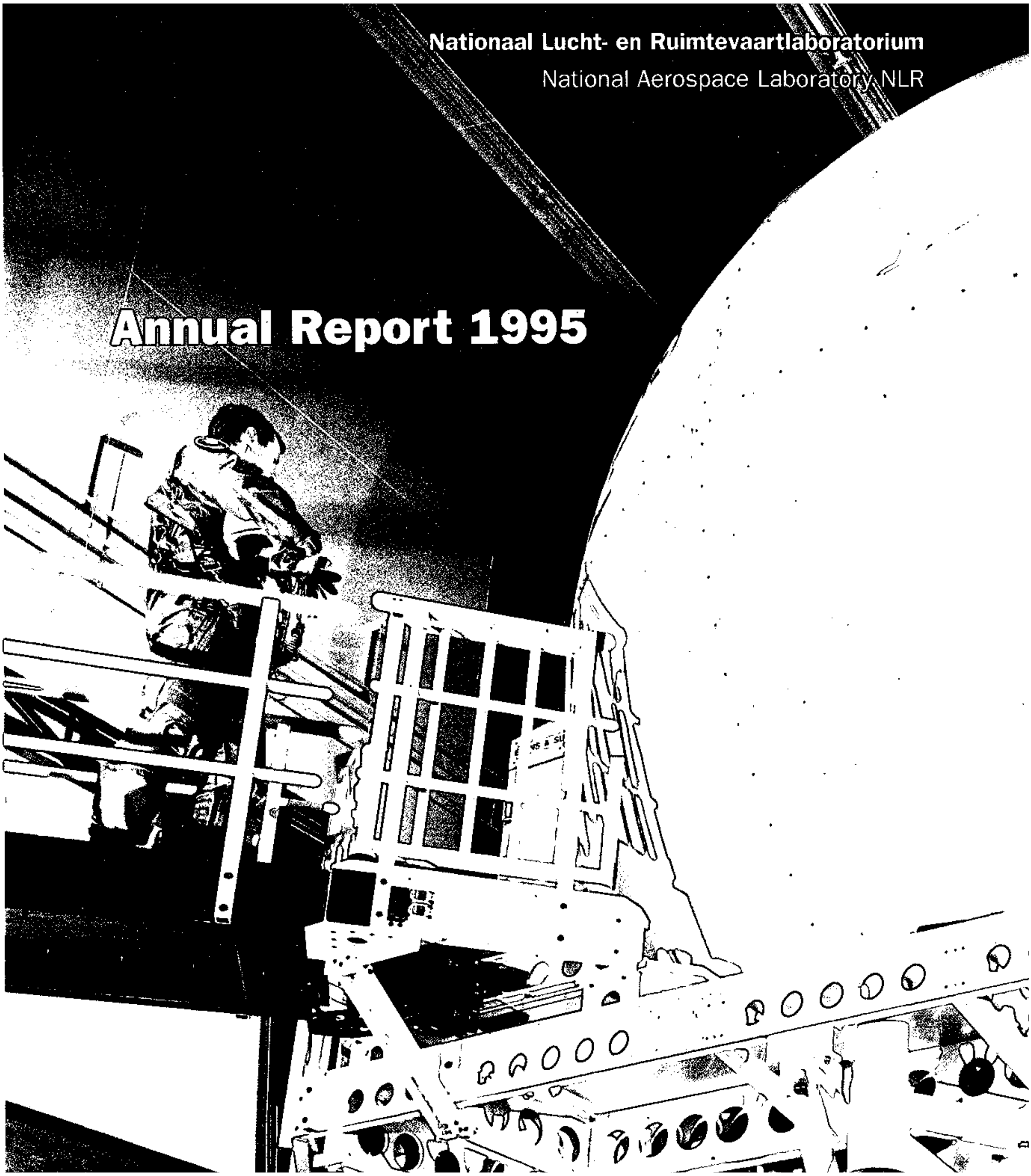
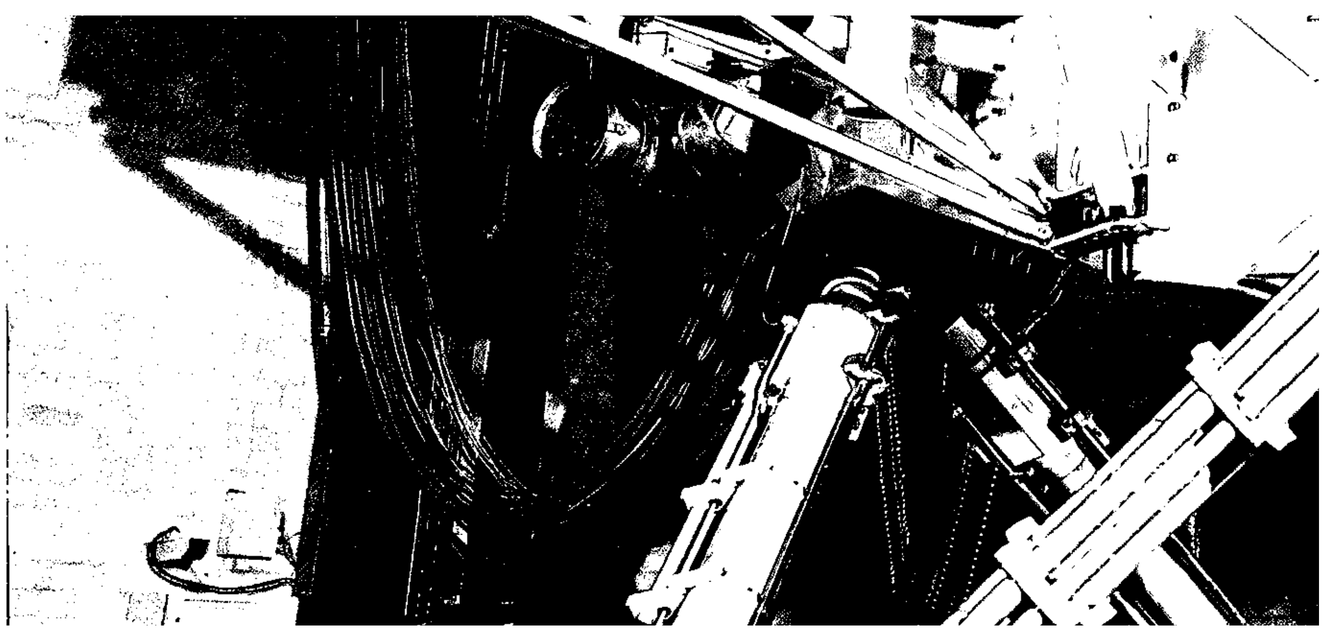
Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 1995





Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

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Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 1995

The Board of the Foundation NLR

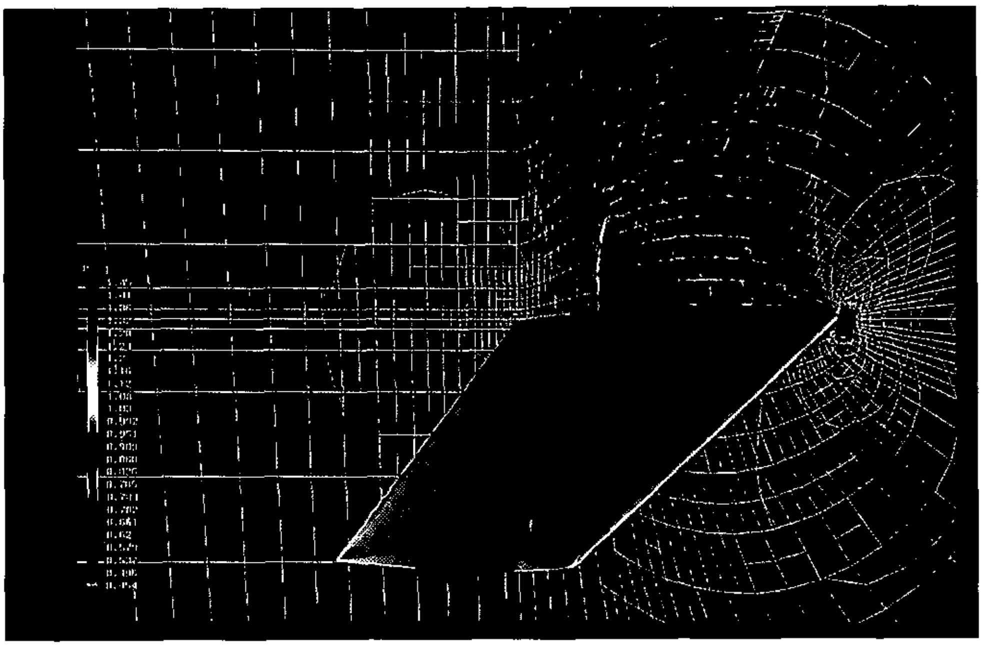
On 31 December 1995

	Appointed by:
J. van Houwelingen, *Chairman*	Ministers of Transport, of Defence, of Economic Affairs and of Education, Culture 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)
Drs. P.G. Winters	Minister of Economic Affairs
Dr. P.A.J. Tindemans	Minister of Education, Culture and Science
vacancy *Post held by Drs. G.M.V. van Aardenne until his death on 10 August 1995*	Netherlands Agency for Aerospace Programs (NIVR)
A. van Bochove	Air Traffic Control The Netherlands
B.J.A. van Schaik	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

On 31 December 1995

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



High-resolution pressure distribution of transonic flow over a wing calculated after grid enrichment

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1 Introduction

The year 1995 has been more difficult for NLR than the past several years. This was due to the fact that the Dutch government reduced its support for aerospace research programmes and due to delays in the decision processes of the projects of various customers. Nevertheless, the volume of contract work was satisfactory and NLR succeeded in realizing a small profit.

1995 showed a continuation of the strong growth of air traffic, at about the same level as in the preceding years. Although this growth, of both passengers and cargo transport, had a positive effect on the position of the airlines, the demand for new aircraft continued to be rather limited. The market for new aircraft is still weak, with fierce competition between the aircraft manufacturers and far too low prices. This situation brings the aircraft industry in a very difficult position, and during 1995 it became clear that it could have very negative consequences, particularly for Fokker. Early 1996 Fokker has gone bankrupt. This will undoubtedly have a strong negative effect on NLR's position.

As a result of its difficult position, the aircraft industry is reluctant to take initiatives for new aircraft projects, especially in Europe. This continues to have a negative effect on the need for support from the research institutes and particularly on the workload of the large test facilities of the institutes. This is further aggravated by the fact that also on the military side there is a lack of new aircraft projects in Europe.

The outlook for the research institutes on the longer term, however, is somewhat more positive. The continuously growing demand for air transport will call for new aircraft which satisfy much stricter rules with respect to environment and safety and which will enable the air transport system to increase its capacity and efficiency. The development of the technical means to solve the problems of the future air transport system requires large contributions from the institutes.

An important impetus to the development of the technology for future aircraft and for the air transport system has been given by the European Union (EU) within the fourth framework programme. This programme is intended to increase co-operation within Europe and to enable the European industry to keep its competitiveness up against the industries in the US and the far East. NLR has been very successful in obtaining a prominent position in many EU projects.

Due to the limited level of activities on civil aircraft development, NLR's attention shifted in 1995 to military development programmes (NH90, F-16 Mid Life Update) and to research programmes in support of aircraft operations, both civil and military. Also, a growing share of NLR's research projects are related to space technology.

In 1995 NLR gave strong support to a more intensive co-operation between the European research institutes both within the framework of GARTEUR, the Group for Aeronautical Research and Technology in Europe, which co-operation includes the industry, and within the framework of AEREA, the Association of European Research Establishments in Aeronautics. At the end of 1994 an important step in the co-operation between DLR, the Deutsche Forschungsanstalt für Luft- und Raumfahrt, and NLR was taken by integrating the low speed wind tunnels NWB-Braunschweig and LST-NOP, of DLR and NLR, respectively, with the foundation DNW.

J. van Houwelingen,
Chairman

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.

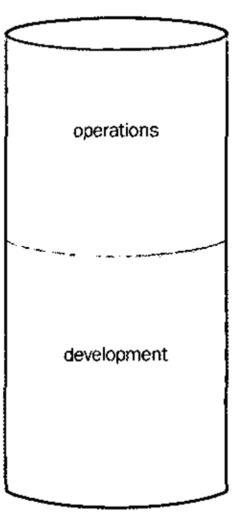
With sites in Amsterdam and in the Noordoostpolder, NLR operates several wind tunnels, laboratory aircraft and research flight simulators. NLR has available an extensive set of equipment for gathering, recording and processing flight test data. NLR also has facilities for research in the areas of Air 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.

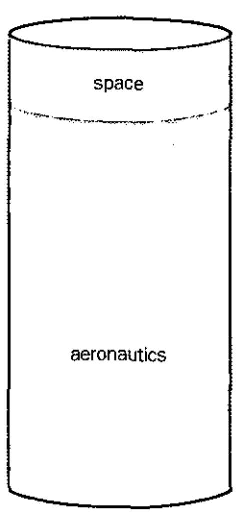
2.2 Activities in 1995

In 1995 NLR's turnover was 144 million guilders compared to 143 million in 1994. The income from contracts was 101 million guilders compared to 98 million in 1994.
In 1995 about 55% of the total of NLR's activities were related to the development, and 45% 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 65% and 35%, respectively. About 25% of the work under contract was carried out for foreign customers.

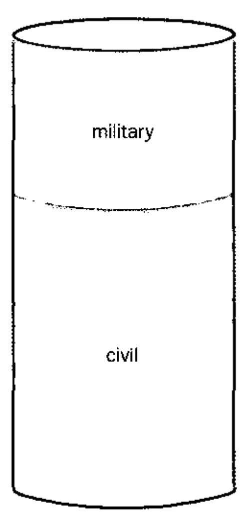
The total operating costs of NLR, amounting to 144 million guilders, included personnel costs of 92 million guilders.



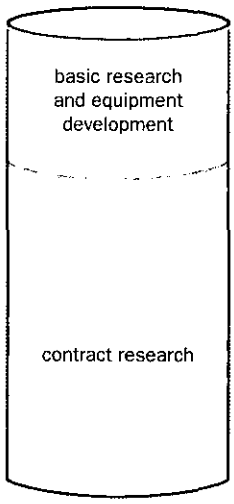
Division of the work into development and operations support



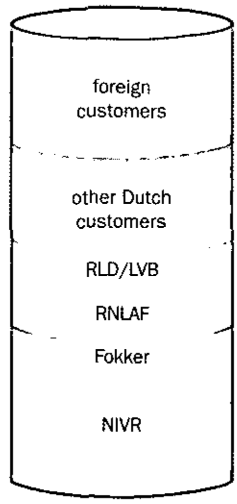
Division of the work into aeronautics and spaceflight support



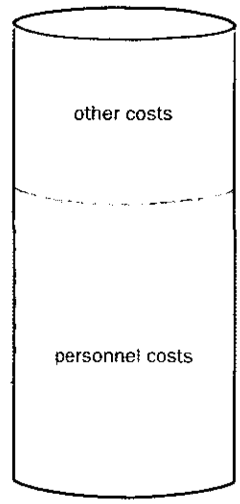
Division of the work into civil and military support



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

Services Provided under National Contracts

Activities under contract to Dutch customers amounted to 74 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 60, the further development of the Fokker 70 and the development of the NH90 helicopter. A major part of the work for the RLD was related to studies on airworthiness and 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 27 million guilders. Major customers were the European Space Agency, the Commission of the European Communities, Eurocontrol and Lockheed Martin. The contracts for Lockheed Martin included research for the development of the F-16 Mid Life Update.

Research and Equipment

NLR spent 24 million guilders on its basic aerospace research programme supported 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 19 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 42 million guilders was used for capital investments, of which the purchase of an NEC SX-4 supercomputer 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). At the end of 1994 it was decided to incorporate the 3-m low-speed wind tunnels of DLR and NLR, located in Braunschweig and in the Noordoostpolder, respectively, in the foundation DNW. The European Transonic Windtunnel (ETW), located near Cologne, Germany, started testing for customers. Germany, France, the United Kingdom and the Netherlands participate in this facility.

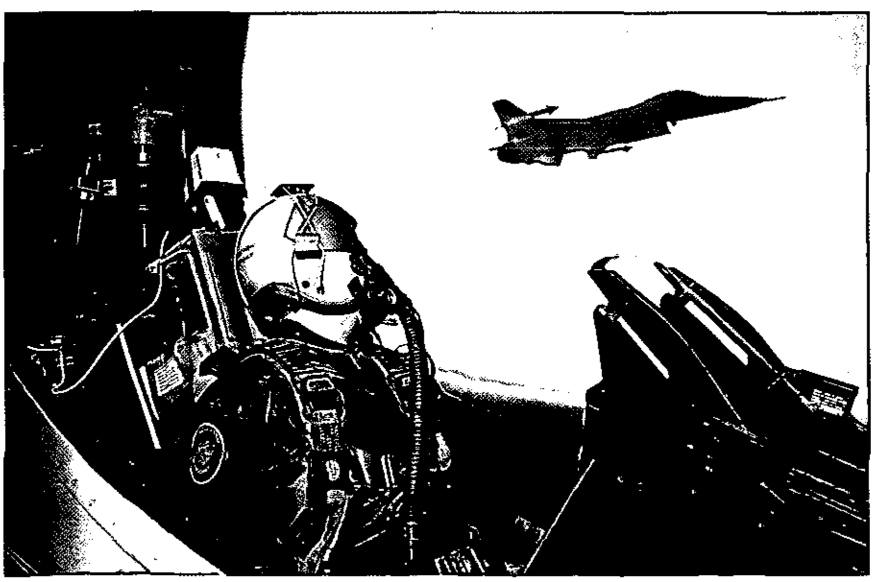
The seven aeronautical research establishments of the countries of the European Union continued their common activities under the agreement for co-operation within the Association of European Research Establishments in Aeronautics. The Association will execute joint research programmes and establish 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.



Detail of projector and head-tracked image in the NSF

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.

Drs. G.M.V. van Aardenne, member of the Board of the Foundation NLR since 1 July 1990, died on 10 August 1995. His death was a great loss to NLR and to the aerospace community in the Netherlands.

As from 1 January 1995, Mr. B.J.A. van Schaik succeeded Dr. R.J. van Duinen as member of the Board appointed by Fokker. As from 1 February 1995, Drs. P.G. Winters succeeded Ir. J.J. Kooijman as member of the Board appointed by the minister of Economic Affairs. As from 1 June 1995, Mr. A. van Bochove succeeded Ir. A.J. van Liere as member of the Board appointed by Air Traffic Control The Netherlands.

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

On 31 December 1995 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. H.A.T. Timmers, *Electronics and Instrumentation 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* and Ing. F.J. Sterk, *Head Support Staff.*

From 1 January 1995, NLR's activities in avionics, electronics and instrumentation are concentrated in the new *Electronics and Instrumentation Division.*

The organization of the laboratory on 31 December 1995 is shown on page 12.

At the end of 1995 NLR employed a staff of 944 (compared with 939 at the end of 1994), of whom 391 (379) were university graduates. Of the total, 840 (839) were employed on a permanent basis, and 104 (100) 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 13.

National Aerospace Laboratory NLR

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

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

ial Director
›erne R.A. **DF**

Associate Director — Drs. A. de Graaff (CPE) **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 — 's **DJ**
- *Legal* DJ
- *Filing* DB
- *Security* DB

Personnel — van Druten **DZ**, e Heer

Co-ord. AGARD / GARTEUR — ıbroek **DA**

Co-ord. Indonesia — **DI**

Company Welfare Work — Wielemaker **DM**, iekema **DM**

Fluid Dynamics
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 and Aeroelasticity** — Prof. ir. R.J. Zwaan **AE**
- **Aeroacoustics** — Dr. H.H. Brouwer **AK**

Flight
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**
- **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
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
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
Ir. W. Loeve **I**
- **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**

Electronics and Instrumentation
Ir. H.A.T. Timmers **E**
- **Avionics** — Ir. M.A.G. Peters **EA**
- **Electronics** — Ing. H. Slot **EE**
- **Instrumentation** — Ir. R. Krijn **EI**

Eng Tec
Ir. G.
- **Tecl** — Ir. C
- **Tecl** — A. v
- **Wor** — Ir. H

ıg and Services **T**
- **rojects** — thoff **TP**
- **esign** — ıerg **TO**
- Lafleur **TW**

General Services
Ir. W.F. Wessels **G**
- **Buildings** — Ing. H. van der Roest **GG**
- **Electrical Engineering** — A.M.G. Reijntjens **GE**
- **Domestic Services** — G. Lipsius **GZ**
- **Guarding** — G. Lipsius **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 Dispatch** — Drs. B.P.E. Haeck **OM**
- **Purchasing** — J.F. Post **OI**

Table 1 - The NLR staff (Cat. I: university graduates, Cat. II: advanced technical college graduates, Cat. III: others) at the end of 1995 (between brackets the numbers at the end of 1994)

		Cat. I		Cat. II		Cat. III		Total	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
- Support Staff		16	(15)	5	(7)	10	(7)	31	(29)
		19	(18)	5	(7)	10	(7)	34	(32)
Fluid Dynamics Division	A	2	(3)	1	(1)	3	(3)	6	(7)
- Aerodynamic Facilities	AF	12	(12)	22	(26)	23	(28)	57	(66)
- Experimental Aerodynamics	AX	16	(17)	9	(13)	–	(–)	25	(30)
- Aeroacoustics	AK	7	(7)	3	(3)	–	(–)	10	(10)
- Theoretical Aerodynamics	AT	19	(19)	–	(–)	–	(–)	19	(19)
- Unsteady Aerodynamics & Aeroelasticity	AE	7	(8)	3	(3)	–	(–)	10	(11)
- German-Dutch Wind Tunnel	AD	3	(3)	13	(13)	16	(17)	32	(33)
- Low Speed Wind Tunnel	AL	1	(1)	2	(3)	4	(5)	7	(9)
		67	(70)	53	(62)	46	(53)	166	(185)
Flight Division	V	4	(3)	1	(1)	1	(1)	6	(5)
- Flight Testing and Safety	VV	8	(7)	6	(6)	1	(2)	15	(15)
- Flight Simulation	VS	12	(11)	14	(13)	2	(3)	28	(27)
- Operations Research	VO	21	(21)	6	(6)	2	(2)	29	(29)
- Aircraft Instrumentation [1]	VA	–	(14)	–	(33)	–	(9)	–	(56)
- Man Machine Integration	VE	17	(18)	–	(–)	1	(–)	18	(18)
- Helicopters	VH	13	(13)	1	(1)	1	(1)	15	(15)
- Air Traffic Management	VL	31	(24)	3	(3)	1	(1)	35	(28)
- Flight Mechanics	VM	12	(12)	–	(–)	1	(–)	13	(12)
- Transport and Environmental Studies	VT	7	(9)	5	(4)	–	(–)	12	(13)
		125	(132)	36	(67)	10	(19)	171	(218)
Structures and Materials Division	S	1	(1)	1	(1)	–	(–)	2	(2)
- Loads	SB	8	(7)	5	(6)	2	(2)	15	(15)
- Structures	SC	13	(12)	3	(2)	1	(1)	17	(15)
- Materials	SM	7	(7)	4	(4)	–	(–)	11	(11)
- Testing Facilities	SL	–	(–)	13	(15)	19	(19)	32	(34)
		29	(27)	26	(28)	22	(22)	77	(77)
Space Division	R	2	(2)	–	(–)	1	(1)	3	(3)
- Remote Sensing	RR	7	(6)	4	(4)	–	(–)	11	(10)
- Systems	RS	15	(15)	–	(–)	–	(–)	15	(15)
- Labatories and Thermal Control	RL	8	(7)	7	(7)	1	(1)	16	(15)
		32	(30)	11	(11)	2	(2)	45	(43)
Informatics Division	I	1	(2)	1	(–)	4	(3)	6	(5)
- Electronics [1]	IE	–	(18)	–	(25)	–	(5)	–	(48)
- Mathematical Models and Methods	IW	15	(15)	–	(–)	–	(–)	15	(15)
- Numerical Mathematics and Applications Programming	IN	33	(28)	23	(24)	2	(2)	58	(54)
- Computing Centre and Systems Programming	IR	24	(25)	19	(18)	10	(12)	53	(55)
		73	(88)	43	(67)	16	(22)	132	(177)
Electronics and Instrumentation Division [1]	E	1	(–)	1	(–)	1	(–)	3	(–)
- Avionics	EA	12	(–)	7	(–)	–	(–)	19	(–)
- Electronics	EE	6	(–)	20	(–)	6	(–)	32	(–)
- Instrumentation	EI	13	(–)	32	(–)	8	(–)	53	(–)
		32	(–)	60	(–)	15	(–)	107	(–)
Engineering and Technical Services	T	1	(1)	–	(–)	1	(1)	2	(2)
- Technical Projects	TP	5	(5)	4	(4)	2	(2)	11	(11)
- Technical Design	TO	1	(1)	12	(11)	1	(1)	14	(13)
- Workshops	TW	1	(1)	15	(14)	21	(22)	37	(37)
		8	(8)	31	(29)	25	(26)	64	(63)
General Services	G	1	(1)	2	(2)	–	(–)	3	(3)
- Buildings	GC	–	(–)	2	(2)	1	(1)	3	(3)
- Electrical Engineering	GS	–	(–)	5	(5)	4	(5)	9	(10)
- Domestic Services	GZ	–	(–)	2	(2)	31	(29)	33	(31)
- Guarding	GX	–	(–)	–	(–)	8	(8)	8	(8)
- Library and Information Services	GB	2	(2)	3	(2)	4	(5)	9	(9)
- Document Processing	GT	–	(–)	5	(5)	31	(30)	36	(35)
		3	(3)	19	(18)	79	(78)	101	(99)
Administrative Services	O	–	(–)	–	(–)	–	(–)	–	(–)
- Administration	OA	2	(2)	17	(16)	16	(16)	35	(34)
- Stores and Dispatch	OM	–	(–)	1	(1)	4	(4)	5	(5)
- Purchasing	OI	1	(1)	6	(5)	–	(–)	7	(6)
		3	(3)	24	(22)	20	(20)	47	(45)
Grand total		391	(379)	308	(311)	245	(249)	944	(939)

[1] On 1 January 1995 the Electronics and Instrumentation Division was created, in which the Flight Division's Aircraft Instrumentation Department and the Informatics Division's Electronics Department were incorporated.

