, *secretary*

Membership of the Subcommittees

Five new Subcommittee members were appointed:

- Ir. P.L. van Leeuwen (Fokker Space & Systems), in the Subcommittee for Space Technology;
- Ir. L.H. van Veggel (Fokker Aircraft) in the Subcommittee for Structures and Materials;
- Drs. H. Walgemoed (Fokker Aircraft) in the Subcommittee for Structures and Materials;
- Major H.J. Koolstra (Royal Netherlands Air Force) in the Subcommittee for Flying Qualities and Flight Operations;
- Ir. H.B. Langeraar (Hollandse Signaalapparaten), in the Subcommittee for Flying Qualities and Flight Operations.

Six members resigned:

- Prof.dr.ir. J.A. Steketee, who, in addition to being a member of the Scientific Committee, was chairman of the Subcommittee for Aerodynamics. His vacancy has not been filled in 1994.
- Prof.dr.ir. J.F. Besseling, chairman of the Subcommittee for Structures and Materials. The chair was taken over by Prof.dr.ir. H. Tijdeman, who was already a member of this Subcommittee.
- Ir. J.P. Groen, of the Subcommittee for Space Technology.
- Prof.ir. P. Jongenburger, who was a member of the Subcommittee for Structures and Materials, as well as of the Scientific Committee.
- Dr. P.V. Kandachar, of the Subcommittee for Structures and Materials.
- Major E.A. van Kleef, of the Subcommittee for Flying Qualities and Flight Operations.

Concluding remarks

The Annual Report of the Scientific Committee contains the following concluding remarks:

'The beginning of the long-awaited recovery of the aircraft market appears to have modestly emerged by the end of 1994. This could, however, not prevent new, drastic reorganizations in the world's aircraft industry from being on the order of the day also in 1994. In the Netherlands, in the beginning of 1995, radical measures were announced that have to safeguard the Dutch aircraft industry's survival in the long term. In the space technology sector a decreasing tendency can be observed as well, mainly because the available government funding is under severe pressure.

Nevertheless, NLR has managed to acquire a large volume of contracts, as in previous years. The Scientific Committee is convinced that the strong position of NLR is partly due to the excellent way in which the basic research is carried out. The basic research provides the knowledge base of NLR, and besides the available facilities determines the attractiveness of NLR to customers. The basic research has been carried out satisfactorily in the opinion of the Scientific Committee also in 1994. NLR co-operates with a large number of partners, but in particular the co-operation with sister institute Deutsche Forschunganstalt für Luft- und Raumfahrt (DLR) is worth mentioning. By this co-operation, the future synergy between Fokker and the German parts of Daimler-Benz Aerospace will be effected on the level of the technological institutes as well. This holds true not only for programmatic tuning, but also for the management and operation of facilities. An example of this is the joint operation of the low-speed wind tunnel LST.

The Scientific Committee has expressed approval with the Work Plan for 1995. In the area of space technology, on the basis of the tendencies observed, the Scientific Committee views as optimal the balance of priorities NLR has made. In the area of aviation technology, NLR pursues the course that it has to be capable of providing support in the fields that are important to an aircraft industry that develops aircraft. In the present situation the Scientific Committee is of the opinion that this is necessary, although in the future tuning with the German partners will be unavoidable. In contacts with DLR, NLR is in the process of giving shape to this tuning.

In the area of new facilities, in 1994 NLR has continued operating energetically. By the end of 1994 the National Simulation Facility was brought into operation, and preparations were made for the second phase of the modernization of the transonic wind tunnel HST. In the opinion of the Scientific Committee it is of crucial importance to both NLR and the national industry that the laboratory has at its disposal the most modern research facilities, also in view of its position with respect to potential customers in the world.

Finally, it must be noted that the output of NLR in the form of technical reports, proceedings of lectures during congresses etc. was again impressive. NLR is represented at many important international congresses at invitation, which indicates that NLR has a good reputation internationally.'

Subcommittees

At the end of 1994 the subcommittees were composed as follows:

Subcommittee for Aerodynamics

Vacancy, chairman
Prof.dr.ir. P.G. Bakker
Dr.ir. R. Coene
Prof.dr.ir. J.L. van Ingen
Prof.dr.ir. F.T.M. Nieuwstadt
Prof.ir. E. Obert
Prof.ir. E. Torenbeek
Ir. N. Voogt
Prof.dr.ir. P. Wesseling
Prof.dr.ir. L. van Wijngaarden

Subcommittee for Space Technology

Prof.ir. H. Wittenberg, *chairman*
Dr. B. Baud
Prof.dr.ir. J.A.M. Bleeker
Ir. P.Ph. van den Broek
Dr.ir. N.J.J. Bunnik
Prof.dr. W. de Graaff
Ir. P.L. van Leeuwen
Prof.dr.ir. L.P. Ligthart
Prof.ir. N.J. Mulder
Prof.ir. K.F. Wakker

Subcommittee for Structures and Materials

Prof.dr.ir. H. Tijdeman, *chairman*
Prof.dr. Joh. Arbocz
Ir. F. Holwerda
Prof.dr.ir. Th. de Jong
Lt.Kol. ir. J.W.E.N. Kaelen
Prof.dr. A. Rothwell
Prof.dr.ir. J. Schijve
Ir. L.H. van Veggel
Drs. H. Walgemoed
Prof.dr. J.H.W. de Wit
Prof.dr.ir. S. van der Zwaag

Subcommittee for Applied Mathematics and Information Technology

Prof.dr.ir. P. Wesseling, *chairman*
Prof.ir. D. Bosman
Drs. P.J.W. ten Hagen
Prof.dr.ir. G.Y. Nieuwland
Prof.dr. J. Olsder
Prof.dr.ir. J. Schalkwijk
Prof.dr.ir. C.R. Traas

Subcommittee for Flying Qualities and Flight Operations

Prof. J.H.D. Blom, *chairman*
KTZSD ir. K. Bakker
Ir. H. Benedictus
Ir. W.G. de Boer
J. Hofstra
Ir. R.J.A.W. Hosman
Ir. H.J. Kamphuis
Maj. H.J. Koolstra
Ir. H.B. Langeraar
Prof.dr.ir. J.A. Mulder
Prof.ir. E. Obert
Lt.Kol.Vl. b.d. A.P. Okkerman
Ir. H. Tigchelaar

Radar image from the ERS-1 satellite
of an area in the East of the
Netherlands at high water levels in
the Rhine and Meuse