3 Activities

As mentioned in the preceding chapter, NLR has reorganized by establishing the new division Electronics and Instrumentation as of 1 January 1995. The activities are since then carried out by six rather than five divisions and three service groups. The present Chapter 3 is subdivided along the areas of technology as represented by the new organization, so that work previously mentioned under Flight or Informatics may now be found under Electronics and Instrumentation.

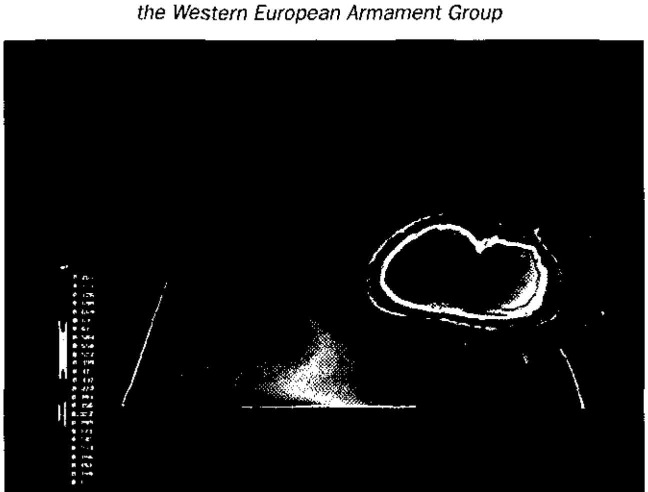
In many of the projects NLR carries out, specialists of several divisions co-operate. Inevitably, aspects of related activities may be described in different sections of this Chapter, although the activities are primarily grouped according to fields of technology.

3.1 Fluid Dynamics

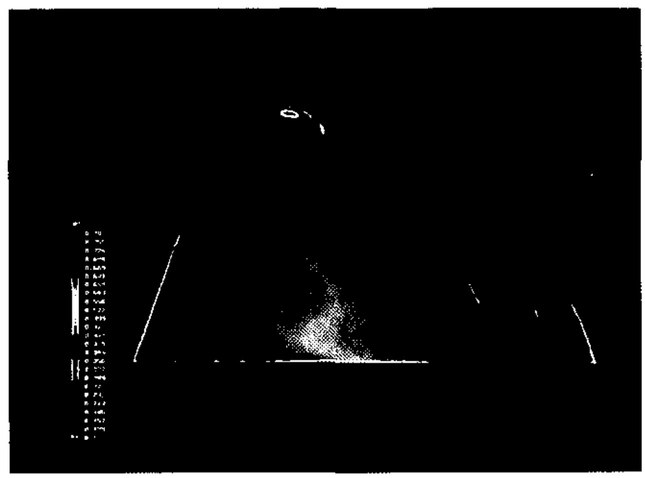
Summary

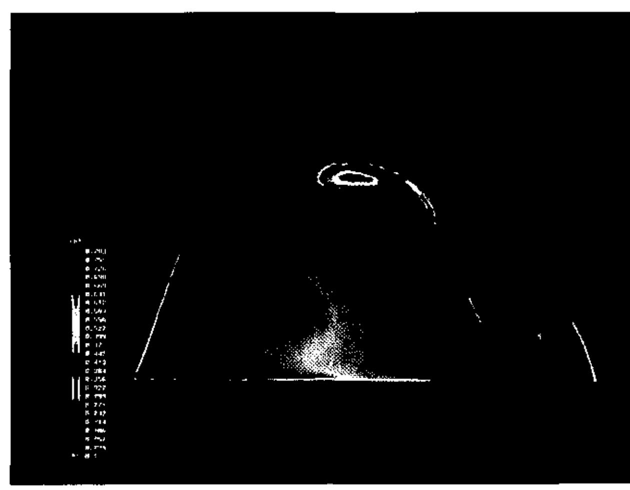
Technology research and development activities in fluid dynamics were executed in the areas of Experimental Aerodynamics, Computational Fluid Dynamics, Applied/Configuration Aerodynamics, Aeroelasticity and Aero-acoustics, both under contract and as part of NLR's basic research programme. Furthermore,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

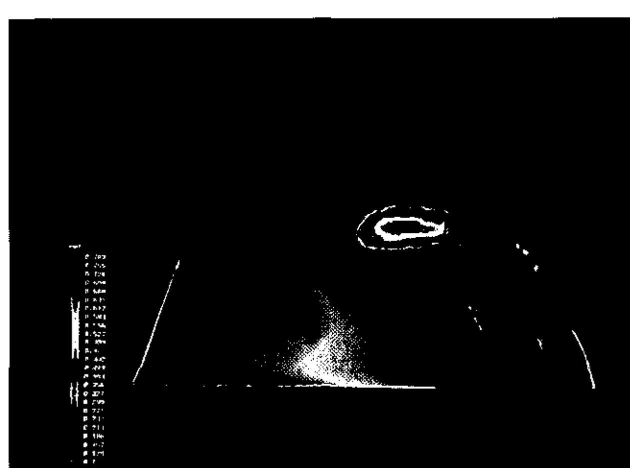
High angle-of-attack vortex flow calculated in an investigation executed in the framework of the Western European Armament Group



The total volume of contract research and development activities in fluid dynamics increased by about 12% relative to 1994. This increase was entirely due to foreign 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 (Group for Aeronautical Research and Technology in Europe) and in BRITE/EURAM (Basic Research in Industrial Technologies for Europe/European Research on Advanced Materials) projects of the European Union, in several areas of the aerodynamics of steady and unsteady flows and in aeroacoustics.

In the area of *applied/configuration aerodynamics* of civil aircraft, the activities were to a large extent aimed at supporting Fokker Aircraft in aerodynamic studies involving design, propulsion/airframe integration and high-lift systems.

The main thrust of the research and development activities in the field of *applied Computational Fluid Dynamics* is directed towards design for propulsion/airframe integration. These activities concentrate on refining NLR's computer code system ENFLOW for solving the Euler and Reynolds-averaged Navier-Stokes equations. Furthermore, in the framework of the Western European Armament Group (WEAG), NLR continued the verification and validation of the computer code system ENFLOW for fighter-type aircraft exploiting high-angle-of-attack vortex lift.

The activities in *aero-thermodynamics* involved the conservation of the Computational Fluid Dynamics (CFD) technology developed for the HERMES space vehicle, using hypersonic flow solutions of the full Navier-Stokes equations. Within the framework of the national programme AEOLUS (Advanced Earth to Orbit Launcher Upgrade Studies), 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.

Propeller *acoustics* research continued to be aimed at the development, validation and improvement of codes for the computation of the noise of installed single and counter-rotating propellers, taking into account the diffraction and refraction of sound by the aircraft fuselage. Research in turbofan acoustics was directed at improved descriptions of noise sources, duct acoustics and liner properties, and at the validation of models for rotor transmission, for rotor-alone noise, for low-frequency noise and for bulk-absorbing liner materials and active impedance control.

In the area of *experimental facilities*, the main efforts were directed at the preparations for Phase II of the modernization of the High Speed (transonic) wind Tunnel (HST), involving the replacement of the power plant and the drive motors, to be executed in 1996 to 1997. Other activities included the continued development of a new generation of accurate balances for force measurements and new measurement techniques such as Particle Image Velocimetry and Pressure Sensitive Paint.

Applied/Configuration Aerodynamics

Aerodynamics of Wings of Transport Aircraft

In collaboration with Fokker Aircraft, design and analysis codes have been applied in wing design studies. Drag prediction and analysis using the MATRICS-V full potential plus boundary layer code system has become a mature capability which has been applied by industry to a large number of wing-body configurations on a routine basis.

The MATRICS-V/WINGDES system was used to explore the design space of transonic wings, and to refine the aerodynamic design of wings at high transonic Mach numbers.

Off-design characteristics of transonic wings, such as drag divergence Mach numbers, buffet onset conditions and low-speed clean wing stall characteristics, were analysed on the basis of MATRICS-V computations.

NLR carried out studies on grid refinement and on the 'lift-carry-over' model of the MATRICS-V code for the analysis of the viscous flow about wing-body configurations. The code was successfully applied to a high-wing configuration. A wing/nacelle/pylon integration study was performed using the ENFLOW and MATRICS-V/WINGDES system.

New methods in wing design were explored as part of the European Computational Aerodynamics Research Programme (ECARP) of the European Union. A multi-point method was studied that uses the residual correction method combining Navier-Stokes and inverse panel methods. Results were presented on an ECARP Workshop. Work started on another very promising method for aerodynamic design, based on the adjoint-operator approach.

A new test entry in the Indonesian Low Speed Tunnel of the joint IPTN/LAGG/Boeing/NLR high-lift wing panel model with variable sweep, to study the slat flow in more detail, had to be postponed to 1996. For the next test campaign NLR has developed a miniature traversing probe to be used for boundary layer measurements.

NLR contributed to the European Laminar Flow Investigation (ELFIN) II programme of BRITE/EURAM by making stability calculations to predict transition in cross-flow dominated flows. Comparison of various approaches is expected to result in a reliable method for transition prediction.

The contribution to another BRITE/EURAM project, Euroshock, was continued. NLR's computer code ULTRAN-V for unsteady transonic flow was applied to investigate means to control shock/boundary layer interaction.

Propulsion Airframe Interaction

Computational propulsion/airframe interaction studies using the ENFLOW and PDAERO codes were continued in collaboration with Fokker Aircraft, both for turbofan and for propeller configurations. The PDAERO code was applied to wing/body/pylon/nacelle/propeller configurations with long and short pylons. Computational results for the span loads were compared with experimental pressure data from a wind tunnel test in the HST. Qualitative agreement between CFD results and experimental values was obtained for the different pylons.

In the GARTEUR Action Group (PT) AG-02 'Model turbofan calibrations' a common exercise was defined to validate model engine calibration facilities. A blown nacelle, a through-flow nacelle and a TPS engine have been tested in the facilities of ARA (Aircraft Research Agency), ONERA (Office Nationale d'Etudes et de Recherche Aérospatiales), DLR (Deutsche Forschungsanstalt für Luft- und Raumfahrt), DA (Deutsche Airbus) and NLR. The analysis of the results will be finalized in 1996.

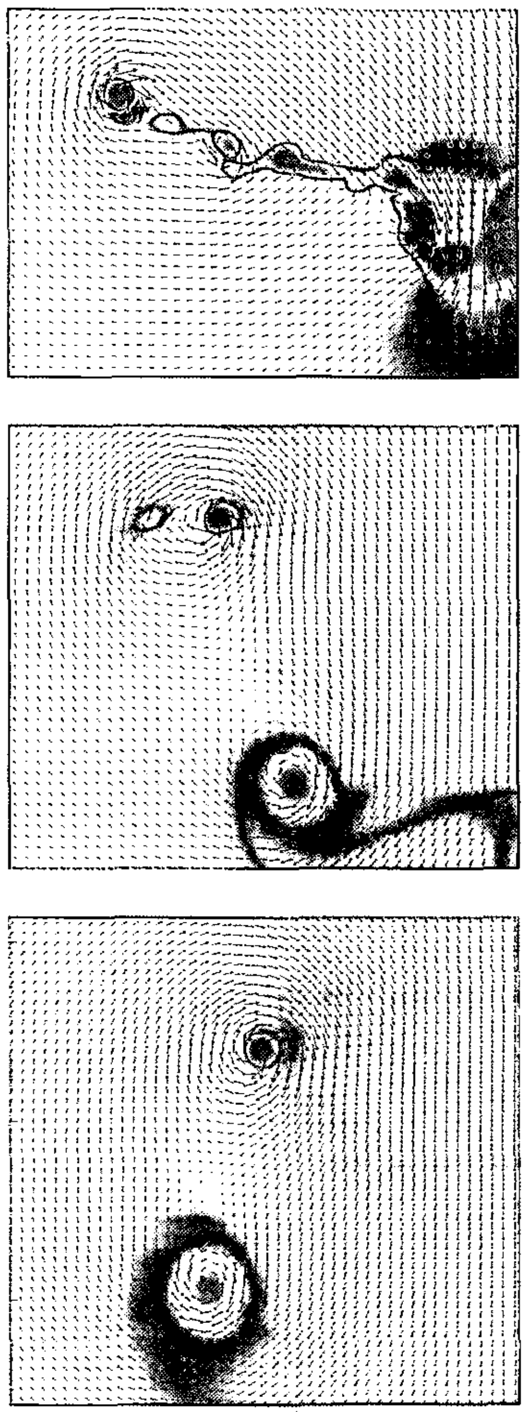
NLR is actively involved in the BRITE/EURAM Ducted Propfan Investigation (DUPRIN) II to study the potential of Ultra High By-Pass Engines. This programme includes wind tunnel tests in the DNW on a transport-type configuration (the 'ALVAST' model) with through-flow nacelles and turbine powered engine simulators. The Counter Rotating Ultra High By-Pass Ducted Fan (CRUF) configuration was tested in the DNW in 1995 following tests on a more conventional configuration in 1994. Both CRUF simulators were calibrated in the engine calibration facility of NLR. The analysis of the experimental results is in progress. Flow calculations based on the Euler equations have been carried out for the two different engine configurations. The effect of the jet on the wing lower surface appeared not to be well predicted. Viscous effects are planned to be taken into account in a follow-on project.

One half of the 'ALVAST' model is also used as a test case in a collaborative project of NLR and DLR aimed at improved understanding of the flow and the interference effects through detailed flow field measurements. The semi-span model, tested earlier in the NWB wind tunnel at Braunschweig, was tested in the LST. Force and pressure measurements were made for comparison with results obtained in the DNW and the NWB. With a fast scanning five-hole probe rake, detailed flow field surveys have been made behind the model with and without a through-flow nacelle. These tests will be continued with the CRUF engine installed. DLR will contribute by executing Particle Image Velocimetry (PIV) measurements.

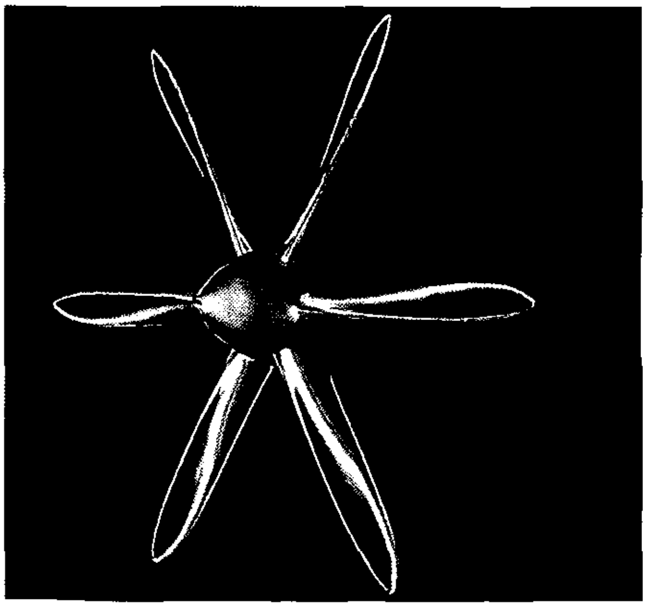
NLR participated in tests carried out in the Indonesian Low Speed Wind Tunnel in a co-operative programme with IPTN (Industri Pesawat Terbang Nusantara), LAGG (Aero-Gas Dynamics and Vibration Laboratory), Fokker, NLR and the Universities of Technology of Bandung and Delft. In these tests, forces on the propeller shaft have been measured in addition to the overall measured forces. This allows detailed thrust and drag bookkeeping for establishing the interference effects. The first phase of the tests was completed and the analysis is in progress.

Aerodynamics of Combat Aircraft

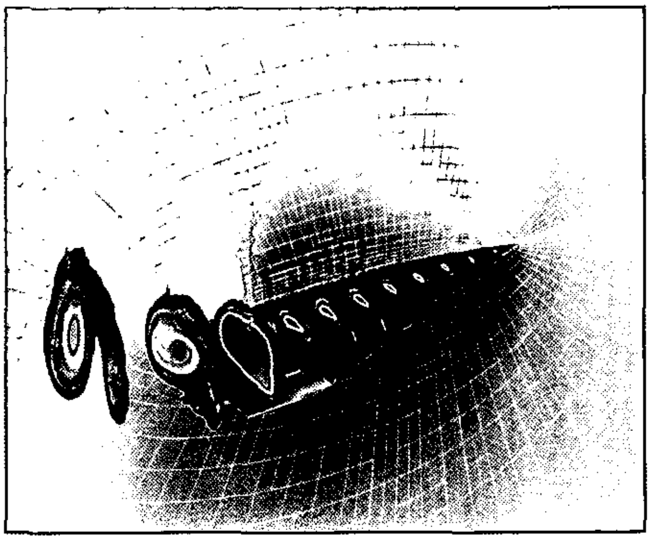
Wind tunnel measurements executed in 1994 on a model, provided by AerMacchi, of a forebody configuration representative of a combat-type aircraft were analysed. The analysis indicated the existence of different flow regimes depending on the state of the boundary layer (laminar or turbulent) and the subsequent separation and vortex formation. This configuration is also used as a test case for Navier-Stokes codes as part of the WEAG TA-15 programme. The greater part of the activities in TA-15 concentrated on the calculation of the flow over a sharp-edged delta wing. A common exercise has been defined to



Trailing wake vortices at 0.67, 2.0 and 4.7 span downstream of a model wing in the LST



Pressure distribution on six-bladed propeller computed with Euler equations to determine forces on propeller shaft

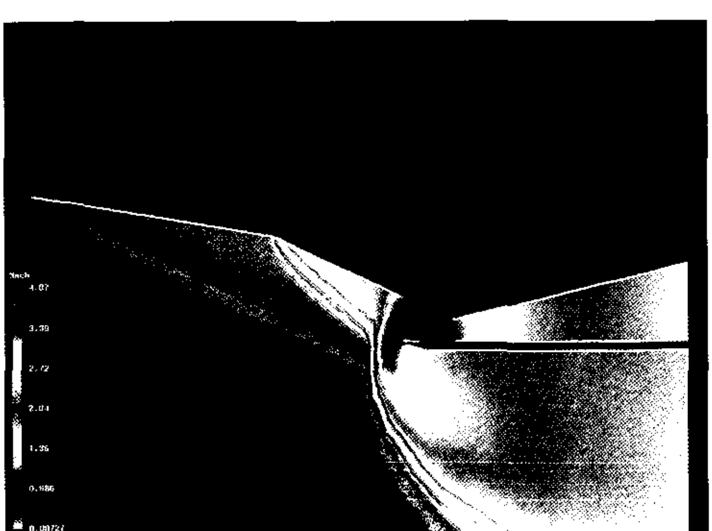


Flow over sharp-edged delta wing computed with high grid density

study the effects of grid density and grid adaption. NLR provided a reference case with a very high density grid of 2 million points. Euler solutions with various grid adaptations have been obtained and work has started on Navier-Stokes solutions.

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. A helicopter rotor code for the calculation of rotor performance was improved by implementing a prescribed wake model and a model representing dynamic stall effects.



Mach number distribution in symmetry plane of a supersonic three-dimensional AEOLUS intake configuration showing an off-design flow condition

The participation in the BRITE/EURAM project HELISHAPE was continued by contributing to the formulation of a computer code for the aerodynamics of a helicopter rotor based on a full potential flow model.

Hypersonic/Space Vehicle Aerothermodynamics

Wind tunnel tests have been carried out as part of the Aerodynamic Re-entry Demonstrator (ARD), the Crew Transfer Vehicle (CTV) and the Manned Space Transportation Programme (MSTP) of the European Space Agency (ESA). The tests concentrated on the overall aerodynamic characteristics, wake flow (for parachute deployment) and static stability of capsule-type configurations at arbitrary orientations. Some of the measurements have been used as test cases for CFD validations. In the Future European Space Transportation Investigations Programme (FESTIP) of ESA, NLR concentrates on CFD calculations for base flows with plume interaction.

Also under contract to ESA, flutter tests on several types of Flexible External Insulation (FEI) blankets were performed in the transonic HST and supersonic SST wind tunnels. This investigation included also shear and peeling tests and a permeability test.

Activities in the national programme AEOLUS (Advanced Earth to Orbit Launcher Upgrade Studies) continued. NLR contributed in the design and calculation of a three-dimensional intake configuration. Mechanical loads and heat loads were estimated. They will serve as a starting point for the mechanical design to be done by other partners.

Computational Fluid Dynamics

Reynolds-Averaged Navier-Stokes Methods

The main thrust in the research and development activities in the field of applied computational fluid dynamics is directed towards the design for propulsion/airframe integration. These activities concentrate on refining the computer code system ENFLOW for Reynolds-averaged Navier-Stokes equations. This work is carried out in close co-operation with Fokker Aircraft and is partly funded by the Netherlands Agency for Aerospace Programs (NIVR).

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. This system contains codes for:

- preparation of 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 (ENSOLV),
- multiblock grid adaption to flow solutions (ENADAP), and
- graphical inspection and further processing of calculation results.

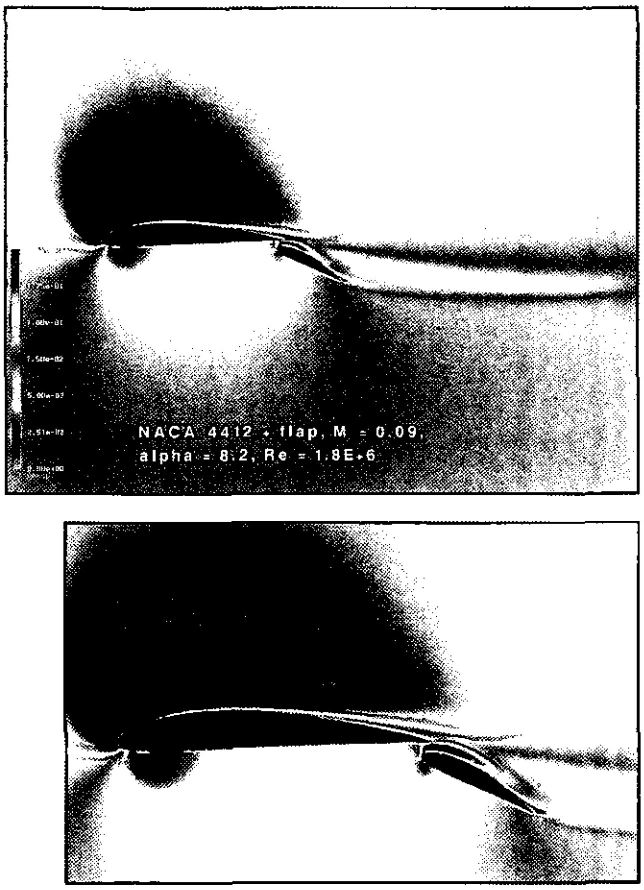
The ENFLOW system has been applied to the design of wing/body/nacelle/pylon configurations that are representative of jetliners carrying underwing engines. Because underwing engines and pylons significantly affect pressure distributions on the wing lower and upper surfaces, the ENFLOW system was combined with the MATRICS-V/WINGDES system into an inverse wing design tool which explicitly accounts for the influence of an underwing pylon/engine installation. ENFLOW results were validated using MATRICS-V computation results and experimental data from tests in the HST. The Johnson-King turbulence model, implemented in 1994, gave the best overall results for the purpose of propulsion/airframe integration. The inverse wing design tool based on ENFLOW/MATRICS-V/WINGDES was tested on a representative example, showing that the influence of the underwing pylon/engine installation can be taken into account in fewer than five design iterations.

The design turnaround time for the propulsion/airframe integration could be kept within reasonable bounds by making use of the SX-3 supercomputer. A typical Reynolds-averaged Navier-Stokes computation for a wing/body/nacelle configuration required a multiblock grid with 1.5 million cells, and took three SX-3 processor hours to converge.

A new activity started in 1995 in the area of applied CFD is the computation of aerodynamic drag for three-dimensional configurations based on Reynolds-averaged Navier-Stokes equations. A sequence of three grids was employed, the one with the highest resolution containing 6.6 million grid cells, to obtain insight into the relation between grid resolution, grid adaptation and accuracy of the aerodynamic drag (pressure plus friction drag) calculated for wing/body configurations.

The further development of the components of the ENFLOW system was aimed at application aspects such as further reduction of turnaround times for generating and improving multiblock grids. The capabilities of ENDOMO were extended by improving the flexibility with which 3D flow domains can be decomposed into blocks. The turnaround time for ENGRID was reduced, multiblock grid adaption by ENADAP was initiated and the parallelization of ENSOLV was investigated.

The development of an unstructured-grid Reynolds-averaged Navier-Stokes solver FANS (Fully Automatic Navier-Stokes) for two-dimensional problems such as multi-element airfoils was continued. A number of 2D test cases were used to demonstrate that both the robustness (with respect to irregular aerodynamic surfaces including roughness) and accuracy were improved. The multigrid convergence acceleration was improved, and parallelization of the algorithm was investigated.



Mach number distribution for NACA 4412 with flap computed with Reynolds-averaged Navier-Stokes solver FANS showing flow separation on flap (bottom: detail)

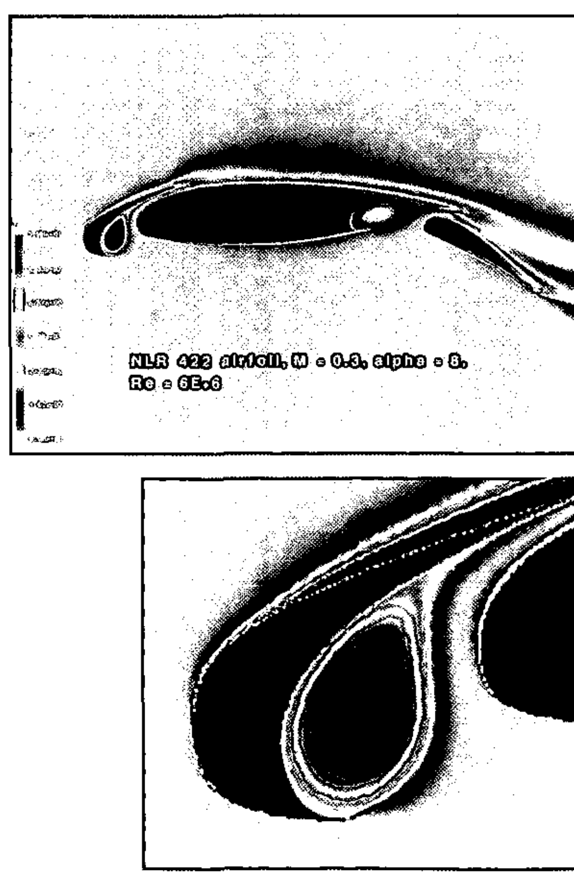
To further validate Reynolds-averaged Navier-Stokes CFD methods NLR participates in four GARTEUR Action Groups initiated in 1995:

- (AD) AG-20 for single-element airfoils,
- (AD) AG-24 for supersonic flow about slender configurations,
- (AD) AG-25 for maximum lift of multi-element airfoils, and
- (AD) AG-26 for transonic wing/body computations.

Turbulence Research

The quality of CFD results based on Reynolds-Averaged Navier-Stokes (RANS) computations depends on the suitability of turbulence models to represent relevant flow physics. The Navier-Stokes evaluation of the k-ω turbulence model was continued by improving the implementation of the two-equation k-ω model in the FANS code for two-dimensional high-lift airfoils. Critical aspects of the Navier-Stokes implementation of this turbulence model resolved in 1995 were the behaviour upstream of the aerofoil, the treatment of the turbulence production term in the stagnation point, the 'low Reynolds number' terms, the boundary condition for rough walls and laminar-turbulent transition trips. The implementation of the k-ω turbulence model in ENSOLV was initiated.

The research in the framework of GARTEUR (AD) AG-07 into turbulence in a three-dimensional boundary layer representative for a transport-type aircraft was concluded with a comparison of the experimental results from the LST wind tunnel in the Netherlands and the F2 wind tunnel in France. A subsequent GARTEUR Action Group, (AD) AG-23, was initiated, to analyse these experimental data by comparisons with boundary layer computations.



Turbulence intensity in viscous flow over three-element airfoil computed with the Reynolds-averaged Navier-Stokes equations and the k-ω turbulence model (bottom: detail)

Large Eddy Simulations (LES) offer an alternative to Reynolds-averaged turbulence models by calculating the large turbulent length scales time-accurately and modelling the more general small scales. The development of a code for Large Eddy Simulations was continued. The time accuracy for Euler equations, the multigrid acceleration and the grid enrichment of the LES algorithm were improved. An indication of the potential the for parallelization of this algorithm was obtained by running benchmark tests on a 16-processor NEC SX-4 supercomputer, in the framework of the acquisition of this computer.

Euler Methods

Progress has been made in the validation of the ENFLOW system at the level of the Euler equations. Configurations ranged from civil aircraft to complete fighter aircraft, including representations of air inlets, subsonic and supersonic jets. Code-to-code comparison of these Euler solutions showed very good numerical accuracy, warranting extension to the Reynolds-averaged Navier-Stokes level.

The activities of GARTEUR (AD) AG-17, 'The verification of 3D transonic Euler methods for complex geometries,' were continued.

NLR and DLR continued the co-operative project 'CFD for complete aircraft' with the objective of jointly developing a fully automatic system for three-dimensional flow simulations. The potential capabilities of this CFD system were investigated by detailed analysis of algorithms for automatic grid generation for Navier-Stokes equations using hybrid grids consisting of a layer of prismatic cells close to the aerodynamic surface and tetrahedra in the remainder of the domain. Euler and initial Navier-Stokes results were obtained on these hybrid grids.

Full-Potential Flow Methods

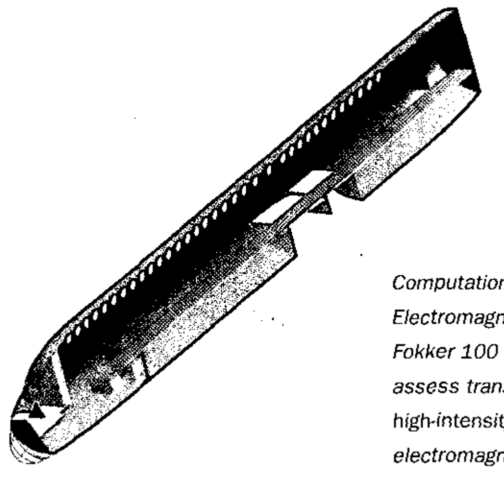
For the aerodynamic analysis of transonic wing-body combinations representative of transport aircraft, NLR has available the MATRICS-V computer code, consisting of a grid generation part and a flow solver. The flow solver includes a special algorithm to compute aerodynamic forces, in particular drag and its decomposition into induced drag, wave drag and viscous drag. The development of MATRICS-V was completed by extending the 3D integral boundary layer model to include improved representations of the 3D boundary layer velocity profiles, 'lag-entrainment' and improved potential flow boundary conditions. The effects of these improved models on the drag as a function of Mach number, on the lift versus incidence curve and on the lift versus drag curve have been established. MATRICS-V has further been adapted to treat high-wing aircraft.

Radar Cross Section (RCS) Prediction

Radar Cross Section (RCS) prediction methods at various levels, such as the approximate high frequency method and boundary integral equation methods to solve the Maxwell equations exactly at moderate frequencies, are under development. The application of the approximate high-frequency method shows how the RCS values can be decomposed into the various underlying contributions, and provides insight into the RCS behaviour of various geometries. The 3D boundary integral equation method was applied to civil aircraft to study the effect of high intensity radiated fields (HIRF) on electronic components inside the aircraft.

Aeroelasticity

The development of a computer code for computational aeroelastic simulation of transport-type aircraft in transonic flow (AESIM) was continued. In this code, the flow is modelled on the basis of a full potential representation. The basic version of the code became operational, and



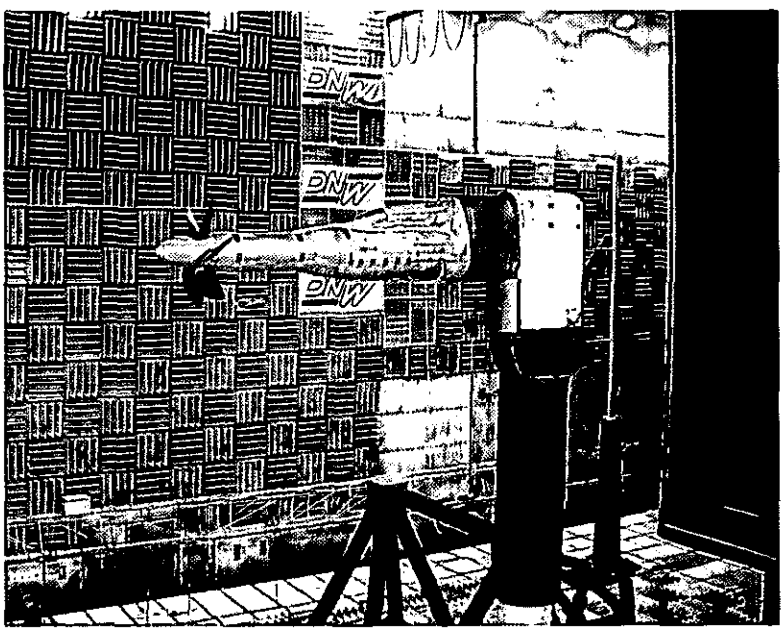
Computational Electromagnetics model of Fokker 100 fuselage to assess transmission of high-intensity electromagnetic radiation validations for a number of wing and tail configurations were performed. These activities were made in close co-operation with Fokker Aircraft, ensuring maximum operational applicability and efficiency. The implementation of a model that represents boundary layer effects in AESIM was continued. As a first step in developing a 'viscous' version, AESIM-V, a coupling was made of AESIM with the integral boundary layer method and viscous-inviscid interaction algorithm used in the existing MATRICS-V Full Potential Flow code. This was tested successfully for steady flow.

The research programme on Limit Cycle Oscillations (LCO) of fighter-type aircraft in transonic flow was continued with a further analysis of the wind tunnel test results obtained in 1992 and 1993. Limit Cycle Oscillations are due to the interaction of shock wave motions and flow separation. The programme will be extended with a flow visualization test in 1996. A preparatory test was performed to investigate the applicability of the technique of Particle Image Velocimetry to unsteady flows occurring under LCO conditions.

NLR, along with Fokker Aircraft, contributed to the GARTEUR (SM) AG-19 with a ground vibration test on an aircraft-like testbed designed and constructed by ONERA, in which a number of current measurement and identification techniques were applied.

Aeroacoustics

Propeller acoustics research continued to be aimed at the development and validation of codes for the computation of the noise of installed single and counter-rotating propellers. The existing code for single propellers and the recently completed extension for counter-rotating propellers were improved further. The code for single propellers was validated by means of data from the open literature and some preliminary wind tunnel data from the BRITE/EURAM Study of Noise and Aerodynamics of Advanced Propellers (SNAAP). The computed performance data compare very well with measured data up to a flight Mach number of 0.6, although some discrepancies are apparent at higher Mach numbers. A preliminary comparison of computed and measured acoustic data was encouraging. To enable the code to be partially validated for counter-rotating propellers,



Acoustic test on an advanced propeller downstream of a wake generator (Photography DNW)

an acoustic test was carried out in the German-Dutch Wind Tunnel on a SNAAP propeller downstream of a wake generator.
As a next step towards the computation of the noise of an installed propeller, a computer code for the diffraction of sound by an aircraft fuselage of circular cross-section, and the refraction by its boundary layer, was completed.

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.
An experiment carried out in the LST in 1992 on the transmission of sound through the rotor of a turbofan engine was only partially successful due to unexpected unsteady boundary layer transition on the stator vanes. The experiment was therefore repeated with tripped stator vanes and rotor blades. The experimental data could successfully be used for the validation of the computer program for rotor transmission completed earlier.
The computer program for the calculation of the sound generated by a supersonic turbofan rotor (rotor-alone noise), completed in 1994, was successfully validated using results of in-flight measurements in the intake of a Fokker 100 engine.
Research into novel liner concepts for reducing low-frequency noise was carried out in the BRITE/EURAM project Fan Noise Prediction And Control (FANPAC). Promising results were obtained for insertion loss measurements on liners with folded Helmholtz cavities.

To assess the possibilities to control the effective acoustic impedance of an inlet liner by means of flow injection into the boundary layer, a test was carried out in the flow duct facility. The achieved variation in impedance appeared to be modest. A computer code for the computation of the noise reduction by inlet liners made of bulk-absorbing materials was completed. The application of this code to the Fokker 100 configuration predicted an improvement of about 1.5 dB.

A comprehensive series of measurements on the transmission of low-frequency sound through fuselage panels was carried out for the validation of a finite-element program being developed by the NLR Structures and Materials Division.

The research on the effects of so-called add-ons on the sound transmission through panels was continued with measurements in the test facility for high frequencies on various configurations, such as skin and trim panels with and without glass wool.

Facilities and Equipment

The Transonic Wind Tunnel HST

Most of the work for the transonic wind tunnel HST was related to the second phase of the modernization. Contracts were agreed with the local public utility for a connection to the electricity network. A new electric fan drive motor was ordered. In co-operation with the supplier of the existing fan, the modifications to the fan required for accommodating higher power and attaining higher efficiencies were determined. The new drive motor and modified fan will result in an increase of the Reynolds number by about 50% at high-subsonic speeds and in a reduction of costs. Site work is planned for the winter of 1996/97.

The Supersonic Wind Tunnels SST and CSST

With the steam boiler power plant driving the wind tunnels in Amsterdam to be shut down, the steam turbines driving the air compressors for charging the pressure vessel for the blow-down wind tunnel SST will be replaced by electric motors. These motors were ordered together with the main drive motor for the HST.

In response to customer requirements, a new pitch mechanism for the SST with a larger angle of attack range was developed and manufactured.

An exploratory test in the CSST was performed to generate noise of specified intensity and spectral content in the boundary layer. The need of having this technique available emerged in wind tunnel tests on Flexible External Insulation (FEI) blankets for space vehicles.

Low Speed Tunnel LST

The Low Speed Tunnel is operated under the management and responsibility of the German-Dutch Wind Tunnel (DNW) from 1 January 1996.

Propulsion and Acoustic Laboratory
The new balance system of the Engine Calibration Facility, for measuring all six force components, was calibrated extensively. The results were within specification.

Instrumentation and Measurement Systems
In the area of flow field measurement techniques, the activities concentrated on the development of a Particle Image Velocimetry (PIV) system primarily for use in the transonic wind tunnel HST. The system, capable of measuring two velocity vector components in the plane of a laser sheet, is planned to be operational in 1996. In parallel NLR participates in the GARTEUR (AD) AG 19 on PIV for large wind tunnels and in a new BRITE/EURAM project EUROPIV, a co-operative action to study the applicability of Particle Image Velocimetry to problems of industrial interest.

The development of a surface pressure measurement system based on the use of Pressure Sensitive Paint (PSP) was continued. In 1995 the GARTEUR Action Group (AD) AG-21, to study possibilities to establish the accuracy of PSP techniques, was started. NLR participates in this Action Group. While PSP techniques currently available provide useful qualitative results, they do not yet reach the accuracy levels of conventional pressure measurement methods.

The accuracy of model incidence data from gravity-sensing inclinometers in wind tunnel models is limited by the occurrence of model vibrations. A method was developed to compensate for these vibration effects.

The experimental and computational equipment of the aero-acoustics laboratory was further improved and extended. A feasibility study was made providing specifications and costs of a Full Scale Facility for investigations on cabin noise.

Experiments were carried out to provide specifications for new image recording and processing equipment to be used for the application of Laser Sheet and Particle Image Velocimetry techniques in unsteady wind tunnel experiments. Preparations were made and equipment was ordered for the installation of a new hydraulic model excitation system.

The development of a new generation of wind tunnel data acquisition and processing systems was continued. Attention was focused in particular on preparations for the introduction of new measuring techniques (PIV, PSP, laser imaging) and higher levels of automation of the wind tunnel measuring process.

3.2 Flight

Summary

In the field of *flying qualities and flight control systems*, NLR in co-operation with foreign research institutes continued the study focused on the development of guidelines for handling qualities of modern civil transport aircraft.
NLR co-ordinates a project of the GARTEUR Action Group which aims to demonstrate how robust control techniques can be introduced successfully into the design cycle.

With the partners in the GARTEUR Action Group on windshear, NLR continued the execution of Phase I of WINDSTREAM (Windshear Technology Research Advances Masterplan). Support was given to Fokker Aircraft's project Computer-Aided Engineering (CAE).

In the field of *human factors*, a great deal of activity was focused on the study of the human factors issues associated with the use of future flight crew interfaces: cockpit displays for 4D navigation functions, datalink interfaces, enhanced and synthetic vision displays and multifunction displays.
Other activities concerned human operator training and familiarisation and workload measurements.

In a National Technology Project, NLR and the TNO Human Factors Research Institute carried out research into the use of voice recognition technology for control functions in military fighter cockpits.

Aircraft operations with NLR's Metro II research aircraft were carried out to test the capabilities of a new spectrometer by measuring ozone absorption spectra in the troposphere.
A flight test programme was carried out with the Cessna Citation II research aircraft for the certification of the radar pod of the Phased Array Universal Synthetic Aperture Radar, PHARUS, on the aircraft.

In the field of *air traffic management*, research and development work in Air Traffic Control (ATC) has been carried out under contract to ATC The Netherlands (LVB) and for Eurocontrol and the European Union in such areas as aircraft and radar models, ATC simulation and automation, controller working position and airport traffic management.
Under the Programme for Harmonized Air traffic management Research in Eurocontrol (PHARE), NLR contributed to the development of several systems and tools. NLR participated also in the PHARE Demonstration 3, a large scale, multi-site, multi-sector demonstration of an advanced ATM concept.
NLR acquired a large share in the EU's fourth Framework Programme 'ECARDA', European Coherent Approach for the Research and Technological Development of ATM.
In the field of airport management, NLR supported Amsterdam Airport Schiphol with studies into the capacity of the airport, using a new software tool called Total Airspace and Aircraft Modeller (TAAM).

NLR assisted the Royal Netherlands Air Force (RNLAF) in flight tests, in tests of several air defence systems and in the investigations of accidents with fighter aircraft, transport aircraft and a helicopter.
The RNLAF and the Royal Netherlands Army were extensively assisted in the activities related to their armed helicopter procurement programme.

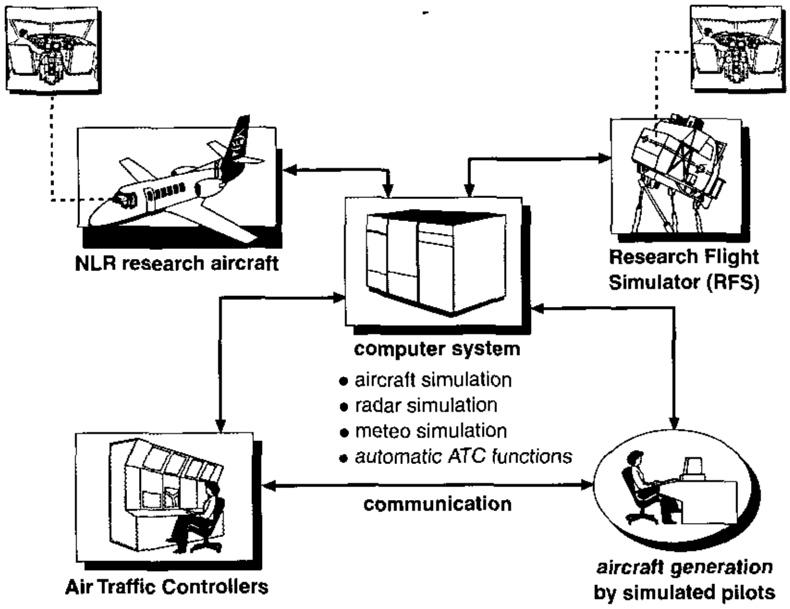
NLR participated in the activities of GARTEUR Action Groups on *helicopter flying qualities* and *helicopter performance modelling*.
In co-operation with Fokker and DAF Special Products, NLR continued its contribution in the Design and Development phase for the future NATO helicopter NH90.

In the field of *transport and environmental studies* NLR took part in international and national consultations on air pollution by aircraft.

Noise exposure was calculated for actual situations at the civil airports and the military airbases in the Netherlands.
The method developed by NLR to assess the external risk in the vicinity of airports was used for different airports.
An investigation into the identification and analysis of factors potentially associated with Controlled Flight into Terrain (CFIT) accidents, has been conducted.

Policy analysis, the service NLR provides since 1994, included a policy analysis study on air pollution caused by aircraft.

With regard to *facilities and equipment*, modifications were made to the NLR ATC Research Simulator (NARSIM) and NLR's Research Flight Simulator (RFS).
A datalink between NARSIM, providing an advanced ATM environment, and the RFS, in which the EFMS was installed, enabled various experiments with the two simulators to be performed.
The National Simulation Facility (NSF) was officially inaugurated. NLR continued the development of the NSF, resulting in additional capabilities and features.
The F-16 mock-up was extensively used for the development, integration and testing of new software features.



Schematic of the NLR ATC Research Simulator (NARSIM) linked to research aircraft and Research Flight Simulator

Flight Test Support

NLR assisted the Royal Netherlands Air Force during flight tests with Lockheed Martin F-16 and C-130H-30 Hercules aircraft, and with tests of several air defence systems. For the F-16, new data processing equipment for use on air bases was put into use.

NLR assisted the Royal Netherlands Army with the certification of Remotely Piloted Vehicles.

Flying Qualities and Flight Control Systems

Flying Qualities

Under contract to the Netherlands Agency for Aerospace Programs (NIVR), NLR is developing guidelines for low speed lateral/directional handling qualities of civil transport aircraft equipped with a glass cockpit, advanced Fly-By-Wire Flight Control Systems (FCS), a sidestick controller, a simulated Head Up Display and autothrottles. This work is carried out in a collaboration with DLR (Deutsche Forschungsanstalt für Luft- und Raumfahrt), DRA (Defence Research Agency) and ONERA (Office National d'Etudes et de Recherches Aérospatiales) in the framework of GARTEUR (Group for Aeronautical Research and Technology in Europe).

Effects of Control Augmentation

Under contract to the Netherlands Department of Civil Aviation (RLD), an investigation was carried out into the effects of control augmentation systems on aircraft handling and pilot workload during approach and landing in adverse weather conditions. This investigation aims at providing a basis for determining the advisability of using such systems as autothrottle and control wheel steering systems during adverse weather conditions. Several airline and technical pilots took part in the experiment, carried out on NLR's Research Flight Simulator.

Robust Flight Control

NLR is co-ordinator of a project of the GARTEUR Action Group that conducts research into methods for speeding up the design of flight control laws. Seven research establishments, seven industries and eight universities participate in this project, which aims at demonstrating how robust control techniques and new methods for the management of control engineering data can be introduced successfully into the design cycle. The Action Group has defined two benchmarks, covering an automatic landing approach control problem and a high-angle-of-attack enhanced manual control problem. Twenty-two teams have started to design controllers for these benchmarks. Furthermore, an interactive Robust Flight Control Literature Survey Data Base has been developed which is accessible through Internet. This data base is aimed at assisting future designers in their choice of a suitable technique for the particular flight control problem they have to solve. Finally, a model for the flight control law design process has been developed, together with a set of preliminary requirements for a computational environment for aircraft control engineering.

Indication of Performance during Take-Off

This year's research into Take-Off Performance Monitor (TOPM) systems has been conducted in the context of a workload programme, which was carried out under contract to the European Union (EU). TOPM systems are aimed at improving crew situational awareness by presenting real-time performance information on the status of the take-off. These systems enable the crew to take corrective actions in a timely manner, should take-off conditions be adversely affected. Previous research showed that the best system should incorporate current ability. The experiment conducted this year was focused on the question whether a continuous display or a discrete warning would suffice to inform the crew in the event of insufficient performance.

Windshear

Under contract to the Netherlands Agency for Aerospace Programs (NIVR) and the Netherlands Department of Civil Aviation (RLD), NLR continued the execution of Phase I of WINDSTREAM (Windshear Technology Research Advances Masterplan). A model of a groundbased Terminal Doppler Weather Radar (TDWR) system, including a windshear hazard display, was completed. Furthermore, reporting on two flight simulator experiments, focused on flight safety, flight operational and man-machine interface implications of forward-looking windshear detection and display systems was continued. The experiments were conducted in collaboration with the partners in the GARTEUR Action Group (FM) AG-07 on windshear. This Action Group also reported results from an inventory, held amongst eighty European airlines, of the willingness to co-operate in the establishment of a European windshear database.

In preparation of a piloted simulator experiment planned for 1996 (Phase II of WINDSTREAM), the development of an airborne windshear detection radar system and an improved flight director for windshear recovery were started.

Verification of Flight Management Concepts

NLR was involved in a design study for a short to medium range commuter aircraft for 60 to 80 passengers, capable of operating in a future 4D Air Traffic Management (ATM) environment. A number of Flight Control System concepts and information display concepts were implemented in the Research Flight Simulator (RFS). Two experiments have been conducted to investigate which flight director display should be used in combination with any of these three control concepts. A 4D Flight Management System (FMS) with datalink capability has been developed in preparations for future experiments. The RFS will then be linked to the NLR ATC Research Simulator NARSIM, which will simulate a future 4D ATM environment based on the Center Tracon Automation System (CTAS). The primary objective of the study is to identify the main requirements for the cockpit of a commuter aircraft in a future ATM environment.

TOPM research in the Research Flight Simulator

Support of Computer-Aided Engineering Project
NLR supported Fokker's Aircraft project Computer-Aided Engineering (CAE). Work in five subprojects was started. Existing tools and models were developed further and new tools were selected and introduced.

The CAE subproject Engineering Design Simulation involved the development of a general tool for the simulation of the dynamics of all Fokker aircraft, planned to be used at all Engineering Departments of Fokker. The tool should have a Graphical User Interface according to the current state of the art, but also be able to utilize earlier investments in simulation models of aerodynamics, engines, landing gears, control systems, etc. The tool has to be capable of being used at various levels of complexity by users varying from non-technicians to technical specialists.

In the CAE subproject Generic Powerplant Heat Management CAE Model, a tool was selected for the analysis, design and simulation of heat management systems in combination with engine and engine accessories. A library of generic models of typical heat management components was developed. The tool was introduced and applied in a pilot study on engine design integration.

Officers of the Royal Netherlands Air Force who attended a symposium hosted by NLR

Support was given in the CAE subproject Simulation of Systems Networks for the definition of requirements to computer tools for the design, simulation and analysis of networks of electric, bleed air and hydraulic aircraft systems. The requirements set was applied in the selection of an appropriate tool.

Participation in the CAE subproject Structured Design of Aircraft Systems involved the definition of a process for the design of aircraft systems in the so-called Design Feasibility Study phase. Methods and activities were selected and introduced. A design exercise was started for the evaluation of the process. The definition of requirements to tools for computer support of systems engineering was initiated, and a candidate product was demonstrated.

The assistance provided in the CAE subproject Interaction of Brakes and Landing Gear consisted of the development of a generic model library for the analysis, design and simulation of typical aircraft brake components: anti-skid control valve, hydraulic pipe and wheel brake.

Mathematical Models of Aircraft
In co-operation with the Faculty of Aerospace Engineering of the Delft University of Technology (DUT), NLR continued work on the determination of the aerodynamic model of the Metro II research aircraft. A Non-Stationary Measurement Method (NSM) and dedicated parameter identification techniques are used in this project.

Ground tests and flight tests were carried out in order to collect data for a liquid slosh model for fuel tanks, inertial parameters and data for the yaw damper, undercarriage and control force models. Several students of the Technical University of Braunschweig have been working on these subjects.

The study into possibilities for the application of the Multi-Input Multi-Output method (MIMO) for aerodynamic modelling, in collaboration with the DUT's Faculty of Aerospace Engineering, was continued.

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. The voice utilisation concept was implemented and tested on a demonstrator based on a personal computer. The concept was then implemented and evaluated on the National Simulation Facility. It has become ready for a structured test and evaluation to be carried out with test pilots and squadron pilots as subjects.

Tactical Recce System Replacement
Following the F-16 Orpheus replacement feasibility study, carried out in 1994, the Royal Netherlands Air Force (RNLAF) was supported in further defining its requirements for new reconnaissance equipment for the F-16.

Military Flight Support
Support has been provided to the RNLAF on the tactical and operational use of fighter aircraft and the safety analysis of airshow flight demonstration programmes for the Lockheed Martin F-16 and Pilatus PC-7 aircraft.

Work was started on the construction of an aerodynamic model of the Pilatus PC-7 aircraft of the RNLAF. This model is required to produce a supplement to the aircraft's flight manual, that will contain data for operation with a reduced propeller speed for noise reduction.