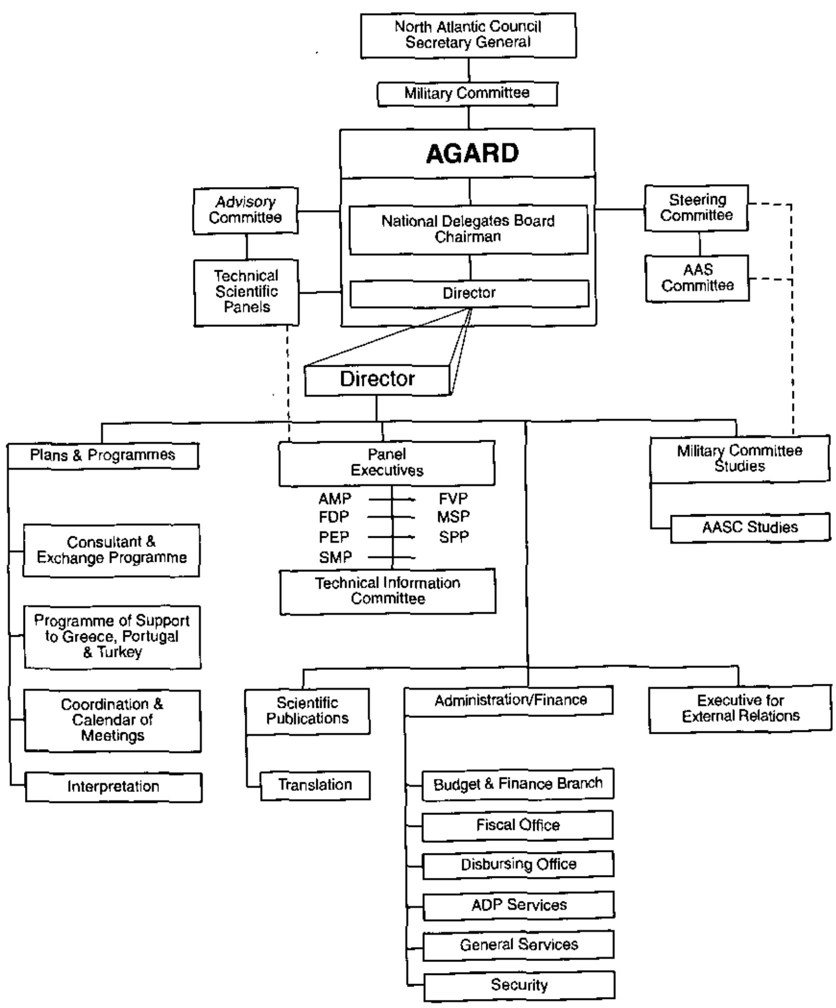
7.1 AGARD

Mission

According to its Charter, the mission of AGARD, the Advisory Group for Aerospace Research and Development, is to bring together the leading personalities of the NATO member nations in the fields of sciences and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving co-operation among member nations in aerospace research and development;
- Exchanging scientific/technical information;
  Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

Organization



Organization Diagram of the Advisory Group for Aerospace Research and Development

AGARD is organized around three main elements:

- The National Delegates Board, the governing body, assisted by a Steering Committee and an Advisory Committee;
- The AGARD staff, the executive body;
- The Scientific and Technical Panels and the Aerospace Applications Studies Committee, which together constitute the expert bodies of the Agency.

These main elements carry out the AGARD mission through a number of differentiated and specialized activities, including:

- Panel programmes of conferences, symposia and specialists' meetings, and meetings of sub-committees and working groups;
- Consultant and Exchange programmes under which individual consultants are provided to NATO member nations, Lecture Series are organized, and personnel exchanges and contacts arranged;
- A programme of Military Committee studies, consisting of aerospace applications and technology studies initiated at the request of the NATO Military Committee;
- A publication programme resulting from the above activities or initiated by them;
- A programme of support to the Southern Flank nations (Greece, Portugal and Turkey).

Summary of Main Activities

Panel Meetings/Symposia

AGARD symposia are technical meetings concerned with subjects of relatively general interest within specific fields. In 1994, sixteen symposia have been organized, one of them in the Netherlands.

Lecture Series

AGARD organizes a limited number of Lecture Series each year. Each series is given for two days, usually in three NATO member nations, as requested by the nations. In 1994, six Lecture Series have been organized, one of them in the Netherlands.

Special Courses

A team of experts presents lectures in one, and rarely in two or three nations on a specific topic. In 1994, five Special Courses have been organized, none of them in the Netherlands.

Support Programmes

The following numbers of support programmes were active in 1994:

Greece: 23
Portugal: 25
Turkey: 35

The Netherlands actively participated as a supporting nation in six programmes.

Consultants Programme

In 1994 a total of 70 consultants missions have been carried out.

Military Committee Studies Programme

The Steering Committee, with advice from the Aerospace Applications Studies Committee, normally recommends two topics from the Military Committee Memorandum as Aerospace Applications Studies each year. In 1994 two studies commenced, AAS-41 and AAS-42.

National Delegates Board Meetings

Twice a year the National Delegates Board comes together for a meeting. The 1994 Spring meeting was held in Paris, whereas the Autumn meeting took place in London. At the Autumn meeting a combined session of the National Delegates Board and the NATO Defence Research Group was implemented. For a period of two years holding such combined sessions will be continued, to discuss common areas of interest and to harmonize politics. The combined sessions will be integrated in the Spring meetings of the National Delegates Board.

Netherlands Delegation to AGARD

The Netherlands Delegation consists of:

- three National Delegates (two provided by NLR);
- one National Co-ordinator (NLR);
- twenty Panel Members (twelve provided by NLR).

7.2 The German-Dutch Wind Tunnel

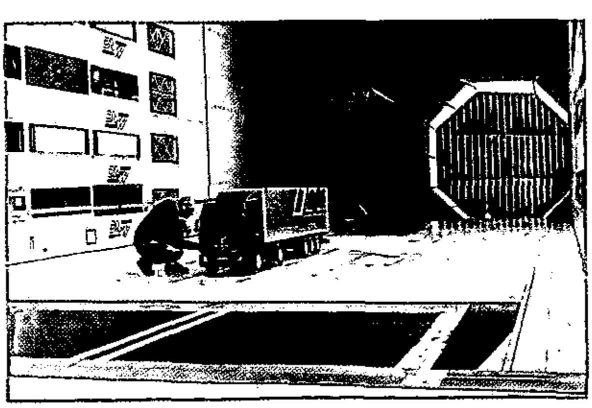
Since 1980, NLR operates – on an equal base together with the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) – the German-Dutch Wind Tunnel (DNW). The tunnel is located on the Noordoostpolder site of NLR.
In 1994 the DNW was well occupied for contract testing. Large efforts were spent for the updating of test systems and auxiliary equipment.