Human Factors

Glass Cockpit Design for Airliners
Prototype cockpit controls and displays for 4D navigation and flight path negotiation functions were designed, based on the principles of 'direct object manipulation' and 'what you see is what you get.' Horizontal and vertical situation displays were implemented in the Research Flight Simulator for testing under operational circumstances. The results showed increased pilot acceptance for new ATM concepts and implications of sharing ground-based and aircraft-based data. Tracker balls were preferred over touch screen input devices, indicating the importance of 'tactile' information during direct object, or trajectory, manipulation. The work is supported by NIVR and the European Union (EU).

NLR carried out cockpit research funded by NIVR and in programmes of the EU, Eurocontrol and the US Federal Aviation Administration (FAA) with the RLD, and partly in collaboration with researchers of the US National Aeronautics and Space Administration (NASA), Ohio State University and the University of Leiden.

In a collaboration with the FAA and RLD, optimized datalink interfaces were designed and compared to a traditional Command and Display Unit (CDU). The automation now allows uplinked trajectories to be 'gated' into the FMS or in the Mode Control Panel. In experiments with airline pilots taking part, the effectiveness and acceptance of such technologies was evaluated.

The human factors issues associated with the civil use of enhanced and synthetic terrain vision displays were studied in a collaborative programme with the industry and the EU. A follow-on programme was specified and selected for support by the Commission of the European Communities. The potential roles for head-up displays and head-down displays were compared and display formats prototyped. The tunnel-in-the-sky concept is one of the display candidates. It is being compared with a modified primary flight display (PFD) baseline to quantify its potential benefits.

The changing nature of the human tasks and the accidents associated with flight mode complexity impose a high priority for cockpit information that provides the crew with insight in, and observability of, functions offered by automation technology. Multi-function display applications were prototyped to assist in engine monitoring and system awareness, including FMS. The goal of these studies, supported by NIVR, is to provide facilities for a better understanding by the crew of the aircraft intent during automatic mode changes.

ATC/ATM Controller Human Machine Interface

Ground Human Machine Interface (GHMI) prototyping was performed in support of the design of advanced human interfaces for ATC controllers, using state of the art technology. This work was done under the Programme for Harmonized Air traffic management Research in Eurocontrol (PHARE), and included comparing a reference system with advanced technology. The advanced systems were completed and tested with controllers assisting during the 'PHARE Demonstration trials' (PD-1) in the UK. The prototypes allow multiple facilities interacting with these tools. Preliminary results were promising, but cultural differences between controllers and their normal teaming arrangements influenced the use of particular software tools. Military controllers, who are used to work with free airspace, seemed to adapt quickly to the advanced concepts and newly designed controller working positions.

The PD-1 activities are concerned with en-route traffic. Subsequent PD-2 experiments, to be held in Germany, will address the extended terminal area. The displays required were defined, tested and specified for implementation.

The GHMI work is performed in the context of the PHARE GHMI project chaired and funded by NLR and Air Traffic Control The Netherlands (LVB).

The introduction and validation of new man-machine interface designs was found to require intensive familiarisation and integrated training facilities for the potential users. A pre-operational training kit, based on computer aided interactive training concepts, was developed for the PHARE GHMI programme. Results from PD-1 trials indicated a significant increase in the acceptance of the system by controllers. An extension of the training tool kit will be required for the PD-2 studies and trials. HMI training kits are considered to be critical for the introduction of new concepts and the quest for gaining acceptance by users and customers.

Experiments on possible automation strategies and their impacts on human performance for ATC and ATM were completed. The human factors research addressed a flexible allocation of functions. Duties could be assigned either to machine (software) functionalities or to human tasks. The actual allocation could be guided by traffic load considerations or controller's intent. The datalink was fully integrated and selectable as well. NLR's SWEAT (Standardised Workload Evaluation and Assessment Techniques) toolbox was used in the evaluation. The results on controller performance indicate that controllers will under time pressure revert to their habitual 'controlling' strategy instead of using tools to 'manage' the traffic. Training and transition problems were identified for further research. This work was performed in collaboration with the Human Factors Division of NASA and the Catholic University of Washington.

The validation requirements for new ATM concepts gained importance as could be substantiated by empirical research. Studies supported by the EU were performed to identify the required strategies, standards and tools, in co-operation with industry and the authorities. The work led to a follow-on study supported by NLR, industry and the Commission of the European Communities.

Military Crew Station Design

The F-16 mock-up was used for investigating the 'visual sampling' strategies that pilots use while operating with different head-up-display formats under varying levels of task loading. The work is supported by the Royal Netherlands Air Force (RNLAF).

Under an F-16 Mid Life Update contract to Lockheed Martin, so-called colour candidates were specified to determine a consistent colour application strategy for displays in fighter cockpits.

The Royal Netherlands Navy was supported in the realization of a single pilot crew concept for the Naval version of the NH90.

Human Operator Training and Familiarisation

Training and simulation research was carried out under two RTPs (Research and Technology Projects) of EUCLID (European Co-operation for the Long term In Defence): RTP 11.1 on 'Simulation based training system concepts' and RTP 11.2 on 'Simulation techniques'. Studies to define the role and necessity of motion systems for skill acquisition were completed. Operational stresses were identified and the feasibility for simulation investigated.

Operator Performance and Workload Measurement

Research on the development of a practical 'Workload toolbox' for studying human interactions with advanced technologies was continued.

The use of 'event related' workload measurement techniques was investigated in a simulator experiment on cockpit data link. The work was supported by the FAA.

NLR's SWEAT toolbox was interfaced with ATC simulation equipment. Head/eye tracking recordings proved effective in observing changes in operator behaviour (by visual sampling) and workload (by observing pupil size). The work was performed in collaboration with Eurocontrol and NASA.

The need for unobtrusive measurement techniques led to a study into the application of event-related brain potentials for display evaluations. In work supported by NIVR, subjects performed tracking and mental tasks with different types of flight displays. Analysis of the results was started.

Man Machine Interface Design Tools

Commercially available prototyping tools are capable of serving in widely different applications. They are not optimized for the aviation environment that requires not only effective design capabilities but also cost effective experiments and validations of concepts involving real-time 'man in the loop' performance. NLR therefore expanded its man-machine interface development package NADDES (NLR Advanced Display Design and Evaluation System). This package allows design conceptualisations to be made using a personal computer, and produces both specifications independent of hardware and software codes fitting target systems.

Aircraft Operations

Research Aircraft

Fairchild Metro II

The PHARS Synthetic Aperture Radar, mounted under the Metro II research aircraft, was used over the Netherlands during the period of severe flooding of the rivers Rhine and Meuse, to collect information on the extent of the flooding.

The applicabilities of two laser altimeters were tested by flying low over different types of terrain. The tests were performed in support of a test programme of a parafoil.

Flights were made to collect flight test data to be used for upgrading the simulator model of the Metro II. Special manoeuvres were performed to observe the sloshing of liquid contained in transparent boxes in the fuselage and to measure the effects of fuel slosh on aircraft control response.

The capabilities of a new spectrometer were tested by measuring ozone absorption spectra in the troposphere. The Airborne Spectrometer for Trace gas monitoring and Underflights (ASTU) is being developed jointly by Fokker Space and NLR on the basis of the Global Ozone Monitoring Experiment (GOME) space sensor.

Cessna Citation II research aircraft with radar pod

Cessna Citation II

The Cessna Citation II research aircraft is owned and operated jointly with the Delft University of Technology. The main programme of NLR was the installation on the Citation II of the Phased Array Universal SAR (PHARUS). This sensor is housed in a relatively large external pod attached to the left forward side of the fuselage. A flight test programme was carried out for the certification of the radar pod under the aircraft. Due to the size and location of PHARUS, particular consideration was given to the effects on the PHARUS pod of aerodynamic forces and other flight-related forces as well as the effect of the pod on the airflow over the wing and into the left engine air intake and the associated effects on aircraft performance and controllability. In two test flights, the Metro II was flown in formation with the Cessna Citation II equipped with the radar pod of PHARUS, to observe the airflow over the Citation's fuselage at several airspeeds. For this purpose, photographs and video recordings were made of wool strings attached to the Citation's fuselage.

Radar data obtained during initial data collection flights showed a good performance of the radar.

In the framework of a project for the European Union, satellite communication equipment has been installed to participate in Automatic Dependent Surveillance (ADS) trials.

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), man-machine interface, human factors and airport traffic management.

Center/TRACON Automation System (CTAS)

A modified version of the Center/TRACON Automation System (CTAS) was used in a series of experiments in which the effectiveness of various levels of Air Traffic Control (ATC) decision-aiding automation was compared. Conflict detection and resolution advisory assistance modes of CTAS were compared to a baseline mode of CTAS displaying traffic status information only. The movement of arrival traffic into the Amsterdam Radar South sector until hand-off to approach at the metering fix was simulated. Licensed air traffic controllers participated in the studies. A voiceless datalink interface was used in all automation conditions.

A variety of data, including data on eye gaze, heart rate variability and monitoring performance as well as ATC system performance were collected. Preliminary analysis has focused on monitoring and mental workload measures.

Air Traffic Management Datalink

Under contract to NIVR, NLR and Fokker co-operate in the development of an ATM datalink simulator, to improve the knowledge on the implementation and use of air/ground data communication in a future ATM environment. The simulator will include NLR's ATC Research Simulator (NARSIM), the experimental European ATN (EURATN), and NLR's Research Flight Simulator (RFS).

Support to Air Traffic Control The Netherlands (LVB)

The evaluation of area conflict detection, short term conflict detection and flight plan monitoring functions continued. This resulted in validated specifications to be included in the Amsterdam Advanced Automation (AAA) system. 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 enabling the landing capacity of Amsterdam Airport Schiphol to be increased. The work was finalized, aiming at the introduction of the converging runway procedure after the summer period.

On behalf of LVB, NLR took part in activities of a number of international organizations, including the SSR improvement and Collision Avoidance Systems (SICAS) panel of ICAO, the Aeronautical Telecommunication Network Panel (ATNP), the Automatic Dependent Surveillance Panel (ADSP), the RGCS panel and the European Air Traffic Management System (EATMS) panel.

Preliminary investigations were made into the possible introduction of an advanced Surface Movement Guidance and Control System (SMGCS) at Amsterdam Airport Schiphol.

SICAS Panel of ICAO

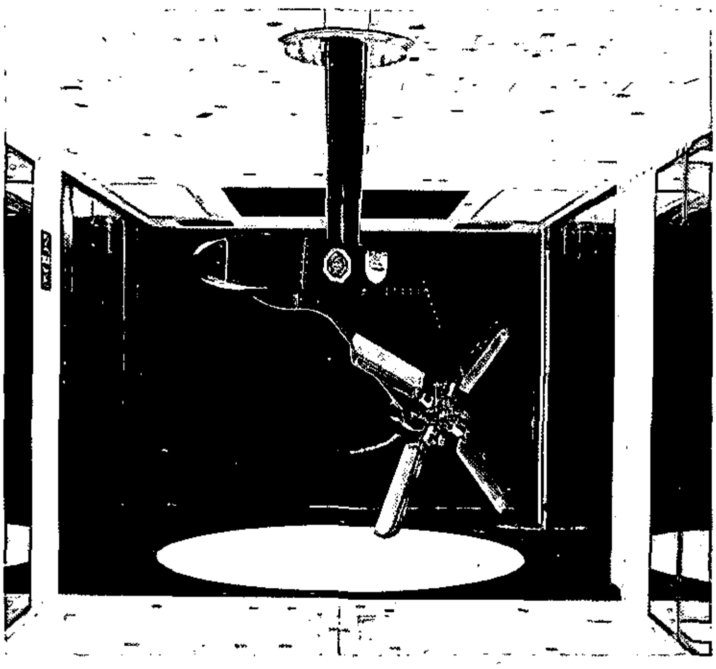
In the field of Air Traffic Management, NLR supported the RLD with studies on the introduction of new CNS (Communication, Navigation, Surveillance) and ATM (Air Traffic Management) systems and on the policy for the introduction of new landing aids such as MLS and GNSS. Studies were made for a transition plan for the introduction of avionics systems in the future EATMS environment and on the operational aspects of a datalink. For this, a datalink user forum was organized, with representatives of all relevant parties in the Netherlands: airlines, LVB and RLD.

Technical and operational aspects of GNSS, not only accuracy but also integrity, availability and continuity of service, were studied with respect to the applicability of GNSS as a landing aid.

Support to Eurocontrol

For the Programme for Harmonized ATM Research in Eurocontrol (PHARE), NLR contributed to the development of several systems:

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



NH90 Tail rotor model in the LST

In addition, NLR participates in the PHARE Demonstration 3 (PD-3), a large scale, multi-site, multi-sector demonstration of an advanced Air Traffic Management concept developed by PHARE partners and intended to be operational in the period 2000-2015. NLR has the lead in both the Airborne and the Ground Human Machine Interface projects. NLR will also provide the real aircraft flying in the PD-3 project.

The EFMS was installed in NLR's Research Flight Simulator (RFS) and was subsequently used in a demonstration in the EU's FANSTIC II programme (and in a 4D navigation display experiment for NIVR). NARSIM provided a potential future advanced Air Traffic Management environment. Communication between NARSIM and RFS was carried out via datalink. Negotiation of trajectories between the Air Traffic Controller and the pilot, using EFMS, was demonstrated.

NLR provided assistance to the PHARE cell at Eurocontrol, Brussels.
NLR provided the project management and further assistance to PRAISE, the Preparation of an R&D programme in support of EATMS (European Air Traffic Management System). The project, defining the necessary research for a successful start of EATMS, was finalized.

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 was held for delegates of the Commission of the European Communities and Eurocontrol.

NLR acquired a significant share of the air traffic management activities in the Fourth Framework Programme, as defined by the programme ECARDA (European Coherent Approach for the Research and Technological Development of Air Traffic Management). NLR can provide up-to-date services to the national air traffic cluster by participating in international programmes. Tasks were acquired in the fields of general Air Traffic Management concepts and validation; Air Traffic Control; airport traffic management and automation; avionics; communication, navigation and surveillance; and facilities and fundamental research.

NLR participates in large industrial consortia (Eurosky, Thomson, Siemens, Sextant) through PHARE-X, a consortium of the PHARE partners Centre d'Etudes de la Navigation Aérienne/

Sofreavia, DLR, Deutsche Flug Sicherung, National Air Traffic Services of the UK Civil Aviation Authority, Defence Research Agency and NLR. NLR provides the chairman of PHARE-X.

Helicopters

NLR participated in the activities of the GARTEUR Group of Responsables for Helicopters. Contributions were made to the GARTEUR Action Groups (HC) AG-09, 'Mathematical Modelling for the Prediction of Helicopter Flying Qualities,' (HC) AG-07, 'Helicopter Performance Modelling,' 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 fuselage model and a powered tail rotor model.

The Royal Netherlands Air Force (RNLAF) and the Royal Netherlands Army were assisted extensively in the activities related to their armed helicopter procurement programme. Support was also given to the Netherlands Chinook Office at Boeing Helicopters, Philadelphia, USA, the manufacturer of the CH-47 transport helicopters for the RNLAF.

A wind tunnel campaign was carried out on a model of a new auxiliary replenishment ship of the Royal Netherlands Navy, in support of future helicopter-ship qualification flight testing. These measurements were verified during a test campaign on board the actual ship.

Transport and Environmental Studies

Policy Analysis

Since 1994 NLR provides a new service to the international aviation community: policy analysis. Under contract to the RLD, NLR participated in a policy analysis on air pollution caused by aircraft. An analysis was started into the position of the relevant stakeholders in relation to air traffic at Amsterdam Airport Schiphol in the early morning.

Air Pollution

Under contract to the national government, NLR took part in international and national consultations on air pollution by aircraft. The models for the assessment of air pollution were provided with new functionality and were applied for different customers.

Noise Exposure

Noise exposure was calculated for the actual situations at the large civil airports and at several military airbases in the Netherlands. Calculations were also made for the establishment of noise zones around Amsterdam Airport Schiphol and around general aviation airfields. Most of the calculations were made under contract to the RLD, the Ministry of Defence or Amsterdam Airport Schiphol.

Noise and Flight Track Monitoring

Under contract to the Ministry of Housing, Physical Planning and the Environment, NLR took care of the management of the noise monitoring network near the airbase of Geilenkirchen. Under contract to the Department of Civil Aviation, NLR started work for a so-called mid-life update of the Flight Track and Aircraft Noise Monitoring System (FANOMOS).

Training Courses

NLR's comprehensive experience in the field of aircraft environmental research is regularly used in courses. In 1995, NLR participated in an international team that provided environmental training courses in Russia, Belarus, Ukraine and Kazahkstan.

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 Analysis

The method developed by NLR to assess the external risk in the vicinity of airports was used for risk analysis for Amsterdam Airport Schiphol, Heathrow Airport and Helsinki Airport.

In this method, the models available to carry out risk assessments around airports were limited to a traffic mix mainly made up of large aircraft. In order to be able to calculate external risk levels around airports with significantly different traffic mixes, models were developed for other categories of aircraft. Although their development was not fully completed, the new models, developed under contract to the RLD, were used for the assessment of risk levels in the vicinity of Groningen Airport Eelde. The models are scrutinised by a government committee that is responsible for their acceptance.

The expertise NLR has gained in the analysis of third party risk around airports has led to NLR participating in government committees for policy making in this field. NLR was invited to the Dutch parliament to elucidate the method used in the analysis of external risk pertaining to the development of Amsterdam Airport Schiphol.

Controlled Flight into Terrain

Accident statistics indicate that Controlled Flight into Terrain (CFIT) is currently one of the leading category of air carrier accidents. Under contract to the RLD, an investigation into the identification and analysis of factors that are potentially associated with CFIT accidents has been conducted. The study has also attempted to highlight differences between CFIT accidents of air-taxi, regional and major carriers. The research focused on the evaluation of 156 CFIT accidents of commercial operators that occurred in the 1988-1994 time frame. 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.

NLR has also been participating within the Society of Automotive Engineers (SAE) G-10 Committee on Terrain Separation Assurance Display Technology.

Airport Safety - Approach and Landing Aids

An exploratory study into factors that influence approach and landing safety at principal airports has been conducted, with emphasis on the influence on risk of fully-functioning precision terminal approach and guidance equipment. This study, supported by the RLD, was performed jointly by the Flight Safety Foundation (FSF) and its sub-contractors NLR and Record Management Systems (RMS) Incorporated. Accident and movement data for almost 600 principal airports worldwide for the period 1984-1993 were evaluated for the risk analysis.

Facilities and Equipment

NLR Air Traffic Control Research Simulator (NARSIM)

The NLR Air Traffic Control Research Simulator (NARSIM) is currently undergoing a major change in a project called 'NARSIM Client/Server'. In order to prepare NARSIM for the PHARE PD-3 project, the software architecture will be modified such that the PHARE Advanced Tools, the Ground Human Machine Interface (GHMI) and the PHARE Aeronautical Telecommunication Network (PATN) can be easily adapted and implemented in the NARSIM system. The project can be seen as an investment in an open and easily extendible simulator system to keep up with national and international developments in the field of Air Traffic Management. A demonstration of a small scale client/server simulator was successfully completed.

NARSIM was used in the 'Annette' project to assess the feasibility of a network for real-time distributed simulations, for which a demonstrator was implemented. Besides NARSIM, the demonstrator involved air traffic simulators of DLR and the Eurocontrol Experimental Centre. NARSIM provided overall simulation control, simulation of a part of the Dutch air traffic and the air traffic control for all traffic in the Dutch airspace.
Evaluations of rapid prototyping tools have been carried out in order to support the development of the user interface system of NARSIM. Ultimately, this system will allow researchers to change the user interface for the air traffic controller without major reprogramming.

Research Flight Simulator (RFS)

Modifications were made to the Research Flight Simulator RFS to enable simulation experiments to be carried out applying the Experimental Flight Management System (EFMS). Interactive Navigation Displays using a tracker ball and/or a touch pad to modify the parameters in the 4-D navigation plan of the EFMS were investigated. Apart from a normal lateral Navigation Display combined with time information, also a Vertical Path Display was developed to conduct research for the Future ATM, New Systems and Technology Integration in Cockpit (FANSTIC) experiments. The symbology and functionality of these displays were developed by means of the NLR Avionics Display Design and Evaluation System (NADDES). Furthermore, new flight control concepts have been developed to conduct experiments in the field of stability augmentation in enhanced manual control.

National Simulation Facility (NSF)

Whereas the year 1994 was marked by the first flight, the year 1995 was highlighted by the official inauguration of the National Simulation Facility by the State Secretary of Defence, Drs. J.C. Gmelich Meijling. The Commander in Chief of the Royal Netherlands Air Force, Lt.Gen. B.A.C. Droste, flew the F-16 simulator at this occasion.

The continuing development of the National Simulation Facility resulted in additional possibilities and features of the simulator.
The two-channel head-tracked visual system was expanded with a third channel. This channel enables sensor system images (e.g. infrared images), required to simulate the capabilities of the F-16 Mid Life Update weapon and sensor systems, to be simulated.

The design of the g-cueing system to be delivered by Sogitec was completed. This system, comprising a g-seat, an anti-g suit, a lap belt and a helmet loader, will enable sustained motion cues characteristic for fighter aircraft to be simulated.

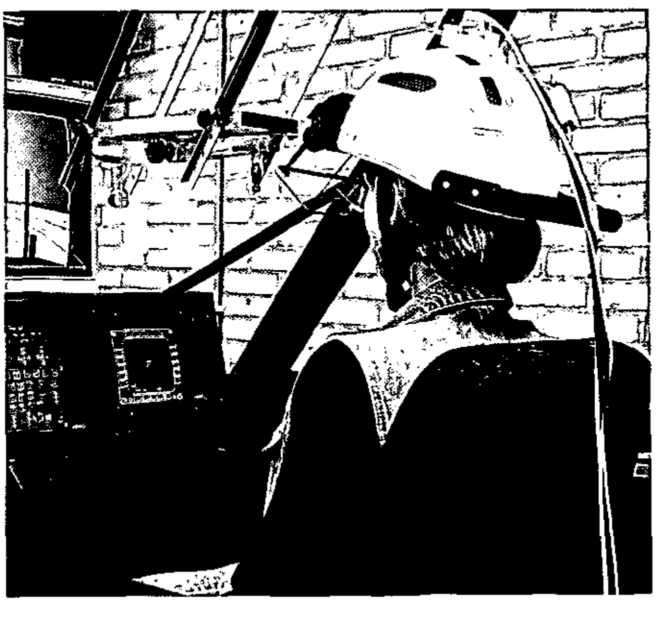
To enable control forces of different types of aircraft to be simulated, a contract was signed with Fokker Control Systems for the delivery and installation of a control loading system and a high-roll center stick.

The mission environment simulation tool 'ITEMS' was installed. This tool creates a realistic operational environment, enhancing the capabilities and realism of the simulator.

The flexibility of the National Simulation Facility was demonstrated when the F-16 side stick was removed and replaced by a center stick. This configuration was used for a foreign customer for the determination of the influence of motion cues on the prediction and evaluation of flight control system characteristics in simulations.

F-16 Mock-Up

The F-16 mock-up was extensively used for the development, integration and testing of new software features. The mock-up also played a key role in the DIS (Distributed Interactive Simulation) demonstration at the International Training Equipment Conference in The Hague, where NLR's mock-up acted as the manned F-16 aircraft giving close air support to ground troops in the simulation. Furthermore, the mock-up was also used to evaluate new HUD (Head-Up Display) symbologies.



Head/eye tracker

The use of eye-tracking equipment for measuring the pilot's eye fixation point and fixation duration was tested in the mock-up before being used for experiments in the NSF.

The two monochrome Multi-Function Displays (MFDs) in the mock-up cockpit were replaced by colour MFDs, to be used in investigations on the use of colours for displays.

Future Aircraft Systems Testbed (FAST)
A preliminary project plan was drawn up for the conversion of the Cessna Citation II research aircraft into the Future Aircraft System Testbed (FAST). The FAST proposal, based on the earlier proposal for a National Fly-By-Wire Testbed, was prepared in co-operation with the Delft University of Technology. FAST will be a facility for airborne research and validation of systems for Air Traffic Management and related on-board functions.

Measurement Equipment for Human Factors Research
The system for physiological measurements was improved and was successfully used in experiments. A second eye/head-tracker system was acquired.

3.3 Structures and Materials

Summary

The mainstream of the development work and supporting research was directed by national programmes to generate technology readiness for participation in future transport aircraft projects.
At the same time, collaboration with European aerospace partners in the field of precompetitive research continued to grow, both in scope and volume.

Usage monitoring is now considered an essential element of fleet management by an increasing number of operators, mainly military. NLR provides total project support including data management and presentation suited to the individual customer's needs.

The existing expertise in the domain of aircraft loads was applied to definition of design gust loads and harmonization of airworthiness requirements.

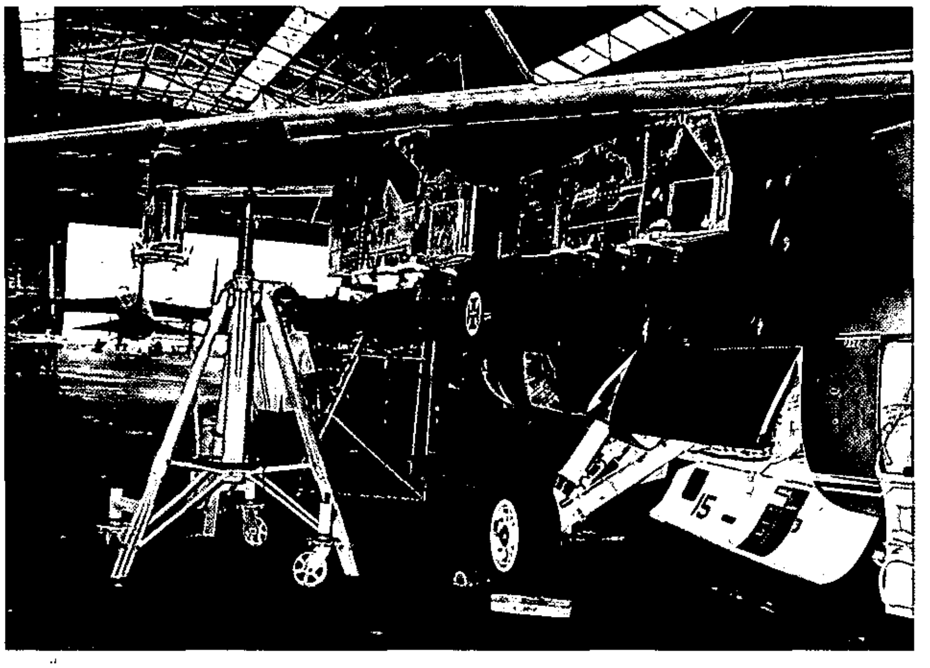
A growing number of suppliers and maintenance firms are turning to NLR for test and evaluation work as they evolve from pure suppliers to developers.

Specific topics in aircraft technology studies include further development of a predictive model of noise transmission through fuselage walls, and demonstration of damage tolerance in stiffened panel structures for a stabilizer demonstrator.
Studies of damage tolerance in aircraft structures and materials included development of methods to reduce the damage sensitivity of composites by locally applying protective layers or by using three-dimensional fibre arrays.
Work continued on predictive models of damage growth mechanisms in composites and failure of fibre metal laminates.

Studies on aircraft loads due to in-flight turbulence were concentrated on gust loading of actively controlled aircraft featuring non-linear response characteristics. Also, the consequences of proposed changes in current airworthiness requirements with regard to dynamic rudder manoeuvres were evaluated.

A measurement programme to determine operational tail loads was completed. The data base contains results from 2000 flights with the Fokker 100 aircraft and is now being analysed.

Support to suppliers and developers of aircraft subsystems included certification testing of a crash tube for a helicopter nose gear and performance evaluation and process improvement of an advanced coating procedure providing thermal protection to aero-engine turbine components.



Ground calibration of a Portuguese Air Force A7 aircraft provided with strain gauge sensors and an eight-channel data recorder at maintenance facilities near Lisbon

Aircraft Loads

Current aircraft designs often feature active control systems leading to non-linear aircraft response characteristics. The design criteria for continuous turbulence (so-called 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), NLR has made a comparative study of methods proposed in the literature to determine continuous gust design loads for such aircraft.

The present work concentrates on a further evaluation of the so-called Stochastic Simulation Method and on the practical problems associated with its application.

NLR takes part in the Gust Specialist Meeting which convenes twice a year under the aegis of the US Federal Aviation Administration to discuss aspects of flight in turbulence and the associated airworthiness rule making.

Under contract to the Netherlands Agency for Aerospace Programs (NIVR), NLR studied the consequences of proposed changes in the Airworthiness Requirements with regard to dynamic rudder manoeuvre load conditions. NLR concentrated on the formulation of a simplified model for the complex control system (including boosters, yaw damping etc.) that would still provide the correct design loads.

In addition, a new method to determine design gust fatigue load spectra on the basis of a continuous gust model has been developed.

In-flight tail load measurements on a Fokker 100 operated by KLM Royal Dutch Airlines have been completed. These measurements, which were carried out under contract to the NIVR, yielded a data base covering 2000 valid flights. The data relate to tail structural loading in actual service, in conjunction with aircraft flight parameters and flight condition. The detailed analysis of this data base was started.

The Fatigue Load Monitoring programme of F-16 aircraft of the Royal Netherlands Air Force (RNLAF) has been continued. Four aircraft within each squadron are equipped with a four-channel digital solid state recorder measuring wing root bending moments and three additional load quantities. From these measurements, average spectra per mission type and per squadron are calculated. Data from the RNLAF's Computer Aided Maintenance System (CAMS) are used to establish the mission mixture flown by each individual aircraft in the fleet. Thus, the load experience and hence the consumed fatigue life of each individual aircraft can be determined. Preparations have started to change over to a new and more advanced system, involving individual multi channel load monitoring for each aircraft.

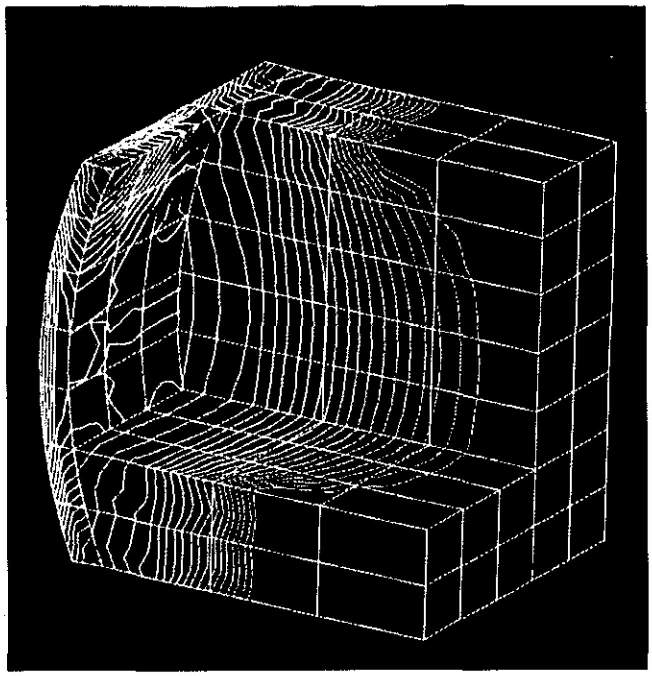
In addition, NLR is carrying out load and usage monitoring programmes for other fixed-wing aircraft and helicopters of the RNLAF and the Royal Netherlands Navy, and programmes of foreign armed forces.

Dynamic Analysis of Structures

Under contract to the 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 Aircraft Internal Noise. The developed method enables different structural wall concepts to be ranked in design studies. Also, the description of damping in the analysis method was being improved and methods to increase the damping by applying tuned dampers or special adhesive layers were investigated.

Strength and Stiffness of Structures

In the programme of the GARTEUR (SM) Exploratory Group 21 'Multi disciplinary design,' several approaches to multilevel optimization were investigated allowing a selection of methods to be implemented in the preliminary design programme ADAS (Aircraft Design and Analysis System).



Predicted pressure contours in the enclosed cabin air volume of a transport aircraft at one of the dominant excitation frequencies

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 a project of EUCLID (European Co-operation for the Long term In Defence). Tests on a first series of these specimens showed results that promised obtaining comparable damage. To improve the strength after impact of composite sheet material, the use of fibres placed in the sheet thickness direction is being investigated.

Composites may replace complex metal parts made by forging or machining. In particular the resin transfer moulding (RTM) technique for this application was studied.
Tools to analyse the static strength and buckling behaviour of composite spars were being developed. Analytical results for different access hole geometries in the web were verified experimentally. Degradation of spar performance owing to impact damage or hot/wet and cold/dry environments were being established experimentally.

Tests on sub-components representative of composite stabilizer structures were done to establish a feasible validation and certification process for composite primary structures. Static and fatigue tests will be performed on a major part of a composite stabilizer. The design of the test set-up including facilities to do the test in a hot/wet environment has been completed.

A composite crash tube for a helicopter landing gear, designed to absorb a specified amount of energy, was subjected to certification tests under contract to DAF Special Products.

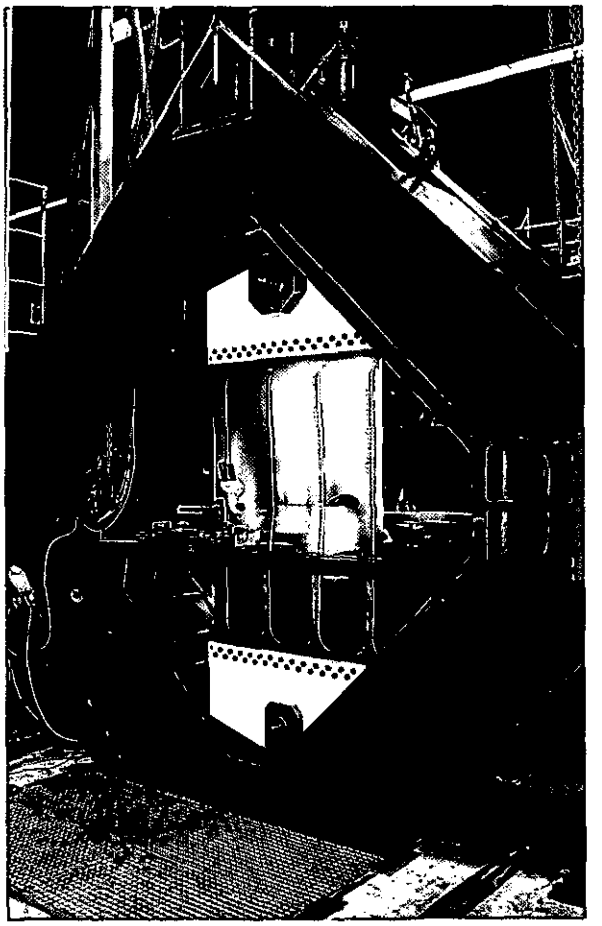
The improvement of the crashworthiness of civil transport aircraft is being studied in a research project of BRITE/EURAM (Basic Research in Industrial Technologies for Europe/European Research on Advanced Materials). A stretchable composite skin concept, the so-called tensor skin, is being developed 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. Crack initiation and crack growth at multiple sites in a lap joint under biaxial loading were investigated in specimens representative of Fokker aircraft fuselages. These tests have provided a better understanding of Multiple Site Damage.

The ageing aircraft problem was also studied in a GARTEUR (SM) AG 18 'Assessment of MSD in highly loaded joints.' Research focused on the analysis and testing of the residual strength of stiffened panels. This activity is continued as a BRITE/EURAM programme SMAAC (Structural Maintenance of Ageing Aircraft). A unique test set-up has been designed and built to test curved, stiffened fuselage panels under biaxial loading and internal pressure.

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. The 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.



In collaboration with the US FAA, the effects of multiple site cracks in the vicinity of a larger damage were investigated. The residual strength of fuselage skin panels was investigated using flat specimens with simulated frame connections and crack stoppers.

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. In a collaborative programme with the Portuguese Air Force, the severity of their aircraft usage is assessed using advanced load monitoring and damage tolerance analysis methods.

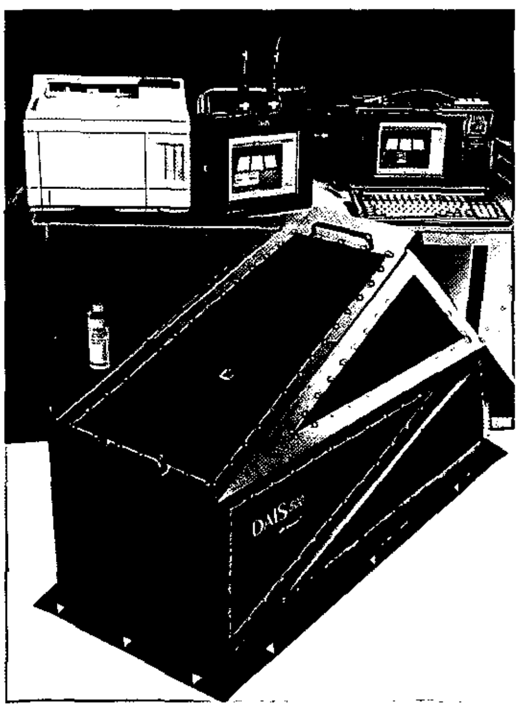
Evaluation of aluminium alloy/fibre laminates was continued under NIVR funding. Two types of laminate have been developed, now both commercially available: ARALL (containing aramide fibres) and GLARE (containing glass fibres).

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 worked on the further development of a blunt notch model for fibre/metal laminates. In the current phase of the project the experimental work concentrates on biaxially reinforced GLARE laminates. Additional experimental data on blunt notch behaviour have been obtained in a BRITE/EURAM programme.

An NIVR programme was begun on the fatigue and residual strength behaviour of riveted lap joints made from biaxially reinforced GLARE laminates. The fatigue behaviour of a GLARE laminate containing a single row of holes was investigated in a BRITE/EURAM programme.

Work has continued in the framework of EUCLID in the Research and Technology Project "Impact and Damage Tolerance of Hybrid Composites." A method has been developed to obtain structurally-relevant damage in coupon specimens. Impact tests were done on specimens with four types of protective layers, which were found to have a large beneficial effect on the residual strength. The D-sight method of non-destructive inspection of the impact damage was evaluated, and methods were developed for repairing lightly damaged skin/stiffener constructions.

Work funded by the Ministry of Defence under the WEAG (Western European Armament Group) TA 31 programme on Lifing Concepts for Aero-Engine components was continued with Corner Crack and Engineering Rim specimen fatigue crack growth tests. The results of earlier Low Cycle Fatigue tests proved useful for interpreting a service failure that occurred in 1995.



In a EUCLID project NLR evaluated a system for global diagnostic inspection of, for example, composite structures containing impact damage. Operator friendliness, accuracy and reproducibility were assessed in a round robin programme involving various composite specimens.

Materials Characterization

An investigation of the damage tolerant aluminium sheet alloy C188 from Alcoa has been started. Comparison of mechanical properties, fracture toughness and fatigue crack growth properties of C188 with those of 2024-T3 showed that C188 can be considered as a potential replacement for 2024-T3 in damage tolerant applications.
The investigation will be continued with fatigue tests on riveted joints.

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

An NIVR programme to develop a cure model for a carbon/epoxy prepreg was completed. The model describes the effects of cure time and temperature on the chemical reaction kinetics of the resin during the cure.
The NIVR-sponsored programme of GARTEUR (SM) AG 17 'Cadmium substitution in aircraft' was continued. This programme includes comparisons of rapid electrochemical test methods and standard corrosion testing, including outdoor exposure. Further, the effect of coatings on fatigue crack initiation was determined.

Engine Materials

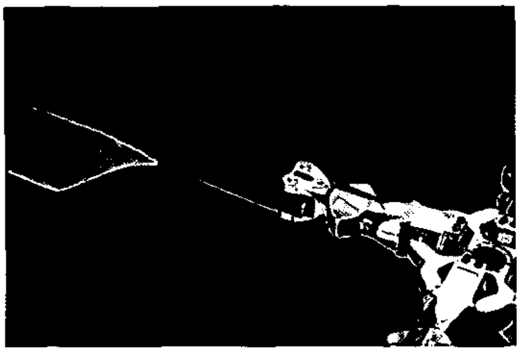
Plasma and flame-sprayed porous seals that can be directly applied to compressor casings were evaluated for the RNLAF and Chromally Holland. The seals showed improved erosion resistance. They are intended to replace soldered-in strip seals worn away during service.

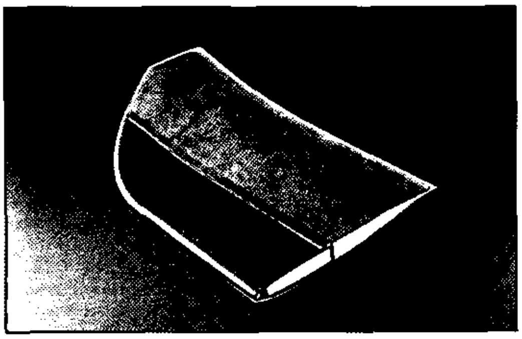
The 'Retirement for Cause' lifing procedure for the F100 engine, and eddy current inspection techniques for coating thickness assessment on turbine parts, were evaluated for the RNLAF. These evaluations will continue in 1996.

Electron Beam Physical Vapour Deposited ceramic coatings on NiCoCrAlY and CoCrAlY bond coatings have been evaluated for Interturbine-Paton. These ceramic coatings on rotating turbine parts allow much higher gas temperatures.

Failure Analysis

The year 1995 was a busy year for the investigation of service failures. As in 1994, a number of failures of cadmium-plated steel components were caused by hydrogen embrittlement.





A dynamically representative wind tunnel model of the NH90 rotor was developed by the Technical Projects Department. The Structures and Materials Division supported the design and manufacture of rotor blades that feature very accurate eigenfrequency values. An extremely high degree of reproducibility in both airfoil shape and dynamic behaviour was achieved partly by composite tooling.

An investigation was done to determine the effect of corrosion on the structural integrity of diaphragms of control stick force transducers. Inspection of several diaphragm surfaces underneath corrosion spots was done with replicating tape. Subsequently a transducer, rejected from service because of intergranular corrosion of the diaphragm, was disassembled and examined in more detail.

Another investigation concerned three bulkheads which were rejected from service because of crack indications. NLR was requested to carry out a non-destructive re-inspection and a destructive verification of a number of selected crack indications. Comparison of the results from eddy current and liquid penetrant non-destructive inspections showed that the eddy current technique is to be preferred. A number of indications were selected for destructive verification. Fractographic examination of forcibly opened cracks indicated that cracking was by fatigue.

Facilities and Equipment

A Noran EDX analysis system has been evaluated and installed for the in situ materials analysis using an electron microscope.

A test rig for curved fuselage panel structures including frames has become operational. The first tests on GLARE panels were started. In this test rig, circumferential loads are generated by differential pressure. A hydraulic system provides longitudinal pressurization loads superimposed by fuselage bending effects.

Procedures and software for a digital image analysis system have been optimized. Deformation analysis by grid measurement has become operational, although its speed and accuracy need to be further increased.

An acoustic emission system for non-destructive inspection has been evaluated. It is being used for the inspection of composite structures during testing.
A D-sight optical inspection technique was evaluated for quick, visual inspection of impact damage in full scale composite structures.

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, micro-gravity facilities and remote sensing. The user support activities were concentrated on the definition of a national data infrastructure for the scientific and operational use of earth observation data. On-board crew support and 'telescience' activities were carried out to prepare for the utilization of the international space station.

The development of modular Test and Verification Equipment (TVE) for the European Space Agency (ESA) was continued. The development of test equipment based on the TVE for the XMM (X-ray Multi-mirror Mission) and integral satellites was started. The equipment will be used for attitude control system testing and for overall system testing.

A number of two-phase flow and thermal control studies were carried out for ESA. The two-phase experiment carried out on board of a Space Shuttle in 1994 will be followed by a similar one, with novel components, an increased number of sensors and extended control software.

For the Space Research Organization Netherlands (SRON) a flight model was made of the Grating Element Support Structure (GESS) for the AXAF (Advanced X-ray Astronomy Facility) telescope.

ESA gave a go-ahead for the development of the Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit), a small satellite for the investigation of the forces exerted on a spacecraft by a liquid in a partially filled tank. The satellite will be launched from the cargo bay of a Space Shuttle. The project will executed in co-operation with Fokker Space, the Belgian companies Verhaert and Newtec, and the Israeli firm Rafaël.

The study on a Container Based Automated Microscope for cell biology was completed. It was followed by studies on a fluorescent detector unit, a video microscopy system for the Biological Glovebox and a video research and stereo microscope for the Biological WorkBench.

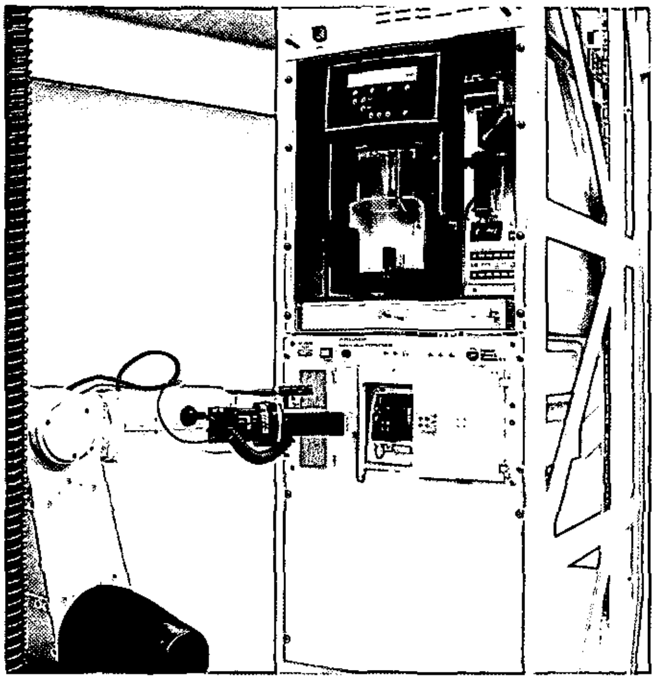
Under contract to the Netherlands Agency for Aerospace Programs (NIVR), a study was made on a future European Military Satellite Communication System including the necessary ground infrastructure.

A conceptual design was made for the Mission *Preparation and Training Equipment for the* European Robot Arm (ERA), and a proposal was made in co-operation with the Belgian companies Spacebel and Trasys. Concepts of the camera and lighting unit for ERA were tested. The study on the Automation and Robotics for Microgravity Applications Demonstrator (ARMADE) was continued. The space robotics laboratory was extended with equipment and cameras for remote control and with a virtual reality system.

The second phase of the feasibility study for a Netherlands Earth Observation Network (NEONET) was completed. This study has defined a national infrastructure for the Netherlands scientific and operational user community. A NEONET Provider Access System (NeoPAS) was developed for the electronic generation and distribution of remote sensing products. NLR participated in studies for the European Center for Earth Observation.

NLR continued work in a consortium to analyse the constraints and opportunities for cost-effective implementation of earth observation data in developing countries.

For the European defence study 'Technology concepts and harmonisation,' NLR continued to act as national representative in an international consortium.



Robot opening the left door of a payload in a simulation test

Testing and Simulation

The development of the modular Test and Verification Equipment (TVE) for ESA was continued. The TVE has to support the integration and testing of the various components of Attitude and Orbit Control Systems (AOCS) and the verification of the correct functioning of 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 test software has been designed as an application of PROSIM (Program and Real Time Operations Simulation Support Tool), a software tool developed for the National Simulation Facility (NSF). The project TVE is carried out in co-operation with Fokker Space and Adelsy of Switzerland, and was partly funded by NIVR.

The development of the AOCS test equipment for the X-ray Multi-Mirror mission (XMM) was started. This equipment is based on the TVE, and will be used for attitude control system testing and overall system testing. This requires extensions for the AOCS stimuli and monitoring, the simulation of the power distribution unit and the remote terminal unit. A similar system will be built for the Integral satellite. The project is carried out under contract to Matra Marconi Space UK.

Two-Phase Flow

The Two-Phase eXperiment TPX has successfully flown on board of the Space Shuttle Discovery in 1994. A second experiment, TPX II, will fly as Get Away Special G 467 on board of a Space Shuttle in early 1997. It will have novel components such as evaporators and a three-way valve, an increased number of sensors, a parallel condenser configuration and an extended experiment control software. TPX II is being developed in the ESA Technology Demonstration Programme 2 and the Earth Observation Preparatory Programme, by NLR as main contractor, with SABCA of Belgium and Bradford Engineering as subcontractors.

In a team with Matra Marconi Space UK, Bradford Engineering and the Russian firm TAIS/Lavochkin, NLR participated in the development of a breadboard model of the thermal control system for the laser head of the atmospheric lidar ATLID. NLR was responsible for thermal modelling and thermal control analysis. The temperature of the laser head is kept at 5 ± 1 degrees by using a capillary evaporator and a two-phase thermal control system. The breadboard model was built and successfully tested.

A high-efficiency two-phase condenser with a low pressure drop was developed for ESA. In this project, Bradford Engineering and Daimler Benz Aerospace Bremen were subcontractors. NLR was responsible for concept selection, testing and evaluation of test results.

As a subcontractor to Daimler Benz Aerospace Dornier, NLR participated in the development of a flexible thermal link for ESA, for use in spacecraft thermal control systems with moving structural parts.

A method being investigated for temperature control of objects is the use of self-regulating heaters. These are usually resistance heaters which, due to the intrinsic characteristics of their constituent materials, maintain the temperature of the substrate within a small range. A number of heaters were tested for ESA to determine the electrical characteristics in a nitrogen environment and during thermal cycling tests in vacuum.

NLR continued the study on liquid flow meters under contract to ESA. In this study, 78 commercially available flow meters were compared. Meters were selected for various working fluids. One of these meters, selected by ESA, will be modified for use in space and tested. The study is performed in co-operation with Bradford Engineering and SABCA.

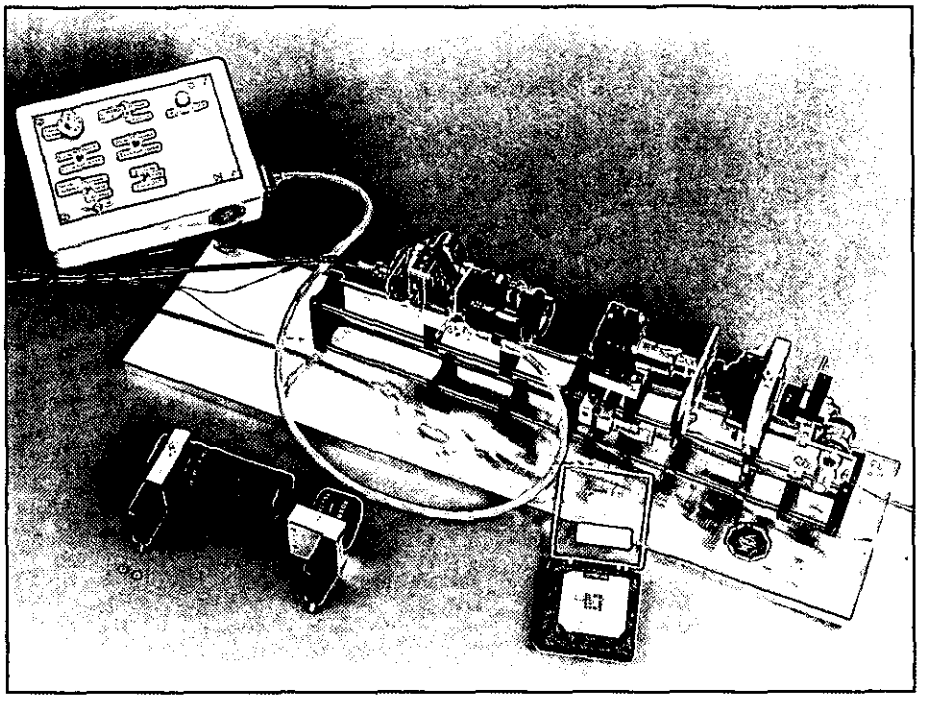
Grating Element Support Structure

For the Space Research Organization Netherlands (SRON), a flight model was made of the Grating Element Support Structure (GESS) for the Advanced X-ray Astronomy Facility (AXAF) telescope. GESS is a complicated mechanical structure for the mounting of individual grating modules in four circles behind mirror shells of the telescope. The project was executed following the NASA/SRON quality assurance requirements.