The Board of DNW at the End of 1994

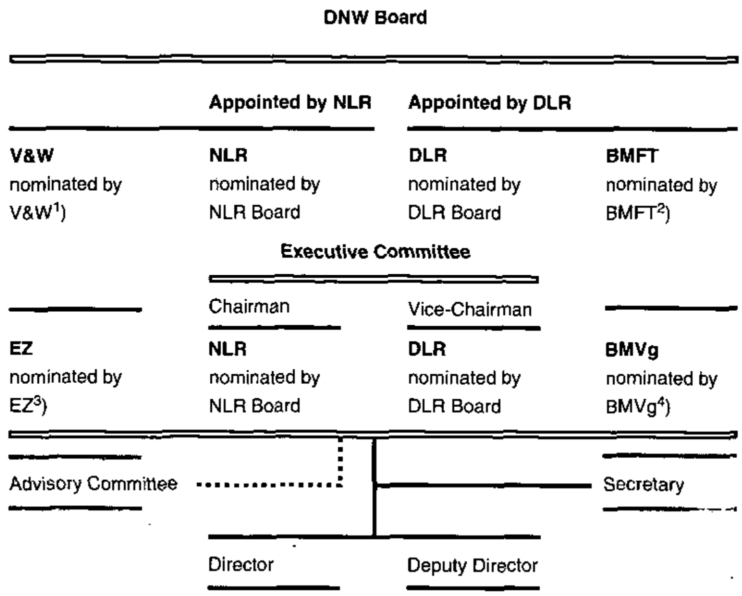
J. van Houwelingen, *Chairman**	NLR
Dr.rer.publ. J. Blum, *Vice-Chairman*	DLR
Drs. G.M. van Aardenne	Netherlands Agency for Aerospace Programs (NIVR)
Min.Rat R. Schreiber	Ministry of Defence of the Federal Republic of Germany (BMVg)
Min.Rat Dr. H. Diehl	Ministry for Research and Technology of the Federal Republic of Germany (BMFT)
Dr.-Ing. O. Lawaczeck	DLR
Dr.ir. B.M. Spee, *Chairman**	NLR
Ir. H.N. Wolleswinkel	Ministry of Transport of the Netherlands (RLD)

Secretary: Dipl.Volksw. A. Dick

* In the course of the year Mr. Van Houwelingen laid down his assignment as chairman and member of the Board of DNW. NLR appointed Dr.ir. B.M. Spee as his successor in the function of chairman. The vacancy he left was not filled at the end of the year.



Big tunnel - small model. A model lorry is tested under near 'free field' circumstances, to examine the effects of test section side walls and roof on the measurements. Test results are compared with those of a full-scale truck in the same test section



Organization diagram of the Foundation German-Dutch Wind Tunnel (DNW)

1) Ministry of Transport and Public Works (NL)
2) Ministry of Research and Technology (D)
3) Ministry of Economic Affairs (NL)
4) Ministry of Defence (D)

The Advisory Committee

The Advisory Committee, providing support to the Board, and representing the aerospace industry and research establishments:

Dipl.-Ing. O. Friedrich	Panavia Aircraft GmbH
Dipl.-Ing. J. Thomas	Deutsche Aerospace Airbus
Prof.dr.ir. J.L. van Ingen, *Chairman*	Delft University of Technology
Prof.ir. E. Obert	Fokker Aircraft
Dipl.-Ing. J. Roeder	Airbus Industrie
Prof.ir. J.W. Slooff	NLR
Dipl.-Ing. K. Buchholz	Deutsche Aerospace Dornier
Prof.Dr.-Ing. F. Thomas	DLR
Ir. F. Holwerda	Fokker Aircraft
Y. Richard	Eurocopter
Secretary: Dr.-Ing. G. Lehmann	

The Board and the Advisory Committee had one joint meeting.

The Board of Directors

The Board of Directors of the DNW consisted of:
Prof.Dr.-Ing. H.U. Meier (DLR), *Director*
Ir. A.H. Runge (NLR), *Deputy Director*

The year 1994 was marked by the agreement reached between NLR and DLR to increase their co-operation. In this context it was decided to concentrate capabilities in their facilities and to use the Foundation DNW as a possible nucleus for (low-speed) wind tunnel testing. It was agreed to enter into a trial period of two years, starting 1 January 1994, during which period DLR leases its Niedergeschwindigkeits-Windkanal Braunschweig (NWB) and NLR leases its Lage-Snelheids Tunnel (LST) to the Foundation DNW. A Joint Operation Team (JOT), consisting of members of both organizations, develops activities 'to harmonize operational and exploitational practices and to co-ordinate interface activities'. This first year of joint operation has shown that an extension of the co-operation existing within DNW with two additional tunnels does not pose too many problems from an organizational point of view. Less simple are issues that arise when 'harmonization' is translated into 'standardization', a matter that cannot be avoided if 'an optimal economic result for all parties concerned is (to be) realized'.

In 1994 some 1000 hours were spent on contract testing, about 225 hours of which for the automotive industry. Aircraft testing comprised twelve entries covering the complete span of the testing capabilities of the DNW:

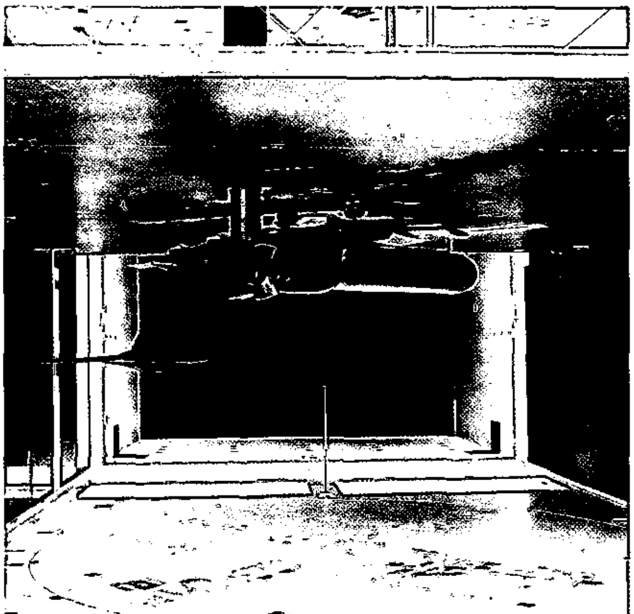
- force and moment measurements on full models of transport type aircraft, both with and without engine simulation, and ground effect measurements;
- near-field and far-field noise measurements on both rotary configurations and fixed-wing aircraft;
- flow field studies on high-lift configurations and helicopter rotors, using laser-light sheet and particle image velocimetry (PIV).

For the automotive industry, eleven test campaigns were executed, nine of which concerned passenger cars and two concerned full-sized lorries. The complexity of these tests and the diversity of problem areas have steadily increased. Ground simulation by means of a moving belt is becoming almost a standard requirement, and tests on interior noise levels, car body deformation, internal flows and cooler efficiency get ever increasing weights in the programmes.

Large efforts were made to increase the testing potential of the DNW. In a two-year programme the complete set of measuring channels of the static data acquisition system (SDA) was replaced; the system now comprises a total of 112 channels. The new channels have a twice better resolution than the previous ones. Their settings can be controlled and monitored from a local and a host computer.

Also, the system for dynamic data acquisition (DDA) has been upgraded. It now comprises a twelve-channel 12-bit front end and a 40-MFLOPS data processing workstation capable of overnight reduction of data from a full eight-hour shift production run.

The LST logged some 860 hours of contract testing, about equally divided in tests for the aircraft industry and tests for other industrial clients. In the latter category some major test campaigns were devoted to navy vessels (exhaust gas dispersion and wind climate on helicopter decks) and rail vehicles (including the internal flow of cooling air). In the category of aircraft testing two major test



Hot-gas recirculation tests in the LST on an aircraft model featuring thrust reverser flaps on the rear-fuselage-mounted jet engines campaigns were notable. The first concerns re-ingestion tests on a model of a twin-engined jetliner with deployed thrust reversers. The second test comprised force and moment measurements on a 1:10-scale model of a transport helicopter with rotating hub (blades off) to determine model support interference, in preparation of future test entries.