Microgravity Technology/Payloads

The definition studies for the Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit), under contract to ESA, were completed. Sloshsat FLEVO (previously known as 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. Studies were made on the movement measuring system and the instrumentation of the liquid container. The development of the Sloshsat Motion Simulation program was continued. After

Container-based automated microscope optical breadboard



the Sloshsat project was accepted by ESA's Industrial Policy Committee, a proposal for the realization phase was made. The project will executed in co-operation with Fokker Space, the Belgian companies Verhaert and Newtec, and the Israeli firm Rafaël.

The Phase B breadboarding of a Container Based Automated Microscope for ESA, a project carried out jointly with Fokker Space, has been completed successfully. A follow-up is expected.

NLR started the development of a fluorescent detector unit to be incorporated in a miniature capillary electrophoresis analysis instrument, in a project performed for ESA by a team with Stork Comprimo as prime contractor.
A microscope development project started end 1995, including a Video Microscopy System for the Biological Glovebox to be built by Bradford Engineering and a video research and stereo microscope for the Biological WorkBench, developed with Fokker Space as prime contractor.
The Phase A1 study on a single rack module for the Fluid Science Laboratory proposed for Columbus has been concluded successfully with a presentation at the European Space Technology Centre (ESTEC).

Telescience and Utilisation

As in the past few years, NLR has co-ordinated the Dutch activities in the development of a Dutch Utilization Centre (DUC). Studies were started on the implementation of new technologies, in particular speech recognition and control, to support crew activities on board of the international space station. A database with information and references to remote control and supervision has been prepared, to be made available through Internet.
For the company BSO under contract to ESA, NLR contributed to the development of the Advanced Crew Terminal, a dedicated personal computer, and to the demonstration and evaluation in a realistic environment.

Satellite Subsystems

Under contract to NIVR, a study is being made on the definition of a future European Military Satellite Communication system (Eumilsatcom). A report on the requirements of the Dutch Armed Forces was prepared in co-operation with Fokker Space and the TNO Physics-Electronics Laboratory (FEL). Recent developments of the Global Navigation Satellite System were monitored, in particular on integrity monitoring and availability issues.

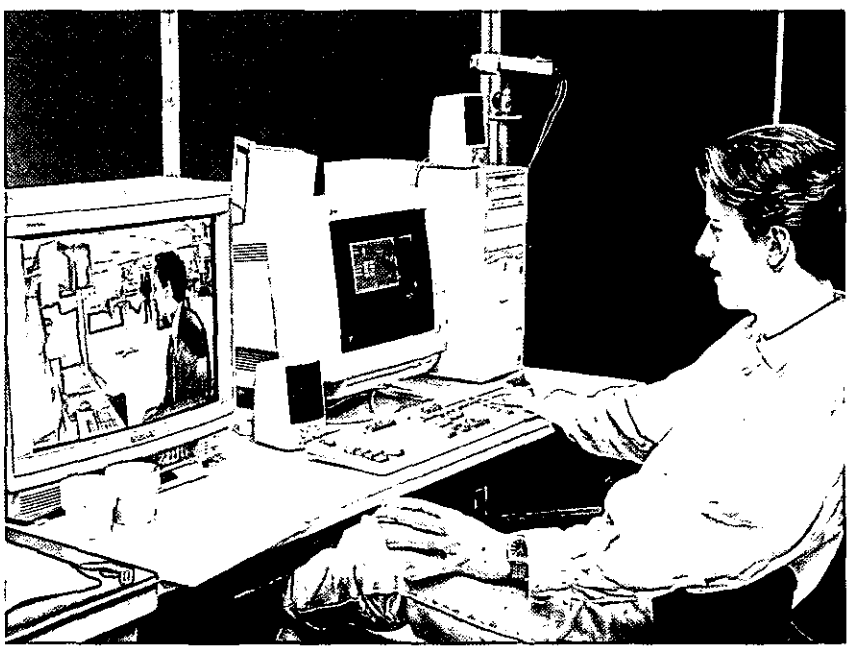
Space Robotics

Under contract to NIVR, development and preparation activities were performed related to space robotics in the Netherlands and in Europe. An updated proposal was prepared for the ERA Mission Preparation and Training Equipment (MPTE). Analysis and design studies on MPTE functions were performed as a preparatory activity. Under contract to NIVR, the utilization of virtual reality techniques in a 'telepresence' concept was studied and a first implementation was realized. A telerobotics experiment was performed during the symposium of the Confederation of European Aerospace Societies (CEAS) at Delft: NLR's Robotics facility in Noordoostpolder was remotely controlled from a tele-operator station at Delft, supported by video links via an asynchronous transfer mode (ATM) connection. Earlier design study results on a robotic flat floor facility at ESTEC were presented at the IAF conference in Oslo and at the CEAS symposium mentioned above.
Concepts of the ERA Camera and Lighting Unit (CLU) were tested, using the previously developed smart telescience camera. In co-operation with Adimec, a proposal was made for the development of the flight version of the CLU. For testing the prototype CLU, adaptations were made to the computer software of the ERA Development model at Fokker Space.

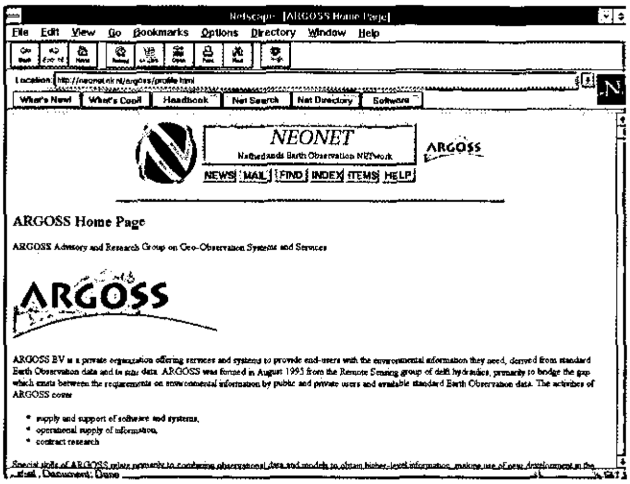
Under contract to NIVR, a study is being performed on the Automation and Robotics for Microgravity Applications Demonstrator (ARMADE). The purpose of this study is the development and demonstration of technologies for automation and robotics to be used in experiment facilities. For ESA, ARMADE will be incorporated in the Columbus Automation and robotics Testbed (CAT). The 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 crew operated implementation. This ARCADE project (Armade in CAT Demonstrator) is performed in co-operation with Fokker Space, Comprimo, Stork Product Engineering and ICT Engineering of Deventer.

Remote Sensing

The second phase of the feasibility study for a Netherlands Earth Observation Network (NEONET) was completed. This phase comprised the realization of a prototype earth observation meta-information system on Internet. Prototype data infrastructures related to atmospheric chemistry and water quality management were also designed. NEONET is planned to 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



Live video connection using a 30 Mbps Asynchronous Transfer Mode link between Delft and NLR Noordoostpolder available to a large international user community. The NEONET study is carried out in co-operation with the Royal Netherlands Meteorological Institute (KNMI) and the Survey Department of Rijkswaterstaat under contract to the Netherlands Remote Sensing Board (BCRS) and SRON. In addition, NLR participated in a number of studies for the design and development of the European Center for Earth Observation.



Part of an Internet World Wide Web page, illustrating support provided by NLR to small private companies

A system for the electronic generation and distribution of remote sensing products, NeoPAS (NEONET Provider AccesS), was started to be developed. NeoPAS will enable customers not only to order products, but also to initiate their generation, without first acquiring the necessary 'half-products.' NeoPAS follows the rules and guidelines proposed in the NEONET project. It is a joint effort of NLR, BSO, Fokker Space and ICT Engineering, and is partly funded by NIVR.

The development of a Meteorological Datafusion Workstation was continued. The concept has resulted in the ARMADA architecture, an Adaptive Reconfigurable Multiplatform Architecture for Data-driven Applications. By means of this architecture in-house computer platforms are connected such that user products are generated with minimal operator interaction with the system. The generation of the product is controlled by a recipe mechanism. ARMADA is a joint effort of NLR and ICT Engineering. The study is partly funded by NIVR.

For the Commission of the European Communities (CEC), NLR participates in a consortium to analyse the constraints and opportunities for cost-effective implementation of earth observation data in developing countries. The concept of a P-band SAR (Synthetic Aperture Radar) mission for forest monitoring was studied. An important aspect of the concept is the ground segment. Studies were performed on the reception of radar data from ESA's Remote-sensing Satellite ERS and the necessary SAR-processing on a personal computer. With respect to application-oriented processing of remote sensing data an inventory was made of requirements, as defined by the UN Food and Agriculture Organization in relation to the ARMADA and NeoPAS concept.

The work in Research and Technology Project 9.1 'Technology concepts and harmonisation' of the European Co-operation for the Long term In Defence (EUCLID) was continued. This project is part of Common European Priority Area (CEPA) 9, Advanced technologies for surveyance satellites. For this study NLR acts as national representative. Simulations were performed to study the atmospheric influences on the data acquired with the optical sensor, and to study the benefits of using actual and statistical cloud information for the optimization of the selection of data taken with the optical and infrared sensors.

Image of Wieringermeer taken from NLR research aircraft using the optical scanner CAESAR (CCD Airborne Experimental Scanner for Applications in Remote Sensing) © LUW/NLR

Under contract to the CEC, NLR has performed geometric correction of Landsat Thematic Mapper satellite images for five East-European countries: Poland, Czech Republic, Slovak Republic, Rumania and Bulgaria. The processing of scenes for this CORINE database was continued.

Under contract to BCRS and in co-operation with the sugar industry, IRS and the Wageningen University of Agriculture, a study was performed into sugar beet yield forecasting, using optical images from Landsat and SPOT satellites.
A separate study was made to investigate the possible use of neural networks for the automatic interpretation of yield characteristics.

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

Facilities and Equipment

The two-phase ammonia loop has been used for the testing of two-phase components. For thermal analysis studies, the software for flow modelling and heat transfer was installed.

A video tele-conferencing system was installed for use in telescience applications, and demonstrated at the international symposium 'Making it Real' held at Delft under the patronage of CEAS, the Confederation of European Aerospace Societies.

In the Robotics laboratory, a robot with a remote controller, a payload rack with demonstration payloads, remote controlled video equipment and various computers for data handling and simulation are available. A virtual reality system was installed. The equipment was used for the ARMADE-project, among other things. It was also demonstrated, in a remote control mode, at the international symposium 'Making it Real' at Delft.

The RESEDA Remote Sensing Data Processing system was connected to a development facility based on personal computers and Indy workstations. The ARC-Info GIS software was installed. For the support of NEONET, a dedicated server was installed which is connected to the Internet. To support the browsing of SPOT data, a SPOT Dali Quick Look system was installed. The Optipares user interface was adopted to the new software of the Flight Test Data Processing System.

3.5 Informatics

Robotics

Following previous studies on force and position control of constrained space-borne manipulators such as the European Robot Arm, a study has been made on the mathematics of impact reduction and controlled contact of constrained robotics manipulators. Hardware-in-the-loop testing was defined.

In close co-operation with the Delft University of Technology, the simulation program TRaCE, Trajectory and Constraint Evaluation, has been extended to include impedance control methods for robotic manipulators. Also, research has been performed into the mathematics of a robust flight control system.
In close co-operation with Groningen University, the mathematical definition and simulation for the control of dynamical systems subject to input/state/output inequality constraints were completed. This has been done for robotic manipulators and for flight control systems.

In co-operation with Fokker Space, the global exception handling concept for the European Robot Arm (ERA) has been refined and the checks needed to handle non-nominal situations have been identified. For some of these checks, algorithms have been developed or detailed descriptions have been generated. A study on the feasibility of continuity checks and consistency checks for detecting various kinds of failures was continued. This work was funded by the Netherlands Agency for Aerospace Programs (NIVR).

NLR participated in the development of the ERA Simulation Facility (ESF). This participation focused on the development of the first, non-real time, version of the ESF and the preparations for the real-time version.

Co-operative Working Environments

In the past several years, the Information System for flow simulation based on the Navier-Stokes equations, ISNaS, was developed for the support of process control in development and application of Computational Fluid Dynamics (CFD). The development of ISNaS was continued, mainly in response to requests from users. Using the hypertext markup language (HTML), an interactive information system for ISNaS was developed. This system includes electronic forms, for fast and direct feedback to users. A facility for the use of ISNaS has been established at the European Space Technology Centre (ESTEC). A part of ISNaS has been installed on a workstation at ESTEC, and a connection to NLR's supercomputer has been made available via ISDN, enabling users at ESTEC to perform interactive simulations on NLR's supercomputer.

ISNaS was accepted as the working environment for the project NICE (Netherlands Initiative for CFD in Engineering). NICE is supported by the Netherlands Ministry of Economic Affairs as one of the main projects in the Netherlands High Performance Computing Network (HPCN) programme. NLR is co-ordinator of the project, which starts in 1996. Partners are Delft Hydraulics, the Maritime Research Institute Netherlands, the J.M. Burgerscentrum for Flow Simulation, the Technical Physics Service (TPD) of the Netherlands Organization for Applied Scientific Research, the Centre for Mathematics and Computer Science (CWI), and the Universities of Delft, Twente and Groningen. In the NICE project, CFD applications are developed for high performance parallel computers. Extensions to ISNaS are defined to generate the CFD working environment. The design of the environment is founded on a network including NLR's supercomputer and at least one workstation of each of the partners, located at their own sites.

The development of a real-time visualization system for CFD working environments was continued, in collaboration with computer manufacturer NEC. Improvements of the user interface and visualization tools were made, an action window for easy-to-use visualization-based interaction was added, and the interface between the visualization and the CFD application was improved.

In co-operation with NEC, SGI (Silicon Graphics) and IBM, NLR has been evaluating parallel and distributed computing servers and related parallelization tools, to prepare the adjustment of the CFD working environment to parallel processing. In particular parallelization using PVM/MPI and parallelization using the available automatic parallelization tools have been evaluated by application-based performance modelling.

The first version of ISMuS, a working environment for Computer-Aided Control Engineering, has been released. ISMuS supports the modelling of dynamical systems and the 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, using NLR's SPINE tools, of three commercially available software tools (MATLAB, PVWAVE, and MAPLE) and the simulation package PROSIM (Program and Real Time Operations Simulation Tool) developed by NLR. ISMuS was installed on NLR's computer network and was used for research in the areas of robotics, sloshing liquids, and flight control.

NLR contributed to the development of the EuroSim facility, an engineering simulator under construction at Fokker Space. NLR has been responsible for the Software User Manual, for the Demonstration Model, for the System Test Plan, and for the independent System Test of EuroSim Mk0.1. NLR will be responsible for the same tasks for EuroSim Mk0.2.

Mathematical and Computational Aspects of Flow Solvers

Numerical modifications have been made to the flow solver ENSOLV of the ENFLOW system for the numerical simulation of 3D viscous flow around complex configurations. These modifications improve the robustness and allow flows to be calculated for specified lift coefficients. Computations have been performed for ESA to simulate subsonic, transonic, and low supersonic flow around a Viking-type capsule.

In collaboration with NEC, NLR has developed an efficient parallel linear solver for Poisson equations to be used on the distributed-memory parallel Cenju-3 computer. Parallelization is based on domain decomposition. For the solution method of the linear equations, the iterative method BiCGSTAB(2) has been chosen, with a two-step preconditioning technique. Communication is by message passing.

The algorithm for flow simulation based on local grid enrichment for future Large Eddy Simulation has been parallelized on two shared-memory machines, the NEC SX-3 and the SGI Power Challenge. The parallelization results show that the algorithm has sufficient parallelism. Large Eddy Simulation around a clean wing at moderate Reynolds numbers is feasible on the sixteen-processor NEC SX-4.

A multi-time stepping algorithm for time accurate simulation of time-dependent flows has been validated. Using the results of the validation, the algorithm has been improved to obtain an efficient, accurate, explicit integration scheme. The algorithm is five times more efficient on two-dimensional turbulent flows than the standard explicit scheme using a single time step.

Safety

Mathematical and software aspects were dealt with in various international research projects under the APAS Programme of the European Union (EU). The MUFTIS (Model Use and Fast Time Simulation) project dealt with different aspects of modelling, simulation and validation in Air Traffic Management (ATM). Particular attention was paid to cost/benefit analysis.

The VAPORETO (Validation Process for Overall Requirements in Air Traffic Operations) project concerned the development of strategies for the validation of future advanced ATM, taking into account the involvement of the different actors. In the Systematic Safety project, the feasibility of developing a quantified causal tree for the safety of the overall air transport system was the objective. Various statistical aspects related to the data and modelling required for such a tree were examined.

Work on the development of an accident location model for regional airports continued. One of the major issues in this development concerns the modelling of the route patterns followed by light aircraft at such airports. Statistical characteristics of a Monte Carlo simulation approach to this problem were analysed, and alternative approaches were proposed.

NLR participated in two meetings of Working Group A of ICAO's Review of the General Concept of Separation (RGCS) Panel. A previously developed model for estimating the lateral collision risk in an Automatic Dependent Surveillance (ADS) environment was extended with the modelling of several system dependencies, and presented to the Working Group. An appendix to the airspace planning methodology under development by the RGCS Panel was prepared, summarizing the original and extended modelling.

Under contract to the Netherlands Department of Civil Aviation (RLD), two collision risk studies have been carried out for the use of parallel runways for landing. The research yielded insight into the collision risk during missed approaches, the critical flight phase for simultaneous parallel approaches at closely spaced runways.
The first study considered the safety related to the use of Schiphol parallel runways 01R and 19R for landing. A risk model has been developed and implemented for the estimation and evaluation of the collision risk between aircraft performing approach or missed approach procedures. Numerical results showed that the use of Amsterdam Airport Schiphol runways 01R and 19R in opposite directions may be judged

sufficiently safe under all operational conditions. The second study focused on the minimum required parallel runway spacing for which the collision risk related to independent parallel approaches is acceptable. In addition, the issues of which risk measure is to be used and which Target Level of Safety is to be adopted are dealt with.

Sensor Modelling

Systematic errors in radar observations pose considerable problems in practice. Methods to extend the aircraft trajectory reconstitution system Muratrec, in use by Eurocontrol, with a means for the modelling and estimation of time-varying systematic radar errors have been examined.

The monitoring of aircraft height-keeping performance is one of the requirements for the introduction and use of a reduced Vertical Separation Minimum above Flight Level 290 in ECAC (European Civil Aviation Conference) airspace. It is practically impossible to monitor every individual flight continuously, but a sufficiently large and representative sample of aircraft height-keeping data needs to be collected. Under contract to Eurocontrol, NLR conducted a study of the number and siting of height monitoring systems required for the ECAC airspace. Some theoretical work on sample size requirements was conducted and traffic flow data made available to NLR were analysed. Based on this, a number of candidate monitoring locations were identified.

In the NH90 helicopter development project, a global description of the data fusion algorithms for the MTAC (Matching of Tracs for Association and Correlation) module has been made.

Multivariable Optimization Techniques

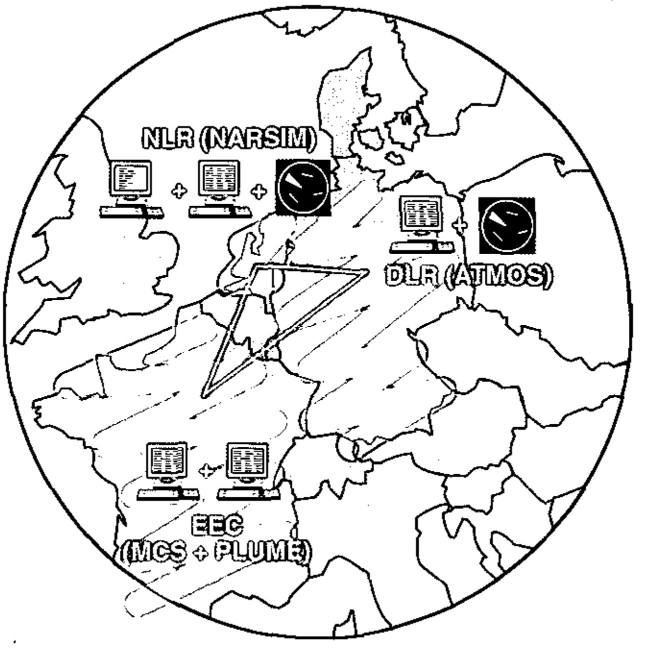
NLR participated in the GARTEUR Exploratory Group (FM) EG-14 that was established in 1995. It defined a Terms Of Reference document that describes in detail the proposed work on Multivariable Optimization Techniques for Experimental and Conceptual Design. The work is to be carried out by GARTEUR Action Group (FM) AG-10.

Network Simulation in Computer Aided Engineering

For Fokker Aircraft, NLR contributed to the requirements specification of a program for the simulation of electrical, hydraulic and pneumatic networks, and combinations of these.

Mathematical and Software Aspects of Air Traffic Control

Distributed Air Traffic Control (ATC) simulations were executed under contract to the European Union. A feasibility study called Annette has been carried out to investigate the application areas of computer networks for the air traffic management (ATM) research community. Two prototype applications have been built, making use of the Internet, to enhance information exchange and to run distributed ATC simulations.



Distributed ATC simulation involved four simulators in three countries: NARSIM (NLR), ATMOS (DLR), and MSC and PLUME (EEC)

The prototype applications developed in Annette have been used by ATM researchers to assess the possible use of computer networks in their field of research. The information exchange application was based on the existing World Wide Web (WWW) technology and infrastructure. The WWW infrastructure was also used in project management, for the distribution of planning and progress reports, for the publication of reports and for the co-ordination between NLR and its four subcontractors: DLR of Germany, DRA of the United Kingdom, ONERA of France and Eurocontrol.

Real-time and co-ordination aspects of computer networks were studied using a prototype distributed ATC simulation. In this simulation the NLR ATC Research Simulator NARSIM was linked with simulators of DLR and Eurocontrol to simulate and control air traffic in Dutch and German airspace. Four ATC simulators were involved. NARSIM provided overall simulation control and simulation of a part of the Dutch air traffic, and provided air traffic control for all air traffic in the Dutch FIR. ATMOS of DLR simulated air traffic around the Frankfurt airport and provided air traffic control for all air traffic over Germany. MCS and PLUME of Eurocontrol simulated all international air traffic.
A theoretical study into network requirements and a survey of current and future networks and network technologies complemented this study.

For radar tracking systems several software and mathematical aspects were given attention. One aspect concerns the Multi-radar Aircraft Tracking System for Eurocontrol. Under contract to Thomson-CSF, NLR develops the core tracker of the ARTAS (ATC Radar Tracker and Server) system. The development of the tracker subsystem was continued. The pre-production version was extensively evaluated in co-operation with specialists from Eurocontrol and contributing agencies. This version was also integrated in the ARTAS system at Thomson-CSF premises.

Two important milestones were reached: the demonstration of the tracker performance and the factory inspection of the complete ARTAS system. Both were completed successfully and consequently, Eurocontrol decided to continue with the optional phases of the project.
The formal qualification of the tracker against the Eurocontrol specifications showed that the basic tracker performed well within the specifications.

During tests and evaluations, intensive use was made of the Eurocontrol-supplied RASS tools (Radar Analysis Sub-System) and of the NLR test tools.
For accessibility and conservation, the test tools were put into one environment, ISRaD (Information System for Radar Dataprocessing).

The second activity for radar tracking systems concerned a facility for quality assessment of multi-radar aircraft tracking systems for Eurocontrol. Work on the development of the Multi-radar TRAcker Quality assessment facility (MTRAQ) was continued. The goal is to provide Eurocontrol with a tool to measure the performance of existing and newly developed aircraft tracking systems, such as ARTAS, and use these measurements to access and tune the quality of the tracker under test, using a comprehensive Human Machine Interface.

MTRAQ provides means to classify the data for which the tracker performance is measured (e.g. aircraft category or radar plot quality). It enables measurements related to tracking accuracy (e.g. position or heading), track detection (e.g. track initiation delay) and tracker Mode-Of-Flight indication (i.e. indication of aircraft behaviour per flight direction) to be made using classified data. Performance characteristics can be computed and presented at different abstraction levels, ranging from raw ground tracks to class-based statistics (e.g. convergence values of root-mean-squared groundspeed errors per class). The Human Machine Interface enables navigation between abstraction levels to support detailed analysis. An example screen layout shows the use for ARTAS testing purposes.

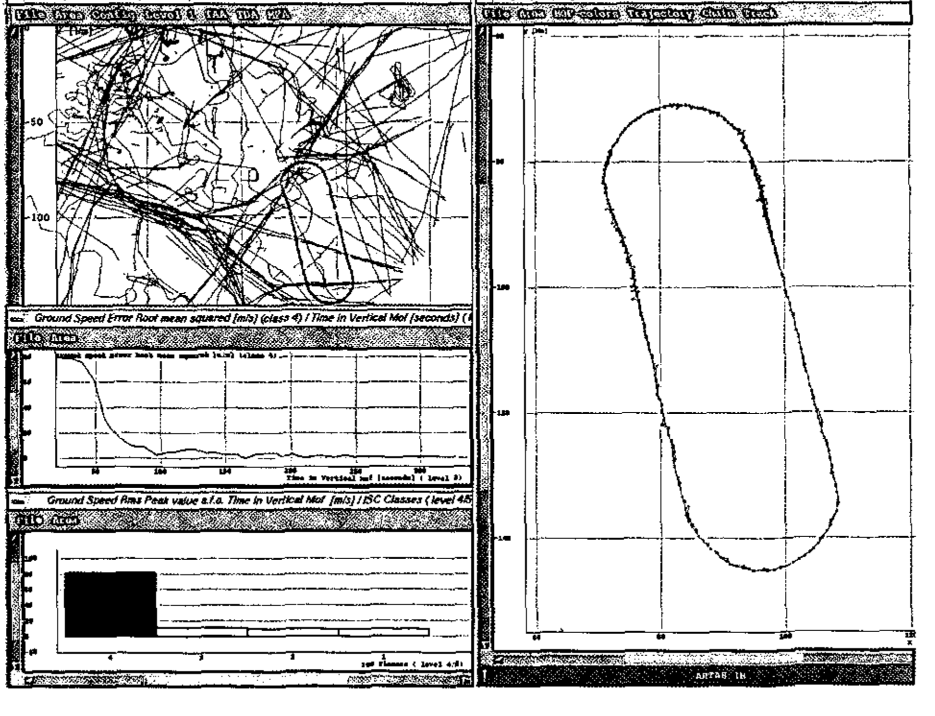
Prototype versions of MTRAQ have been provided to Eurocontrol, Air Traffic Control The Netherlands (LVB) and the ARTAS development team. At present the facility has passed Provisional Acceptance and is planned to be integrated in Eurocontrol's Radar Analysis Support System (RASS) by mid-1996. RASS already includes the Muratrec aircraft trajectory reconstruction facility and SMART (Simulator for Multi-Radar Analysis for Realistic Traffic). Muratrec and SMART were developed by NLR under contracts awarded by Eurocontrol, the US Federal Aviation Administration and LVB. MTRAQ was presented to RASS users during Eurocontrol's SSGT workshop. A majority of the RASS users has expressed the wish to become user of MTRAQ.

Multi-sensor Data Fusion

Under contract to the Western European Armaments Group (WEAG), NLR participates in a consortium consisting of Signaal, Thomson-CSF, TNO-FEL, Inter Access and Matra Cap Systèmes, to perform Phase B of the TA-10 project 'Multi-Sensor Data Fusion through Advanced Information Processing'. The project is aimed at a near-real-time demonstrator for multi-sensor data fusion. The application chosen for the demonstrator is battlefield surveillance, where sensor data from various sensors (Moving Target Identification radar, infrared, television and Electronic Support Measures) mounted on different platforms (ground, helicopter, drone) are fused. The multi-agent-based architecture and data fusion methods and techniques are generic and applicable to many other domains such as distributed simulation applications, air traffic management, and earth observation.

A second multi-sensor data fusion study is being carried out for the Royal Netherlands Navy. A precursor of this study concluded with promising methods from Advanced Information Processing technology which potentially comply with the real-time demands of current applications. Two of the promising methods (approximate and progressive reasoning) were selected for evaluation by performing small-scale simulations. The simulations have proven that approximate reasoning performs slightly better than progressive reasoning in a static environment, without interruptions. In dynamic environments, however, progressive reasoning outperforms approximate reasoning.

Analysis of live radar data sample.
The ground speed error is analysed for a selected mode of flight, with specific attention to one of the related tracks (right) for this sample.



On-board Decision Support

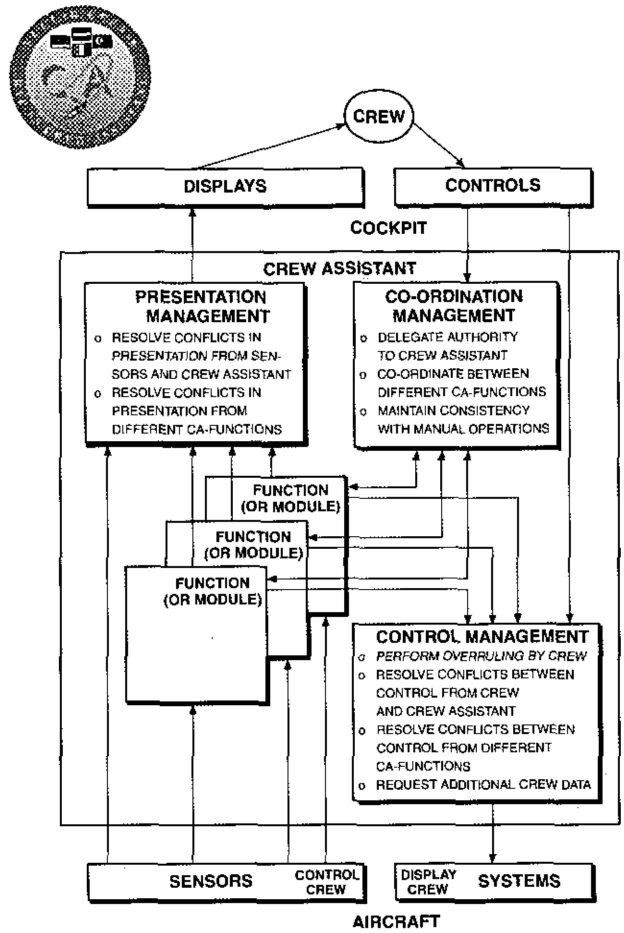
NLR has completed its first project under the European Co-operation for the Long Term in Defence (EUCLID) programme. The Research and Technology Project RTP 6.5, *Crew Assistant*, was led by NLR as Single Lead Industrial Entity. Participants in the consortium were DASA of Germany, Alenia of Italy and Boğaziçi University of Turkey.

The Crew Assistant is planned to exploit advanced information processing technology to support aircraft crews by organizing the data and control flow such that the crew is provided with concise and relevant information.
The initial phase of the Crew Assistant programme has resulted in the definition of user requirements for the Crew Assistant, and of a generic architecture independent of the aircraft type. Advanced information processing technology suitable for the Crew Assistant were evaluated, and the system specifications for a Crew Assistant to be realised in a follow-on RTP were made.

Decision Support, Planning and Tasking

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 decision support, planning and tasking. NLR focuses on real-time execution and updating of planning, using real-time dynamic AI planning methods. In 1995, research and experiments on the application of anytime computing and progressive reasoning techniques have been performed.



Schematic of Crew Assistant

In the definition of test scenarios for validating the new Artificial Intelligence and software engineering methods in the C^3I Workstation, NLR has defined air elements in two military scenarios, a peace enforcement mission by a multi-national army division, and an amphibious landing mission by a multi-national naval task force.

NLR has participated in domain analysis using the latest techniques in software engineering and domain modelling. For domain analysis, the object-oriented Rumbaugh Object Modelling Technique (OMT) has been extended with the concepts of agents and functional units. Groups of co-operating agents providing services to other functional units and agents enable an agent-based approach to be used in (military) organisation modelling.

To support domain analysis activities within the geographically distributed consortium of companies working on this project, NLR has participated in the definition and construction of an ontology for the problem domain. An ontology defines the basic terms and relations comprising the vocabulary of a problem domain, as well as the rules for combining terms and relations to define extensions to the vocabulary, with the aim of establishing ground rules for modelling in a domain.

The experience gained in RTP 6.1 with object-oriented analysis and design is being used in Air Traffic Management applications. Spin-off in real-time planning is also expected in Air Traffic Management projects starting in 1996.

Decision Support System for Runway Use

As a continuing activity, NLR designs and develops software for the selection of preferable runway combinations at Amsterdam Airport Schiphol. The system has been extended to be capable of being operated in real-time, and was installed on site for a test period. By a Graphical User Interface, it shows a list of permitted runway combinations in preferential order. The combinations are based on wind models, the actual UTC time, meteorological conditions, runway availability and ILS categories. All data are shown on the screen. Using a forecast screen, the controllers can manually input data for which the system determines the preferred runway combination.

Genetic Algorithms

In co-operation with the Centre for Mathematics and Computer Science (CWI) and Leiden University, NLR has investigated the use of Genetic Algorithms for free route planning in Air Traffic Control (Evolutionary Free Route Planning). A representation based on Mode Of Flight was chosen. A fitness function has been defined on the basis of the premises that each aircraft must reach its destination with minimal detours and that no conflicts are allowed. This fitness function guides the genetic algorithm through the multi-dimensional search space.

Genetic algorithms have also been used to optimize airfoil pressure distributions. In this case, an existing evaluation function was adapted for the genetic algorithm. In order to increase speed, problem-specific knowledge was included to steer the genetic algorithm.

In both projects, simulations carried out to find an optimal combination of parameters showed promising results.

Training Concepts and Systems

Under contract to LVB, and in close co-operation with Netherlands Air Traffic Control instructors, NLR is studying the possibilities to support ATC instructors. In the Procedural Approach Student Achievement (PASA) project, methods are being devised to support instructors in assessing student skills.
A prototype of an electronic strip panel was developed to enable the actions of a student to be recorded. Usage of the prototype by LVB instructors showed the promising possibilities.
To identify relevant events for situation determination, a real Procedural Approach Training lesson at LVB was recorded on video and analysed. It appeared possible to identify relevant events. Some manual actions may be performed automatically in future. Overall, PASA seems a promising approach to support instruction.

Software Certification

For the Netherlands Department of Civil Aviation (RLD), NLR conducts studies for the certification of on-board software. This year, two studies were performed related to the international avionics guidelines RTCA/DO-178B.

One study examined the role of formal methods in avionics. A general survey of the most commonly used formal methods has been carried out. Advantages such as the reduction of ambiguity of specifications and the automatic transformation/code generation were identified, as were restrictions on possible applications related to expressiveness, understandability for developers, conformity of intentions to specifications and lack of tools support. It was shown how the methods can be used to follow the certification guidelines.

A second study investigated how Computer-Aided Software Engineering, and in particular the use of Teamwork as a CASE tool, can be applied in each of the processes of RTCA/DO-178B. Certification of software will especially benefit from a sound application of Teamwork's software development, configuration management and verification and validation facilities.

Data Management

Data management support was given in a variety of civil and military projects. Examples include the package ORACLE that NLR has coupled to a special multi-level secure environment. This environment has been used in a number of heavy multi-radar applications for LVB, Thomson-CSF and Eurocontrol, on various platforms. In the past year, it has been included in FANOMOS, the monitoring system used at airports around the world.

NLR started phase C of the Measurement Configuration Database System (MCDB) and Historical Configuration Database (HCDB), two coupled data management systems for flight tests, using the Accell/UNIFY combination for MCDB and IBM's DB2 for HCDB.

In EUCLID and WEAG projects, new Common Object Request Broker Architecture (CORBA)-compliant (distributed) Object Database Management Systems (ODBMS) have been evaluated.

Mission Preparation Support

Under contract to Lockheed Martin, assistance was given at Lockheed Martin's facilities in the preparation for the final acceptance test of the Mission Support System/Campal (MSS/C). The final acceptance test was successfully concluded. The final software release was distributed to the air forces of the participating countries, Belgium, Norway and the Netherlands.

The feasibility study of an MSS/C derivative for mission preparation for transport helicopters was concluded with a detailed requirements document and a technical and financial proposal for the adaptation of the F-16 MSS/C to the Chinook MSS/C.

By end of the year an contract for MSS/C interim contracts support was concluded.

System for Scanning Topographical Maps

On the map scanning station for the production of electronic maps to be used in MSS/C, a CCD (Charge Coupled Device) camera was installed for map scanning at higher resolution (8-10 pixels per mm). Resulting electronics maps showed just like the original map. Both the final MSS/C release and the enhanced electronic maps were demonstrated to the Royal Netherlands Air Force Staff during the Open Day of Wing Mission Planning section at Volkel Airbase.

Multimedia Applications

NLR was involved in the continuation of the PAGEIN (Pilot Application on a Giga-bit European Integrated Network) project of RACE (R&D in Advanced Communications Technologies and Services), with ONERA as co-ordinating partner. In co-operation with industrial users Alenia and CASA, NLR demonstrated the advantages of high-speed multimedia connections. Results of different flow solvers around space systems could be easily compared and enhanced. The system has also been used to demonstrate at the Airshow of Le Bourget that the NLR SX-3 supercomputer can be easily accessed and used for aerodynamic problem solving, by distributed users. Results of the project have been successfully integrated in NLR's 'middle ware' system SPINE that facilitates the application of software on heterogeneous computer networks.

NLR started participation in the Advanced Communication Technologies and Services project MULTICUBE, with the Italian PNO CSELT as co-ordinating partner. Together with Alenia and CASA, and South European car industries as users, NLR will demonstrate via teletesting and DIS (Distributed Interactive Simulation) the advantages of new features in European high speed networking. Aerospace applications have been defined using NLR's working environment for computer aided control engineering ISMuS in combination with NLR's space robotics laboratory.

Computer Facilities

The hardware facilities of NLR's computer network included an NEC SX-3 supercomputer, several UNIX servers and a non-UNIX mainframe. A communication network based on the TCP/IP protocols connects the facilities with workstations, X-terminals, personal computers and other terminal equipment all over NLR. Wind tunnels, simulators and other facilities are also connected to the network, which is linked to networks of major customers and to national and international networks as well. The number of stations connected to NLR's network increased from 650 to 963.

The computer network has been upgraded to accommodate the rapid growth of the number of stations and the bandwidth required. The two sites of NLR are connected by a 34 Mbps ATM (Asynchronous Transfer Mode) link. In both sites a segmented network provides the users with a high communication performance inside NLR as well as to facilities of external users. A start was made with the design of a growth path to an ATM infrastructure at NLR. The NLR network has been used in European projects connecting partners via high speed IP and ATM links.

A start has been made with the upgrade of the central computer facilities. A contract was signed to replace the SX-3 by its successor, the SX-4, in 1996. This will increase the supercomputer processing power ten-fold. The processing power will be doubled two years later.

The gateway from NLR to the outside world becomes very important to NLR. Both the traffic from NLR to the outside world and the use of the NLR facilities from outside are increasing rapidly. To maintain a good security level, a start was made with an upgrade of the network security measures.

The use of the computer facilities showed considerable growth. The file server provides to all UNIX systems in the network a file system. The total size of the files stored on this server increased in 1995 from 70 GB to 115 GB. The number of workstations that use the file server for automatic backup increased with 81 to 219.

A start was made with the definition of an upgrade of the file server facility, to accommodate the projected use.

To lower cost and to improve user support for NLR's computer and network infrastructure, operational and development activities were separated in the organisation. This will also improve the support to customers in network developments.
The support structure for personal computers at NLR has been formalised. The use of central servers together with site licenses and a well-defined support structure will provide an efficient and cost effective infrastructure for personal computers.

Middleware for Computer Networks

In past few years, SPINE, a general tool to create working environments has been developed. SPINE has become a coherent system that includes a graphical user shell, a tool for defining working environments, a tool for managing versions of software source code, a tool for managing data files, tools for managing on-line documentation, and a tool for automatic generation of graphical user interfaces. The information management capabilities of SPINE have become valuable tools for the support of the execution of quality assurance procedures according to the ISO-9001 standard. Parts of SPINE were implemented in organizations supported by NLR.

SPINE supports the construction, customization, maintenance, and operational use of working environments for specific application areas, in networks of UNIX computers. A SPINE-based working environment presents the network to the user as one single virtual computer. Networking details, such as logins to remote systems, file transfer between computers, start and operation of programs on different computers, and data conversions, are transparent. In this context SPINE has been used for the implementation of an enhanced version of the CFD working environment ISNaS, the Computer-Aided Control Engineering (CACE) working environment ISMuS, the CASE working environment ISEnS, and the ISRaP working environment for processing radar data.

3.6 Electronics and Instrumentation

Summary

On 1 January 1995 the new Electronics and Instrumentation Division was established. In the new division, consisting of the departments Avionics, Electronics, and Instrumentation, the activities of NLR in these areas are concentrated.

The establishment of the new division reflects NLR's view on the importance of electronics and instrumentation for aerospace research and development. Especially electronics is considered to be of growing importance, whereas by combining forces in electronics and instrumentation, higher efficiencies and better cross-fertilization are expected.

The new division took care of about 16 per cent of the volume of NLR's contract work.

In the field of avionics, major research efforts were undertaken in the areas of modular avionics, a phased-array airborne Synthetic Aperture Radar (SAR), an avionics suite for the F-16 Mid Life Update programme and the NH90 programme (mission system and vendor equipment).

In the area of electronics, several activities were undertaken related to the Data Link Processor Unit (DLPU), an important building block in Eurocontrol's research programma for future air traffic Management concepts. Activities in the area of wind tunnel data acquisition equipment – remote control and miniaturization – were also of importance. Activities in the area of electronics for space applications concentrated on a mass memory for manned spaceflight and the control and data acquisition equipment for life science experiments on sounding rockets.

In the area of instrumentation, the activities were concentrated on the flight test programmes of Fokker Aircraft for the Fokker 50, Fokker 60, Fokker 70 and Fokker 100 aircraft.

Development work was continued on flight test instrumentation subsystems: a high-capacity Arinc 429 Avionics Data Acquisition System (ADAS); a GPS-based real-time precision Positioning Reference System (PRS) and on-board instrument control.

Research to develop flight test measurement methods was carried out. The development of instrumentation for Air Traffic Management research purposes is becoming increasingly important.

A major contribution has been made to the instrumentation of a 'Parafoil Technology Demonstrator' for an experiment of ESA in the framework of manned space/reentry.

In the area of facilities and equipment, efforts concentrated on a major update of the EMC laboratory, to comply with the new requirements to field strength, 100–200 V/m.

NLR's Infrastructure for Computer Aided Engineering of Electronics was extended with new functions such as MTBF (Mean Time Between Failures) calculations and FMECA (Failure Mode, Effect and Criticality Analysis).

The data processing system for flight test data (DVSV) was upgraded considerably.

The calibration laboratories for pressure and for electromagnetic quantities were successfully audited by the accrediting Netherlands Calibration Organization (NKO).

Avionics System Engineering

Integrated Modular Avionics

NLR continued to be heavily involved in the Research and Technology Programme 4.1 'Modular Avionics Harmonization Study' of EUCLID (European Co-operation for the Long term In Defence). This collaborative study by six European nations, in which a total of 27 companies participate, is headed by Daimler Benz Aerospace. The areas in which the NLR was involved in the project covered: data buses and networks, digital signal processing (DSP), system aspects, component and rack cooling, and system development. Work in the area of data buses and networks is of particular interest. It involved an analysis of communication requirements, an evaluation of existing and emerging protocols, a pre-selection of candidate protocols, and modelling and simulation of one of the candidate configurations. The candidate configuration that was modelled and simulated was an optical switch matrix under control of a cell switched network. The optical switch matrix offers the avionics system high-speed, point-to-point connections. A bandwidth of 2 GBit/sec is projected. The main purpose of the matrix is to connect sensors producing high data rates, such as radar and FLIR (Forward Looking Infrared), with the core avionics processing cluster.

The cell-switched network – in this case ATM (Asynchronous Transfer Mode) – controls the optical switch matrix and provides data transfer at lower data rates, file transfer, and status messages. Currently, ATM supports up to 622 Mbit/sec. The computer-based tool used to model the avionics network was SES/Workbench.

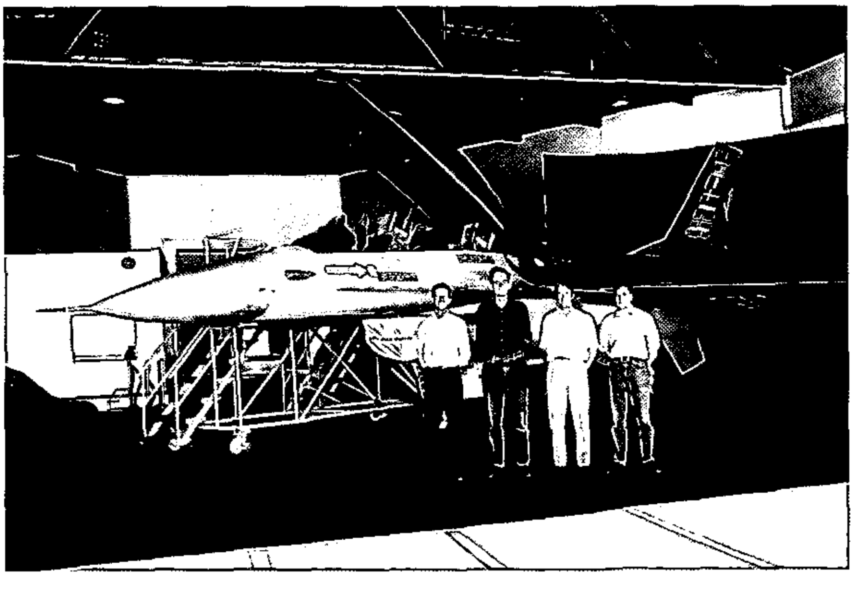
F-16 Mid Life Update

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 Martin (LM) in Texas, USA, under contract to LM. Three were working in the Avionics System Requirements and Verification Team of the LM's F-16 MLU design team, one participated in the activities of the Systems Integration Laboratory (SIL), and one participated in the Attack Radar Flight Tests at Edwards Air Force Base.

Also under contract to Lockheed Martin, 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.

NH90 Mission System Development

NLR continued contributing to the design of the Mission System of the NH90 Nato Frigate Helicopter. A detailed specification of mission system functions was made. NLR will develop a module that performs track-to-track associations of tracks from surface and subsurface vessels using information from the NFH mission sensors such as the radar, FLIR, ESM and sonar. This module will reside in the NFH mission system. The main goal of this module is to reduce the operator's work load. These kinds of associations were previously done manually, but with this module the operator only has to confirm or reject the suggestions by the module. Functional evaluations and simulations are part of the design approach in order to establish a correct behaviour of the module and to validate the design goals.



F-16 Mid Life Update: members of NLR staff in front of RNLAF F-16

Avionics Studies and Evaluations

Under contract to the Royal Netherlands Air Force (RNLAF), NLR continued its research and development in the area of airborne electronic moving maps for navigation purposes. The developed demonstration system is composed of a Precision Light Weight Military GPS Receiver (PLGR) and a notebook personal computer in which a digital map data base resided. The functionality of the system was extended for the use of vectorized maps. The system is now capable of displaying raster, vectorized, and satellite (SPOT) images.

Under contract to the Netherlands Department of Civil Aviation (RLD), NLR worked on a study of methods for the implementation of fault-tolerant avionics.

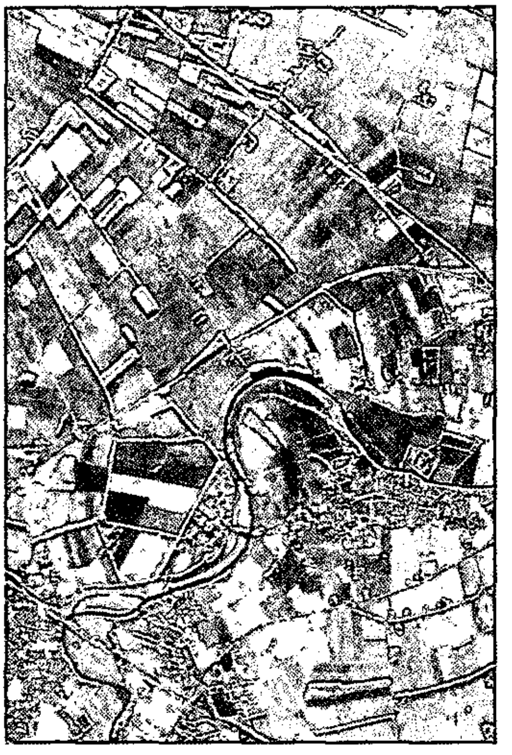
A study of the immunity of electric and electronic systems of civil aircraft to radiation from transmitters used in the vicinity of airports, also under contract to the RLD, was concluded.

Sensors

NLR continued work in the project Phased Array Universal Synthetic Aperture Radar (PHARUS), consisting of the development of a fully polarimetric airborne Synthetic Aperture Radar (SAR), to be flown on the Citation II research aircraft. The development, under contract to the Netherlands Agency for Aerospace Programs (NIVR), is a co-operative project of the TNO Physics and Electronics Laboratory, the Delft University of Technology and NLR. A major milestone was reached by the first flight of the PHARUS system, which resulted in high-quality SAR images.

Space Applications

For manned space applications, NLR was involved in several activities of ESTEC and NIVR concerning spaceborne mass memories. NLR designed a Mass Storage Device (MSD) to be used as a component of the Data Management System in the Russian module of the International Space Station. The MSD design will also be compatible with the MSD specifications for the Columbus Orbital Facility.



PHARUS image showing river, roads and various buildings (PHARUS data by TNO-FEL, NLR and DUT)

The fully space-qualified MSD provides non-volatile data storage for which state-of-the-art PCMCIA Winchester disk drives are used. The drives will be housed in a sealed cartridge protecting them from vacuum conditions, and allowing a convenient exchange mechanism. Special precautions were included in the MSD design to prevent a so-called 'latch-up' of the MSD, which could occur due to radiation.

NLR is responsible for the design, development, and production of the MSD and a so-called unit tester. Furthermore, NLR will perform qualification tests, acceptance tests, and radiation tests on the selected disk drives.

The chosen solution has growth potential, because the drives can be replaced by higher density PCMCIA drives that will come available in future.

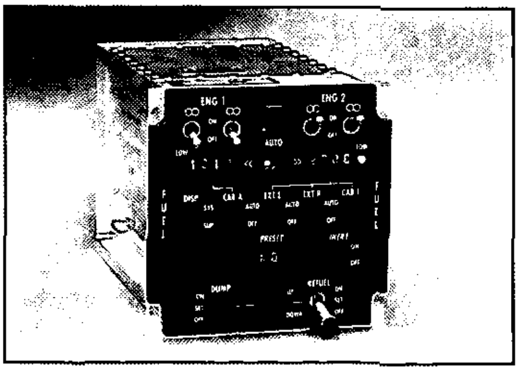
Electrical model of Mass Storage Device

Under contract to the European Space Agency (ESA), the remote sensing ground station ARTEMIS was extended with a Network Interface Unit. ARTEMIS (the Africa Real-Time Environmental Monitoring Information System developed by NLR for the FAO), is used for remote sensing information processing for monitoring of food supply conditions in Africa. The Network Interface Unit enables remote users, mainly in Africa, to request ARTEMIS products in a fully automated fashion, by issuing a formatted e-mail request.

Electronics

Electronic Systems for Airborne and Spaceborne Applications

NLR received a subcontract from Fokker Space to upgrade the Service Electronics System of the Cells In Space (CIS) sounding rocket experiment facility. The CIS facility of ESA is used to perform biological experiments under microgravity conditions. One of the responsibilities of NLR was the development of the miniaturized data acquisition and control electronics for a new generation of experiment hardware, which is part of the upgrade from CIS-4 to CIS-5. NLR has a long tradition in supporting Fokker Space in the development, test and operation of the CIS experiment facility.