7.3 The European Transonic Windtunnel (ETW)

On behalf of the Netherlands, NLR is a 7% shareholder in the European Transonic Windtunnel GmbH, established in 1988. An important milestone in 1994 was the start of the initial operation of the facility per 1 July 1994, following a successful completion of the commissioning and calibration period. In the second half of 1994, strong marketing efforts resulted in the first contracts for test campaigns to be executed for the industry.

At the end of 1994 the membership of the Supervisory Board, from which Mr. Van Houwelingen retired, was as follows:

France	IGA G. Dorey	(ONERA)
	IGA J. Chéret	(DRET/SDCE)
	ICA E. Lisack	(DPAC)
Germany	Dr. H. Diehl	(BMFT)
	Dr.rer.publ. J. Blum, *Chairman*	(DLR)
	Mr. H. Max	(DLR)
United Kingdom	S.I. Charik	(DTI)
	Dr. G.T. Coleman	(DRA)
	Dr. D.S. Woodward	(DRA)
The Netherlands	Ir. H.N. Wolleswinkel	(V&W)
	Dr.ir. B.M. Spee	(NLR)

Managing Director Operation of ETW is Mr. T.B. Saunders, assisted by:

Dr. G. Hefer (G)	Manager Aerodynamics and Projects
Ir. J.C.A. van Ditshuizen (NL)	Marketing Manager
J.P. Hancy (F)	Manager Technical Operations
J.F. Moutte (F)	Administration Manager

7.4 GARTEUR

The Group for Aeronautical Research and Technology in Europe (GARTEUR) was formed in 1973 by representatives of the government departments responsible for aeronautical research in France, Germany and the United Kingdom. The Netherlands joined in 1977 and Sweden in 1992.

The aim of GARTEUR is, in the light of the needs of the European Aeronautical Industry, to strengthen collaboration in aeronautical research and technology between countries with major research and test capabilities and with government-funded programmes in this field.

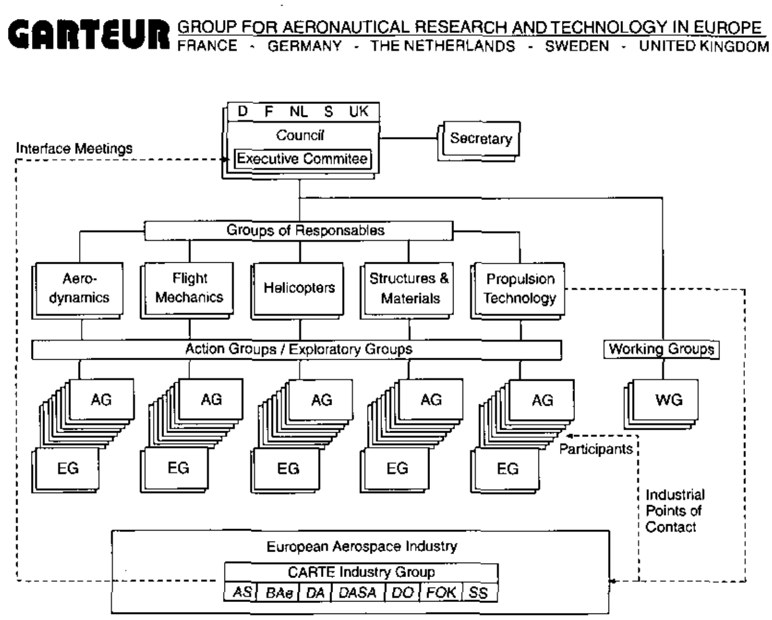
GARTEUR co-operation is concentrated on pre-competitive aeronautical research. The potential research areas and subjects are identified by Groups of

Responsables and investigated for collaboration feasibility by Exploratory Groups. If the subject is feasible, an Action Group is established in which normally all GARTEUR countries participate.

GARTEUR provides no special funding for its activities. The participating parties provide for all costs of their part of the work.

Organization

The organization diagram shows three levels: the Council/Executive Committee, the Groups of Responsables and the Action Groups. Via CARTE (Group for Collaboration on Aeronautical Research and Technology in Europe) GARTEUR has an interface with the European Aerospace Industry.



Organization Diagram of the Group for Aeronautical Research and Technology in Europe

Composition GARTEUR Council and Executive Committee

France

IGA J. Chéret	(DRET/SDEP) *)
IGA M. Bénichou	(ONERA)
ICA J.M. Duc	(ONERA) **)
ICA E. Lisack	(DGAC/DPAC)
ICA J.L. Moulibert	(DCAé/STPA)

Germany

Dr. W. Döllinger	(BMFT) *)
Dr. D. Diehl	(BMFT)
Dr. R. Haupt	(DLR) **)
Prof.Dr. W. Kröll	(DLR)
Prof. F. Thomas	(DLR)

United Kingdom

M.J. Earwicker	(DRA) *)
S.I. Charik	(DTI)
Dr. G.T. Coleman	(DRA) **)
Dr. C. Sanger	(MOD)
Dr. R.H. Warren	(DRA)

Sweden

MGen L.B. Persson	(FFA) *)
A. Gustafsson	(FFA) **)
Ch. Heinegard	(Nutek)
BGen P. Lundberg	(FMV-FML)

The Netherlands

J. van Houwelingen	(NLR) *)
Prof.ir. F.J. Abbink	(NLR) **)
Dr.ir. B.M. Spee	(NLR)

*) member of the Executive Committee
**) Head of Delegation

From 1994, Mr. Van Houwelingen holds the chairmanship of the Council for a period of two years. Prof. Abbink holds the chairmanship of the Executive Council for the years 1994 and 1995. The Secretary of GARTEUR for the period 1994-1995 is Mr. L. Sombroek (NLR).

Garteur Strategy

At the 15th GARTEUR Council meeting on 29 October 1994, the Council discussed the report of a study by Mr. Frank W. Armstrong. The Council decided to adopt the main recommendation, viz 'The GARTEUR Council should resolve that GARTEUR shall play a stronger and more strategic role in the long-term development of aeronautical research and technology acquisition in Europe and that appropriate enabling steps shall be taken'. In order to enable the Council to operate in a more strategic and pro-active manner, with improved continuity of action, the Council decided to accept the following specific recommendations of the Armstrong Report:

a. Chairmanship of the Council to be held for two years;
b. Council to meet twice a year (in such a way that the Spring Council meeting will include discussing the Annual Report whereas at the Autumn Council meeting the long term planning and policy matters will be discussed);
c. Council to consider and keep under active review such topics as:
   - the long term strategic evolution of aeronautics research and technology acquisition in Europe, including its status in relation to competition from the USA and elsewhere;
   - the evolution of relationships between European research establishments, including the implications of new alignments between industrial enterprises;
   - the evolving situation regarding important facilities;
   - the development of GARTEUR research programmes, and their relationship to those of other organizations;
d. to consider the access to the Council of senior industry representatives;
e. to review the possibility of Spain and Italy to become more closely associated with GARTEUR in the near future.

NLR Participation

NLR participates in all five Groups of Responsables.

At the end of 1994, twenty-five Action Groups were active; NLR participates in all of these Groups.

7.5 Co-operation with European Research Establishments in Aeronautics

DLR/NLR Partnership

Background

On 26 January 1994, a formal partnership agreement between DLR and NLR was signed. This partnership is based on the good experience obtained with the co-operation within DNW. The aim of the partnership is to strengthen the ties between the two establishments in order to make more effective use of the extensive knowledge and facilities available.

In order to manage this task, a Joint Executive Board has been set up, consisting of representatives of DLR and NLR. The chairmanship will rotate annually.

DLR/NLR Executive Board at the End of 1994:

J. van Houwelingen (*chairman*)	NLR
Prof. W. Kröll (*vice-chairman*)	DLR
Dr. B.M. Spee	NLR
Prof. F. Thomas	DLR

The Board was assisted by Dr.K.H. Kreuzberg (DLR) and Drs. A. de Graaff (NLR).

Two Committees were established, a Facilities Committee and a Programme Committee.

The Facilities Committee

Dr.-Ing. J.W. Beck (*chairman*)	DLR
Prof. F.J. Abbink	NLR
Dr.-Ing. H. Körner	DLR
Prof. J.W. Slooff	NLR

The Programme Committee

Prof. F.J. Abbink (*chairman*)	NLR
Dr. G. Bartelds	NLR
Dr.-Ing. E. Breitbach	DLR
Dipl.-Ing. H. Max	DLR

Facilities

The partners will stimulate joint operation and use of existing research facilities. Furthermore, the partners will exchange information on planned investments and where possible embark on joint or complementary investments. Potential facilities for close co-operation are supercomputers, research aircraft, flight simulation equipment and wind tunnels. To start the enhanced co-operation, the DLR-owned NWB wind tunnel and NLR's LST wind tunnel were leased to DNW, which is now responsible for the management of the new conglomerate of DLR/NLR low-speed wind tunnels. It is the intention of the partners to transfer the legal ownership of the two smaller low-speed wind tunnels to the foundation DNW at the end of 1995.

Basic Research

The partners agreed to strengthen their collaborative efforts with respect to a number of basic research topics, such as aerodynamics (propulsion/airframe integration, CFD), structures, design techniques, avionics and safety. The co-operation should strengthen the co-operation within GARTEUR and form the nucleus for proposals for research projects under the Framework Programme of the European Union and Euclid.

AEREA: Association of European Research Establishments in Aeronautics

Supported by the Commission of the European Communities (CEC), the seven European aeronautical research establishments have developed a joint vision on future co-operation. The aim of this co-operation is to serve the European market in future by creating the aeronautical technology base needed in Europe in the most effective and efficient way. The joint vision was presented to the seven national governments, the CEC, the industry and others during a seminar on 9 September 1993. As the initiative was well received by all concerned, on 11 October 1994 the research establishments formed an Association, in order to realize the first steps in a process which ultimately should lead to setting up a Union between regional centres. In the Union, strong organisational ties should exist, resulting in integrated management of joint activities, pooling of facilities and the creation of interdepencies and specialisation.

The parties within the Association realize that the speed and outcome of this federative process will be highly dependant on the developments within the markets and the environment of the research establishments. Therefore, the Association has started with a modest action plan comprising facilities, basic research and personnel exchange.

Organization

Within AEREA, a Heads of Establishment Board has been set up, as the highest body within the Association.
The Heads of Establishment Board consisted of:

IGA M. Bénichou, *Chairman*	(ONERA)
M. Earwicker	(DRA)
Prof. Dr. C. Golia	(CIRA)
J. van Houwelingen	(NLR)
Prof. W. Kröll	(DLR)
Maj. Gen. L.B. Persson	(FFA)
Prof. E. Trillas	(INTA)

The Heads of Establishment Board is assisted by a Strategy and Co-ordination Group, chaired by Dr. K.H. Kreuzberg, in which NLR is represented by Drs. A. de Graaff.

Facilities

The Associates will establish a policy of co-ordinated use of and investment in large facilities. This should result in a rational utilization of existing and future facilities for common European needs. A Facilities Committee will be established to prepare this common policy.

In 1994 a Subcommittee on Wind Tunnel Facilities was already established in which Prof. Abbink and Drs. De Graaff took part. This Subcommittee reviewed the European needs and capabilities regarding large wind tunnels, also with respect to plans in the United States, Russia, Japan and other countries. The Subcommittee will recommend actions to be taken to facilitate pooling and joint acquisition of wind tunnel facilities in Europe.

Research

The associates intend to develop and execute a number of joint research programmes. Therefore a Programme Committee will be set up to propose and manage strategic multidisciplinary programmes. The Programme Committee will link its activities to those in GARTEUR.

Personnel Exchange

In order to strengthen the co-operative efforts, a Personnel Exchange and Development Committee will be set up. Personnel exchange will stimulate the creation of interdependence amongst the Associates and create the right European spirit amongst the staffs of the establishments.

Relations to CEC

Since 1989, the aeronautical research establishments have worked together in the Aeronautical Research Group (ARG) to facilitate the communication with the CEC and the information exchange amongst the establishment on CEC-related issues. It has been agreed that the ARG, chaired by Drs. A. de Graaff (NLR), will be part of AEREA.

7.6 Co-operation with Indonesia

Background

In 1980 a co-operation with Indonesia was started between NLR and the Agency for the Assessment and Application of Technology (BPPT) in Indonesia, primarily to realize the foundation of an aerodynamic laboratory (LAGG) in Serpong, near Jakarta, to support the fast developing aircraft industries in Indonesia. The main project, the design and construction of the Indonesian Low Speed Wind Tunnel (ILST) was completed in 1978.
The support by NLR was part of the Technical Assistance projects TTA-79 and TTA-79, Phase II 'Integrated Support for Aeronautical Research and Development' (ISARD). The Delft University of Technology (DUT) and Fokker, together with their Indonesian counterparts Institute of Technology Bandung (ITB) and Indonesian Aircraft Industries IPTN), respectively, also took part in the projects; ISARD was successfully completed in September 1991.

With the same participants an interim programme for education, research and development (APERT) was started in the beginning of 1992, planned to last two years. Like in the foregoing projects, NLR and BPPT are the co-ordinating bodies for APERT, which is sponsored by Fokker and NLR on the Dutch side and by IPTN and BPPT/LAGG on the Indonesian side. The programme is supported by both Governments, which was upheld by the signing of a MoU by the Ministers B.J. Habibie and J.M.M. Ritzen in September 1992.

Execution of APERT

The co-operation of APERT consists of:

- Project Bandung – Continuation of the integrated support of ITB by DUT;
- Project Serpong – Continuation of the integrated support of ILST operations by NLR;
- Project Joint Research – Definition, preparation and execution of joint research programmes.

Owing to certain circumstances the execution of several activities lagged behind the two-year plan. In April 1993 the APERT Governing Group therefore decided to extend the programme with one year. Additional funds were allocated for the activities in Serpong; for the other activities no extra funds were needed, because sufficient money remained to finish the activities that had been planned, but not yet executed.

On 10 May the second and final meeting of the Joint Working Group on Aerospace Technology resulted in a proposal to continue the co-operation in 1995 for another three years under the name APERT 95. An overall financial plan was also presented. During the Plenary Programme Meeting on 11 May in Jakarta, the proposal was discussed and in principle approved by the Governing Group.

In a letter of 19 September Minister J.M.M. Ritzen informed his colleague Minister B.J. Habibie, that he fully supported the intention of the institutes and organizations involved to continue the co-operation after 31 December 1994. At the end of the year an official response from the Indonesian side regarding the follow-up of APERT was not yet received. APERT was therefore officially concluded; in accordance with the original planning a small number of activities, for which funds were already allocated (Dutch contribution), will be executed. Although the objective to have the APERT 95 programme approved before the end of 1994 was not met, it became clear that parties concerned in both countries are prepared to start joint activities as soon as the go-ahead is received.

Other Activities

Activities under the umbrella agreement between IPTN and NLR, signed on 30 June 1988, were modest.

Appendices

1 Publications

In 1994, NLR produced a total of 620 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

TP 91062 U (3)
European studies to investigate the feasibility of using 1000ft vertical separation minima above FL290 - Part III: Further results and overall conclusions
Moek, G.; Have, J.M. ten; Harrison, D.; Cox, M.E.

TP 92046 U
The layered safety concept, an integrated approach to design and validation of air traffic management enhancements
Blom, H.A.P.

TP 92135 U
System design for Artemis environmental monitoring
Ingen Schenau, H.A. van; Spaa, J.

TP 92333 U
KADAM -knowledge-based assistant for diagnosis in aircraft maintenance- final report
Donker, J.C.; Piers, M.A.

TP 92429 U
Integration of simulation and visualization aids in aircraft accident investigation
(Paper presented at the Conference 'The use of simulation in aircraft accident prevention and investigation', Royal Aeronautical Society, London, 11 and 12 November 1992)
Groeneweg, J.

TP 92455 U
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(Paper presented at the AGARD joint FMP/GCP Symposium on "Combat Automation for Airborne Weapon Systems: Man/Machine Trends and Technologies", Edinburgh, 19–22 October 1992)
Urlings, P.J.M.; Pijpers, E.W.; Hagmeijer, R.; Cock, K.M.J. de

TP 92456 U
Flight path calculations for a helicopter in autorotative landing
(Presented at the "18th European Rotorcraft Forum", Avignon, France, 15–18 September 1992)
Gebhard, A.

TP 92459 U
Structural optimization in preliminary aircraft design – A finite element approach
(Presented at the "18th ICAS Congress", Beijing, China, 20–25 September 1993)
Arendsen, P.; Wiggenraad, J.F.M.

TP 92464 U
Tracking splitting targets in clutter by using an interacting multiple model joint probabilistic data association filter
Bar-Shalom, Y.; Chang, K.C.; Blom H.A.P.

TP 92468 U
Parametric uncertainty modeling using LFTs
(Presented at the "1992 AIAA Guidance, Navigation and Control Conference", Hilton Head Island, South Carolina, USA, 10–12 August 1992)
Terlouw, J.; Lambrechts, P.; Bennani, S.; Steinbuch, M.

TP 93017 U
Worst case gust shapes for atmospheric turbulence with known spectrum
Noback, R.

TP 93028 U
Some aspects of aircraft response to atmospheric turbulence
Noback, R.

TP 93055 U
On the radar cross section prediction of a cylindrical cavity
(Paper presented at the "Workshop RCS '92", Marseille, France, 10 November 1992)
Heijstek, J.J.; Maseland, J.E.J.; Schippers, H.

TP 93057 U
Analysis of the alignment of a schlieren system for tele-operation
Spaan, F.H.P.; Kramer, A.J.

TP 93067 U
A damage tolerance study conducted with structure relevant specimens
Labonte, S.; Wiggenraad, J.F.M.

TP 93084 U
A position reference system for the Fokker 70
(Paper presented at the "Second International Symposium on Differential Satellite Navigation Systems", 29 March–2 April 1993, Amsterdam)
Leijgraaf, R. van de; Breeman, J.; Moek, G.; Storm van Leeuwen, S.

TP 93105 U
Mathematical modelling and numerical simulation of a two-phase heat transport system condenser
Dam, A.A. ten; Berg, J.I. van den

TP 93107 U
A knowledge-based assistant for diagnosis in aircraft maintenance
(Paper presented at the AGARD Symposium in Lisbon, Portugal, May 1991)
Piers, M.A.; Donker, J.C.

TP 93109 U
Review of aeronautical fatigue investigations in the Netherlands during the period March 1991–March 1993
(Paper presented at the "23rd ICAF Conference", Stockholm, 7–8 June 1993)
Jonge, J.B. de

TP 93143 U
Acquisition of service flight load data
(Paper presented at the "5th Australian Aeronautical Conference", Melbourne, September 1993)
Jonge, J.B. de

TP 93153 U
The crack severity index of monitored load spectra
(Paper presented at the "77th Meeting of the AGARD Structures and Materials Panel", Bordeaux, September 1993)
Jonge, J.B. de

TP 93154 U
Space-qualified optical memory for the Columbus pressurized module
Algra, T.

TP 93155 U
Compressive strength of various CFRP's tested by different laboratories
Hart, W.G.J. 't

TP 93175 U
Design methodology for a damage tolerant HAT-stiffened composite panel
Wiggenraad, J.F.M.

TP 93182 U
Workload in air traffic control communication
(Paper presented at the "Ergonomics Society's Annual Conference 1993", Heriot-Watt University, Edinburgh, 13–16 April 1993)
Nijhuis, H.B.

TP 93185 U
FAME: A forest assessment and monitoring environment scenario
(Paper presented at the "United Nations/ Indonesia Regional Conference on Space Science and Technology for Sustainable Development", Bandung, Indonesia, 17–21 May 1993)
Burg, G. van der; Looyen, W.J.; Venema, J.C.

TP 93193 U
Similarity transformations between minimal representations of convex polyhedral cones
Dam, A.A. ten

TP 93196 U
Description of the CN-235 fatigue load monitoring programme
(Paper presented at the "ICAF '93 Conference", Stockholm, Sweden, 9–11 June, 1993)
Lameris, J.; Dominicus, J.; Sulaeman, K.; Suryo, D.; Sudrajat, A.R

TP 93198 U
The development procedures and tools applied for the attitude control software of the Italian satellite SAX
(Paper presented at the 65th avionics panel meeting/symposium "Aerospace software engineering for advanced system architecture", Paris, France, 10–14 May 1993)
Hameetman, G.J.; Dekker, G.J.

TP 93214 U
A fast and robust viscous-inviscid interaction solver for transonic flow about wing/body

configurations on the basis of full potential theory
Wees, A.J. van der; Muijden, J. van; Vooren, J. van der

TP 93226 U
A position reference system for flight tests based on GPS/IRS integration
Storm van Leeuwen, S.; Leijgraaf, R. van de

TP 93247 U
On the simulation of fluid spacecraft interactive dynamics
Guelman, M.

TP 93256 U
The designing, fabrication and testing of discrete stiffened CFRP compression panels with different stringer concepts
(Paper presented at the "Second Canadian International Conference on composite Structures and Materials (CANCOM 1993)", NRC-CNRC, Ottawa, Ontario, Canada, September 1993)
Thuis, H.G.S.J.

TP 93257 U
Rotating shaft balance for measurement of total propeller force and moment
Custers, L.G.M.; Hoeijmakers, A.H.W.; Harris, A.E.

TP 93260 U
Drag prediction for transonic transport aircraft using a full-potential method
Vooren, J. van der; Doctor, F.; Wees, A.J. van der

TP 93274 U
Preparation and demonstration of a support technology concept for in-orbit payload operations
(Paper presented at the Third European In-Orbit Operations Technology Symposium, ESTEC, Noordwijk, 22–24 June 1993)
Pronk, C.N.A.; Visser, F.B.; Sijmonsma, R.M.M.

TP 93276 U
The impact of the SSR Mode S data link within the ATN on air/ground information exchanges (Executive summary of NLR TR 93249 L)
Esser, R.G.W.J.

TP 93280 U
A comparative evaluation of three take-off performance monitor display types
Verspay, J.J.L.H.; Khatwa, R.

TP 93286 U
"Space for the User", DUC in The Netherlands
(Paper presented at the "Ninth Columbus Symposium", Ischia, Italy, 28 June–2 July 1993)
Visser, F.B.

TP 93288 U
Effect of cooling rate on interlaminar fracture energy and shear strength of APC-2 laminates
Hoeven, W. van der

TP 93289 U
FIRST: A flexible remote sensing tool
(Paper presented at the IGARSS '93 Conference)
Borger, J.; Weegink, J.; Oostdijk, A.; Hurink, M.

TP 93301 U
Multigrid convergence acceleration for the 2D Euler equations applied to high-lift systems
Cock, K.M.J. de

TP 93304 U
Characterization of impact damage in carbon-epoxy composites
(Paper presented at the European Symposium on 'Impact and Dynamic Fracture of Polymers and Composites', 20–22 September 1993, Porto Cervo (Sardinia), Italy)
Heida, J.H.; Konijnenberg, P.; Hart, W.G.J. 't

TP 93343 U
Development of a smart camera optimized for telescience operations
Kuijpers, E.A.; Sabbatini, M.; Gjaltema, T.; Versteeg, J.B.

TP 93348 U
Development of advanced approach and departure procedures - failure scenarios -
Erkelens, L.J.J.; Dronkelaar, J.H. van

TP 93349 U
Clebsch variabale model for unsteady inviscid transonic flow with strong shock waves
Westland, J.; Hounjet, M.H.L.

TP 93356 U
Fatigue and fracture properties of aerospace aluminium alloys
Wanhill, R.J.H.

TP 93360 U
The analysis of integrated air traffic management environments – A functionality driven approach
Have, J.M. ten

TP 93388 U
Integrated adaptive control for space manipulator operations
(Paper presented at the 44th Congress of the International Astronautical Federation, 16–22 October, 1993)
Woerkom, P.T.H.L.M. van; Guelman, M.; Ehrenwald, L.

TP 93393 U
Similarity transformations between minimal representations of convex polyhedral sets
Dam, A.A. ten

TP 93394 U
In-orbit demonstration of two-phase heat transport technology: TPX/G557 development & pre-launch testing
Delil, A.A.M.; Heemskerk, J.F.; Dubois, M. (SABCA); Oost, S. van (SABCA); Supper, W. (ESA); Aceti, R. (ESA)

TP 93403 U
Embedding adaptive JLQG into LQ Martingale with a completely observable stochastic control matrix
Blom, H.A.P.; Everdij, M.H.C.

TP 93418 U
Validation of the helicopter rotor code HERO
Bosschers, J.

TP 93423 U
Reduction of fatigue load experience as part of the fatigue management program for F-16 aircraft of the RNLAF
Spiekhout, D.J.

TP 93432 U
Robust inverse shape design in aerodynamics
Soemarwoto, B.I.

TP 93459 U
Space manipulator deformation models and accuracy of berthing manoeuvres
Woerkom, P.Th.L.M.; Boer, A. de

TP 93467 U
Man-machine interface for future civil aviation
Abbink, F.J.

TP 93478 U
Simulation of fully automated traffic control concepts
Braven, W. den; Bos, J.C. van den

TP 93511 U
Numerical investigation into vortical flow up to incidences at which vortex breakdown occurs in experiment
Berg, J.I. van den; Hoeijmakers, H.W.M.; Brandsma, F.J.

TP 93535 U
Re-analysis of European flight load data
Jonge, J.B. de; Hol, P.A.; Gelder P.A. van

TP 93554 U
Two-dimensional elliptic grid generation based on the Laplace equations and algebraic transformations
Spekreijse, S.P.

TP 93563 U
In-flight acoustic mode measurements in the turbofan engine inlet of Fokker 100 aircraft
Sarin, S.L. (Fokker); Rademaker, E.R.

TP 93576 U
Gas turbine compressor corrosion and erosion in Western Europe
Kolkman, H.J.

TP 94005 U
Pilot performance in automated cockpits: a comparison of moving and non-moving thrust levers
Folkerts, H.H.; Jorna, P.G.A.M.

TP 94022 U
Dutch Participation in Columbus APM mission simulation
Pronk, C.N.A.

TP 94045 U

A tensor-skin concept for crashworthiness of helicopters in case of water impact
(Paper presented for the "American Helicopter Society AHS 50th Annual Forum and Technology Display", Washington, U.S.A., 11–13 May 1994)
Thuis, H.G.S.J.; Wiggenraad, J.F.M.

TP 94058 U

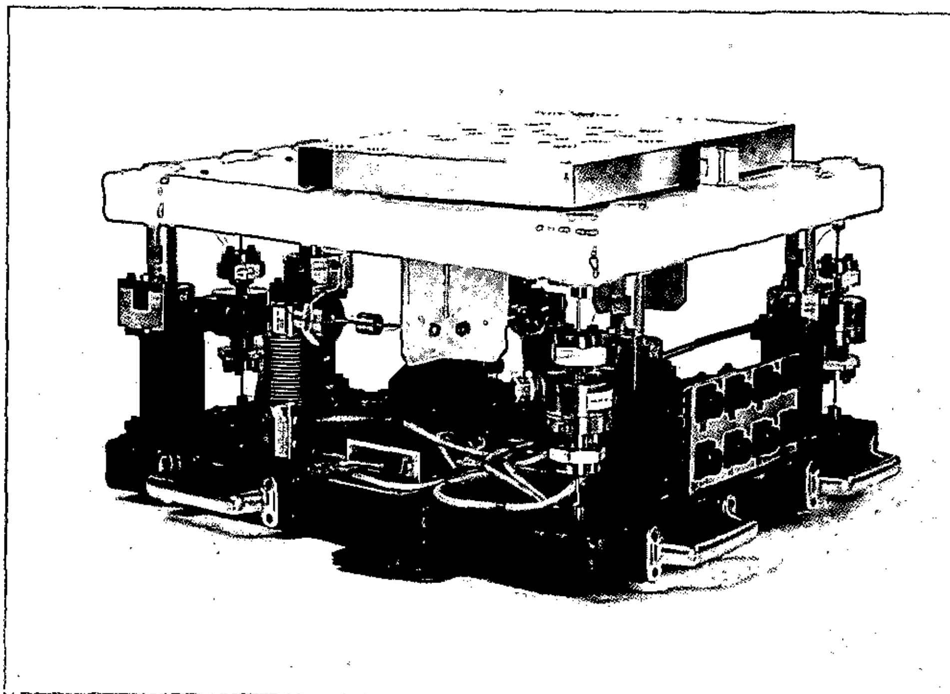
Stress distribution around a circular hole in a fibre metal laminate finite-width plate specimen
Rijn, J.C.F.N. van

TP 94083 U

Optimization of composite stiffened panels with postbuckling constraints
(Paper presented at the "4th International Conference on Computer Aided Design in Composite Material Technology (CADCOMP 94)", Southampton, England, 29 June–1 July 1994)
Arendsen, P.; Thuis, H.G.S.J.; Wiggenraad, J.F.M.

TP 94102 U

Elliptic grid generation based on Laplace equations and algebraic transformations
Spekreijse, S.P



Six-component balance for non-aerospace model testing

2 Abbreviations

AEREA	Association of European Research Establishments in Aeronautics
AGARD	Advisory Group for Aerospace Research and Development (NATO)
AIAA	American Institute of Aeronautics and Astronautics
APERT	Aerospace Programme for Education, Research and Technology
ARALL	ARamide Aluminium Laminate
ATC	Air Traffic Control
BCRS	Beleidscommissie Remote Sensing (Netherlands Remote Sensing Board)
BMFT	Bundesministerium für Forschung und Technologie (Federal Ministry for Research and Technology)
BMVg	Bundesministerium für Verteidigung (Federal Ministry for Defence)
BRITE	Basic Research in Industrial Technologies for Europe
CAE	Computer-Aided Engineering
CAESAR	CCD Airborne Experimental Scanner for Applications in Remote Sensing
CARTE	Collaboration on Aeronautical Research and Technology in Europe
CEC	Commission of the European Communities
CIRA	Centro Italiano Ricerche Aerospaziale
DLR	Deutsche Forschungsanstalt für Luft- und Raumfart
DNW	Duits-Nederlandse Windtunnel (German-Dutch Wind Tunnel)
DRA	Defence Research Agency
EC	European Communities
EFIS	Electronic Flight Instrument System
EMI	Electro-Magnetic Interference
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESOC	European Space Operations Centre
ESPRIT	European Strategic Programme for Research and Development in Information Technology
ESTEC	European Space Research and Technology Centre
ETW	European Transonic Wind Tunnel
EUCLID	European Co-operation for the Long term In Defence
EURAM	European Research on Advanced Materials
Eurocontrol	European Organization for the Safety of Air Navigation
EZ	Ministerie van Economische Zaken (Ministry of Economic Affairs)
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FEL	Fysisch Elektronisch Laboratorium (TNO) (Physics-Electronics Laboratory)
FFA	Flygtekniska Försöksanstalten (Aeronautical Research Institute of Sweden)
FSS	Fokker Space & Systems
GARTEUR	Group for Aeronautical Research and Technology in Europe
GPS	Global Positioning System

HSA	Hollandse Signaalapparaten B.V.
HST	Hoge-Snelheids Tunnel (High Speed Wind Tunnel)
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IEPG	Independent European Programme Group
ILST	Indonesische Lage-Snelheids Tunnel (Indonesian Low Speed Tunnel)
INTA	Instituto Nacional de Técnica Aerospacial (Aerospace Research Institute of Spain)
IPTN	Nusantara Aircraft Industries (Bandung)
ISARD	Integrated Support for Aeronautical Research and Development
ITB	Institut Teknologi Bandung (Indonesië) (Technological Institute of Bandung, Indonesia)
JAR	Joint Airworthiness Regulations
KLM	Koninklijke Luchtvaart Maatschappij N.V. (KLM Royal Dutch Airlines)
KLu	Koninklijke luchtmacht (Royal Netherlands Air Force)
KM	Koninklijke marine (Royal Netherlands Navy)
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
KNVvL	Koninklijke Nederlandse Vereniging voor Luchtvaart (Royal Netherlands Aeronautical Association)
LAGG	Aero-Gas Dynamics and Vibration Laboratory
LST	Lage-Snelheids Tunnel (Low Speed Wind Tunnel)
LVB	Luchtverkeersbeveiligingsorganisatie (ATC The Netherlands)
MBB	Messerschmitt-Bölkow-Blohm
MLS	Microwave Landing System
MRVS	Meet-, Registratie- en Verwerkingssysteem (Measurement, Recording and Data Processing System)
NAG	Netherlands Aerospace Group
NASA	National Aeronautics and Space Administration (USA)
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation System with Time and Ranging
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programs)
NKO	Nederlandse Kalibratie Organisatie (Netherlands Calibration Organization)
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory NLR)
NLRGC	Nationaal Lucht- en Ruimtevaartgeneeskundig Centrum(National Aerospace Medical Centre)
NPOC	National Point of Contact
NSM	Niet-Stationaire Meetmethode (Non-Stationary Measurement Method)
NSF	Nationale Simulatie Faciliteit (National Simulation Facility)
ONERA	Office National d'Etudes et de Recherches Aérospatiales (Aerospace Research Institute of France)

RESEDA	Remote-Sensing Dataverwerkingssysteem (Remote Sensing Data Processing System)
RLD	Rijksluchtvaartdienst (Netherlands Department of Civil Aviation)
RTCA	Radio Technical Commission for Aeronautics
SICAS	SSR Improvement and Collision Avoidance System
SPOT	Système Probatoire Observation Terrestre
SSR	Secondary Surveillance Radar
SST	Supersone Snelheids Tunnel (Supersonic Wind Tunnel)
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)
TPD	Technisch Physische Dienst TNO-TU
TPS	Turbine-Powered Simulation
TTA	Technological/Technical Assistance
V&W	Ministerie van Verkeer en Waterstaat (Ministry of Transport and Public Works)
VKI	Von Kármán Institute of Fluid Dynamics
WEAG	Western European Armament Group
WL	Waterloopkundig Laboratorium (Delft Hydraulics)

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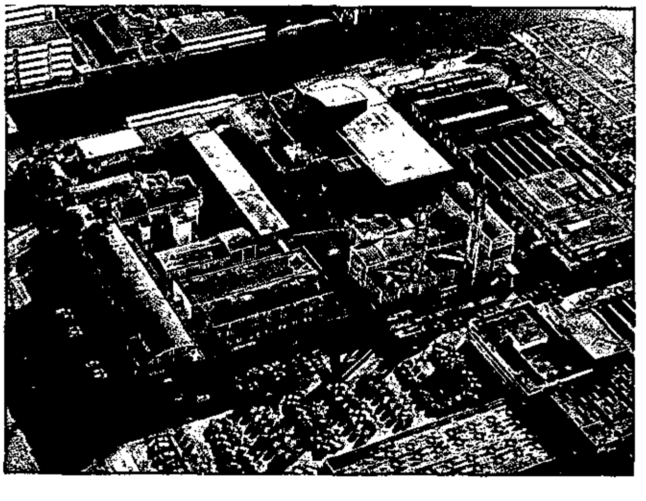

NLR Amsterdam
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NLR Noordoostpolder
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