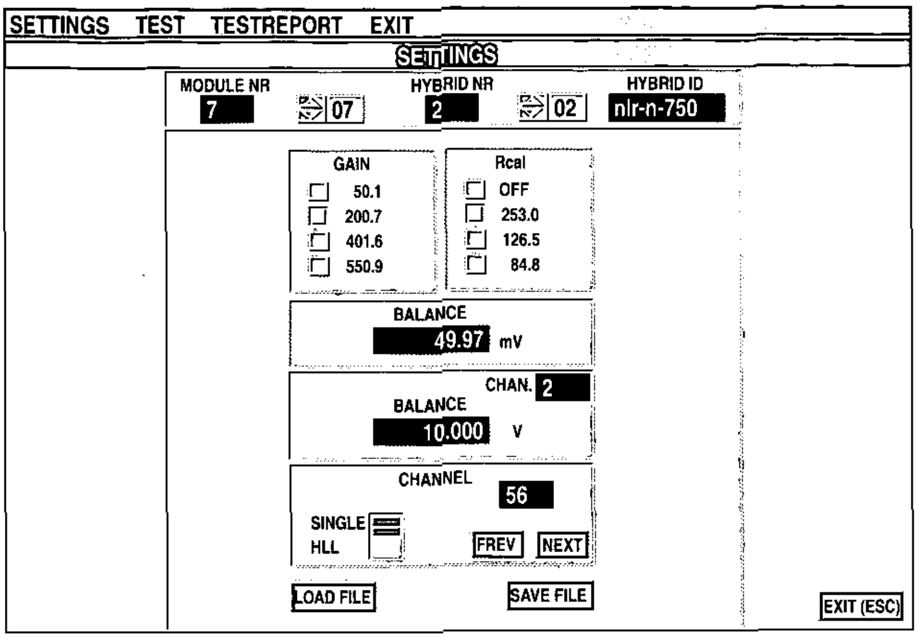
Prototype of NH90 Fuel Panel

NLR supports Dutch industries in the design and development of avionics equipment for the NH90 helicopter. Within an international consortium selected by Eurocopter, BF Goodrich Aercor of Zevenaar is responsible for the design and development of a Cockpit Fuel Panel and an external Fuel Panel for the NH90 fuel management system. Equipment manufacturing will be done by BF Goodrich. Part of the contract is the delivery of early prototype equipment that was designed, tested and qualified for flight clearance of the prototype helicopter by NLR.

Based on experience gained in this programme, NLR has supported Dutch aerospace industries in their efforts to acquire other design and development contracts. NLR successfully co-ordinated the acquisition activities, including feasibility analyses and predesign, for the NH90 Remote Frequency Indicator.

Data Link Processor Unit (DLPU)

Since 1988, under contract to Eurocontrol, NLR has been involved in the development and realization of airborne instrumentation used for Secondary Surveillance Radar (SSR) Mode S data link experiments. Twelve airborne Data Link Processor Units (DLPUs) are operational for possibly automated message transfer from aircraft to ground and vice versa. One major software upgrade, to cope with the adaption of the DLPUs to a new type of associated transponder, was completed. The development of five additional units was started, capitalizing on new module developments.



User interface of data acquisition system for DNW

Signal Conditioning, Wind Tunnel Instrumentation

The work under contract to the German-Dutch Wind Tunnel (DNW), for the delivery of equipment for the Static Data Acquisition System was completed. This contract was awarded in 1994. NLR has developed a new-generation data acquisition concept. A complete package was delivered, including conditioning equipment, calibration equipment, computer interfaces, patch panels and cabling. The conditioning equipment of the new generation consists of remote-controlled equipment for amplification, filtering, analog-to-digital conversion and local computing capabilities, and has high standards of accuracy, stability and resolution. Also the user interface was developed, based on Digital Equipment Vax minicomputers and high-end personal computers. The equipment, configured into two static data acquisition systems, and became fully operational.

Also for the DNW, NLR has developed a set of miniature remote-controlled amplifiers for use on-board of wind tunnel models, partially based on the concept mentioned above. These amplifiers will be used to amplify to Volt levels the low-level, microvolts, outputs of temperature, strain and/or pressure sensors. Especially on large wind tunnel models that are equipped with many sensors, on-board amplification is needed to obtain accurate test results.

Computer Aided Engineering of Electronics

The NLR infrastructure for Computer Aided Engineering of electronics was expanded with two workstations. Existing workstations were replaced by more powerful ones. The set of software tools was extended with programs for the calculation of MTBF (Mean Time Between Failures) and FMECA (Failure Mode, Effect and Criticality Analysis) predictions.

Instrumentation Design, Development, Operation

Flight Testing and Flight Test Instrumentation

Evaluation and Certification of the Fokker 50, 60, 70 and 100

The Measurement, Recording and Data Processing system MRVS was used in the flight trials of the Fokker 50, Fokker 60, Fokker 70 and Fokker 100. A team of NLR personnel supported the system and was responsible for the operation of the system during the flight tests that were conducted because of initial certification, new developments or customer requirements.

Fokker 50

Flight tests with the Fokker 50 prototype P1 mainly concerned a new digital autopilot system. A programme for exterior noise measurements and several flights for improved runway performance were carried out at Granada, Spain.

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

Fokker 60

The flight test certification programme of the Fokker 60 'Utility', an enlarged military version of the Fokker 50, was started. Most of the flight test instrumentation was designed and installed by NLR. During the tests, NLR personnel were operating, controlling and maintaining the flight test instrumentation systems on board of the two participating aircraft.

Fokker 70

The flight test programme of the Fokker 70 continued, aimed at the certification of its steep approach (6° glide path) and landing performance and at the certification of the automatic landing system. NLR provided the flight trajectory measurement system for these tests.

The Production Flight Test system (PFT) was used for the factory acceptance of all new Fokker 70 aircraft.

Fokker 100

NLR's flight test instrumentation system installed in the prototype Fokker 100 aircraft was used for tests of the main landing gear in Granada, Spain and for tests on the Auxiliary Power Unit (APU). The measurement system was reconfigured for tests of the new 'Jet Line Avionics' equipment.

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

MRVS-90

The MRVS-90 project, under contract to NIVR and carried out 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 already in use 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 was continued. The GPS-based Position Reference System (PRS) entered full-scale testing of the high accuracy phase-tracking mode. The medium accuracy code-tracking mode was pre-operationally used during an exterior noise measurement programme with the Fokker 50. In this mode, the PRS generates flight guidance for the pilot. This guidance capability was also used to simulate a 6° glide path to facilitate steep approach flight tests in the absence of a real Instrument Landing System (ILS) signal.

Measurement and Analysis Techniques for In-Flight Research

Interior Noise Measurement System

Under contract to NIVR, a digital data collection and recording system for research into the interior noise of an aircraft was designed. The system is capable of simultaneously measuring the outputs of 128 microphones with a 400-Hz bandwidth at a sample rate of 2 kHz.

In-Flight Wing Deflection Measurements

The investigation on the use of a video-based system for measuring wing deflections in flight was concluded.

Laser Airspeed Measurements

The results of in-flight airspeed measurements in the boundary layer of the Cessna Citation research aircraft using laser anemometers of NLR and DLR were analysed. The laser anemometer of NLR was successfully applied in one of NLR's wind tunnels.

Mathematical Models of Aircraft

The determination of the aerodynamic model of the Fairchild Metro II research aircraft, a co-operative project of NLR and the Faculty of Aerospace Engineering of the Delft University of Technology, was continued. A Non-Stationary Measurement Method (NSM) and dedicated parameter identification techniques are used in this project. Earlier results revealed the dynamic fuel displacement during the manoeuvres as a possible cause of the large dispersion of some of the model coefficients. A flight test programme to verify this assumption was carried out.
In collaboration with the Faculty of Aerospace Engineering of the Delft University of Technology, the study into the possibilities for the application of the Multi-Input Multi-Output method (MIMO) for aerodynamic modelling was continued. Computer programs became available for evaluation.

The work for the GARTEUR Action Group (FM) AG-02 on 'Mathematical Modelling of Aircraft' was concluded with the delivery of the final report of the group.

Support to Eurocontrol

Experimental Flight Management System

Within 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). Other 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 data link communication and pilot-EFMS interface. Additional functionality was developed for the application of EFMS in experiments with NLR's Research Flight Simulator.

Support to the European Union

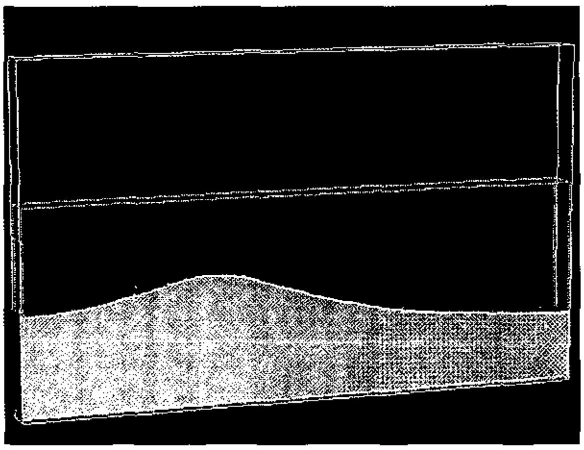
Automatic Dependent Surveillance

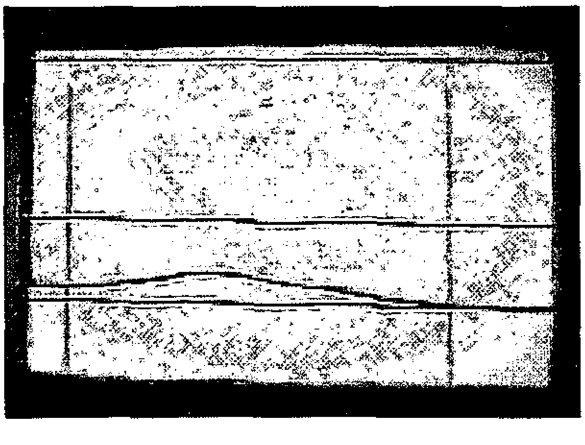
NLR participates in the European Automatic Dependent Surveillance (ADS) project, a part of a programme of the European Union. The Cessna Citation research aircraft will be equipped with a full Arinc 745 ADS system. ADS messages will be routed through satellite datalinks to stations in the UK and in France. The new ADS equipment was acquired and tested in co-operation with CENA of France and the Eurocontrol Experimental Centre.

Military Flight Test Support

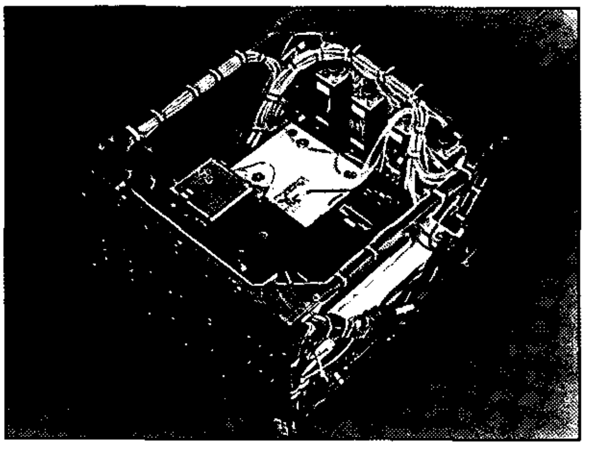
Support to the Royal Netherlands Air Force

NLR assisted the Royal Netherlands Air Force during flight tests with F-16 aircraft and during air defence flight trials.





Displacement of fuel in tank-
bottom: video picture of mock-up test,
top: simulation



Part of the instrumentation for the Parafoil Technology Demonstrator with sensors including Attitude and Heading Reference System, Global Positioning System and accelerometers

Flight Loads Monitoring Programmes

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

Support to the Ministry of Transport

Road Profile Measurements

NLR's experience in the field of aircraft trajectory reconstruction was used to advise the Road and Hydraulic Engineering Division of the Ministry of Transport in a project for the upgrading of a road profile measurement vehicle. Results of experimental measurements were analysed.

Support to the European Space Agency

Parafoil Technology Demonstrator

Under a subcontract to Fokker Space, the instrumentation for controlling the Parafoil Technology Demonstrator, aimed at demonstrating the feasibility of a controllable parafoil to safely land a space re-entry module, was designed. The sensor package includes a laser height measurement device, a fibre optic angular rate sensor, airspeed sensors and differential GPS for navigation purposes. The system is controlled by an airborne computer loaded with software from NLR and DASA. An NLR specialist acted as the lead engineer for the electrical design of the complete Demonstrator.

Facilities and Equipment

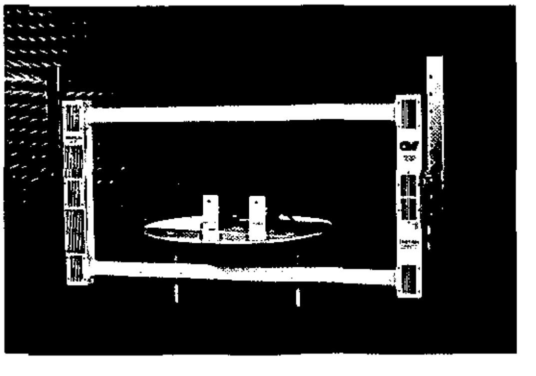
Environmental Testing, EMI/EMC and VST

For both the facility for Electromagnetic Compatibility (EMC) tests, and the facility for Vibration and Shock Tests (VST), preparations are under way for obtaining accreditation from the Netherlands Accreditation Council (RVA) as part of NLR's activities in quality assurance.

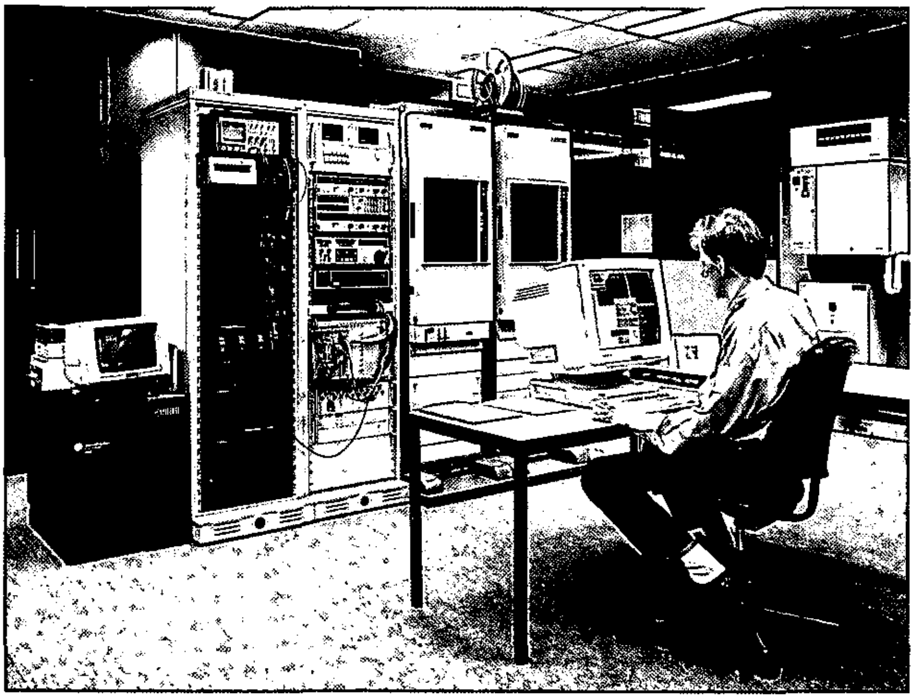
In both the EMC and the VST facility, many tests were carried out on various equipment under contract to military and civil equipment users and manufacturers.

EMI/EMC Facility

To cope with the new requirements for Electromagnetic Interference (EMI) test levels such as described in RTCA/DO-160 issue C, new test amplifiers and measurement equipment were selected, procured, and installed. The modernized EMC Facility became operational. It is capable of providing a field strength of 200 V/m in the frequency range of 10 kHz – 18 GHz in full compliance with RTCA/DO-160C.



High field strength immunity test in the EMC facility



Data processing system for flight test data (DVSV)

Vibration and Shock Test Facility

The Vibration and Shock Test (VST) facility was upgraded by adding new sensors. New test software was installed, enabling new test methods to be executed. Tests can be executed in a clean room.

Avionics Design and Evaluation Facility

Modern avionics incorporate an ever increasing functionality and criticality. In order to be able to evaluate and design avionic systems it was felt necessary to have an avionics design and evaluation facility. Activities commenced to identify detail requirements, and two computer-based tools were procured for the facility.

ART (Avionics Research Testbed)

For research into the use of data links for air traffic management, new telemetry equipment was acquired. Satellite communication equipment was installed in the Cessna Citation II research aircraft, to enable test flights to be conducted for the European Automatic Dependent Surveillance project.

Standard commercial colour Liquid Crystal Displays were acquired to be evaluated for their suitability for research on board of aircraft into Man Machine Interface items.

FAST (Future Aircraft Systems Testbed)

The National Fly-by-wire Testbed project (NFT) for converting the Cessna Citation research aircraft into a testbed dedicated to Active Flight Controls research was substituted by a new approach, combining the ART and NFT ideas into the Future Aircraft Systems Testbed project (FAST). FAST will incorporate active flight control capabilities as far as required for air traffic management research. A preliminary project plan for FAST was drawn up.

Facilities for Measurement and Processing of Flight Test Data

The suitability of optical measurement techniques for in-flight analysis of the exhaust emission of aircraft engines was studied in an investigation partly funded by the Ministry of Public Health.

The Helicopter Data Acquisition System (HEDAS) was extended and prepared for measurements on board of the Navy vessel 'H.M. Amsterdam'.

A new system for the analysis of video images was acquired and evaluated. The system enables video frames to be digitally recorded in real time, considerably enhancing the process of selecting frames for further analysis.

The modernization and upgrading of the data processing system for flight test data was completed. The throughput of the system has been improved by a factor of five. Recordings on a number of new recording media such as the high density digital data recordings of the Ampex DCRSi type can be accommodated, both for flight test data and for remote sensing data.

Measurement Equipment for Human Factors Research (HFR)

The acceptance programme for the eye/head-tracker system Observer was concluded. The system was used for HFR projects. The extension of the system for two-men crews was prepared.

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. A new software package 'VuSoft' for decommutation and presentation of IRIG-PCM data was acquired and tested.

The pressure calibration facility VACAL, accredited by the Netherlands Calibration Organization (NKO), was successfully audited by NKO. Technical developments included the start of a major update of the pressure calibration hardware and the formalization of software procedures and documentation.

The test station for the PCU (Programmable Conditioning Unit) basic data acquisition systems was further developed. Special requirements of Fokker were implemented.

3.7 Engineering and Technical Services

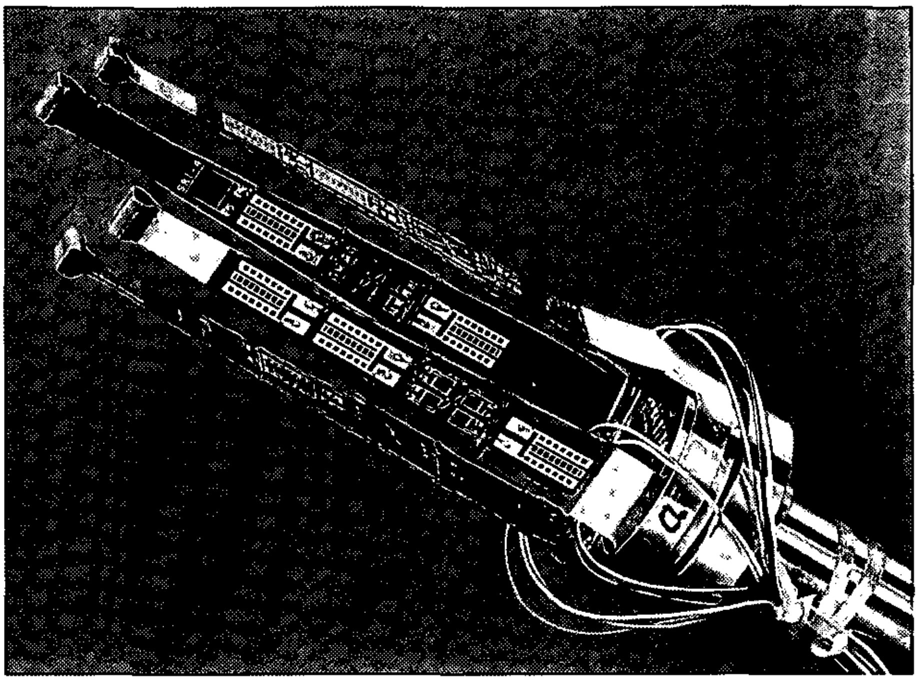
Wind Tunnel Models and Model Equipment

A large variety of wind tunnel models and related equipment were designed and manufactured; in many cases in international programmes. Several models were made for programmes of the Netherlands Agency for Aerospace Programs (NIVR). The manufacturing of a model of the Fokker 100 for the cryogenic European Transonic Wind Tunnel (ETW) was started. A space capsule model with a newly designed system that makes 360 degrees of pitch rotation (relative to the balance) possible was designed and manufactured. The designing and manufacturing of a jet interaction model was started. As part of the NH90 helicopter development programme, a complete (rotating) main rotor model was designed and manufactured, and several modifications were made to existing models. A tail shake model and an open rear ramp model were designed and manufactured. Models for aerospace and non-aerospace research and development (ship models, noise control models), were made for a variety of customers. Carbon fibre reinforced propeller and rotor blades were also made for several customers.

Strain Gauge Balances and Model Instrumentation

The development of strain gauge balances and special purpose instrumentation has been increasingly supported by the use of finite element method calculations. This has improved predictability and reliability.

Many new devices have been designed and manufactured. A new capsule balance has been designed and manufactured for use in high-angle-of-attack trim investigations on capsule models. A new general purpose internal balance for use in the High Speed Wind Tunnel (HST) has been completed and has undergone calibrations; the installation of the instrumentation on an identical balance was started.
The manufacturing of a new six-component balance for use in the Small Anechoic Tunnel was started. The manufacturing and installation of the instrumentation of the second rotor balance for the Tilt Rotor Model was completed;



Part of rotor blade angle measuring device equipped with strain gauges

after function testing the balance was delivered to NASA. Several balances for model parts have been developed and manufactured for various customers. A new blade angle measuring device for use in the NH90 main rotor model has been designed, and manufacturing was started. A large quantity of strain gauge bridges were installed in the rotor blades of the NH90 main rotor model.

Various Structures

Besides models and balances, several structures of very different nature were designed and manufactured.

- The manufacturing of the flight model of the Grating Element Support Structure was completed and the structure was delivered to the Space Research Organization Netherlands.
- A pressure rake, traversable in wind direction, was developed.
- Fast pitching equipment was designed and manufactured.
- A test rig for fuselage panels loaded in two directions was designed and manufactured.
- Equipment for the National Simulation Facility was made.
- A design was made for a 4-m test box consisting of panels with stiffeners made of carbon fibre reinforced resin.

Proposals were made for modifications of the HST, concerning the 2D model support, the flow rectifier, the foreign object detainer screen and the traversing mechanism for flow visualisation.

Development of New Techniques

To ensure the capability of manufacturing highly specialized products, the development of new techniques has been given constant attention. Large dynamically scaled composite rotor blades were made with embedded instrumentation. The expansion of the use of Finite Element Methods in the design phase was investigated. Instrumentation techniques for cryogenic wind tunnel models were studied. Improvements and extensions to the use of the CATIA CAD/CAM system were realized and the introduction of 5-axes high speed machining was prepared.

4 Internal and External Relations

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

The State Secretary of Defence, Drs. J.C. Gmelich Meijling, in the pilot seat of the National Simulation Facility

Visitors from the Netherlands

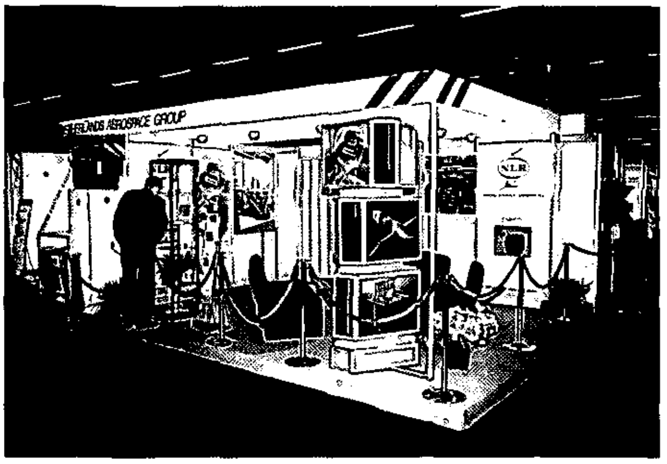
- Ir. J.G. Kroon, Ir. H.J. Wennink, Ir. F. Holwerda and Ir. D.M. Passchier of Fokker Aircraft.
- Dr. P.J. Idenburg and mr. N.J. van Putten of the Ministry of Economic Affairs.
- Dr.ir. R. Roos and Ir. J.J. Kooijman of the Netherlands Agency for Aerospace Programs (NIVR).
- The partners of the members of the Board of the Foundation National Aerospace Laboratory (NLR).
- Mr. J.W. Weck, Ir. H.N. Wolleswinkel and Ir. R.C. Cadée of the Netherlands Department of Civil Aviation (RLD).
- Mr. M.A.J. Knip, Burgomaster of the Noordoostpolder and members of the VVD (Liberal Party).
- Mr. J. van Houwelingen, Burgomaster (and Chairman of the Board of NLR), and eldermen of the Municipality of the Haarlemmermeer.

Foreign Visitors

- Dr. I.A. Habibi of IPTN, Indonesia.
- Dr. Shon-Pang Chang, Mr. Bao Zang and Mr. Yen Yang Guo of the Centre for Aviation and Space Technology Industrial Technology Institute of Taiwan.
- A delegation of the Aviation Industry Corporation of China (Avic).
- Members of the Steering Committee of Cepa II of the European Co-operation for the Long Term in Defence (EUCLID).
- Dr. Paul Kaminski, Under Secretary of Defence of the USA.
- Mr. A. Har-Even, Director of the Israel Space Agency.
- Mr. K. Sung Ho and Mr. A. Dong Mahn from Korea.
- Mr. Toshio Bando and Mr. Masao Takano of the National Aerospace Laboratory of Tokyo and the Tokyo Aircraft Instruments Co, respectively.
- Mr. M.G. Bernardini of the Commission of the European Communities
- Mrs. T.K. Ohnsorg of the International Scientific Technical Information Office of NASA.
- Mr. E. Wegman of Aerotek CSIR of Pretoria, South Africa.

Excursions

- Staff of the Royal Netherlands Meteorological Institute (KNMI).
- Pilots of the Society of Pilots at Teuge Airport.
- Students of the 'European University' of the Hague.
- Students of the 'Avionica Dispuut' of the Delft University of Technology.
- Members of ATcom of the US Army.
- Participants of the Symposium 'Making it Real' held under the patronage of CEAS (Confederation of European Aerospace Societies) at Delft.
- Students of Information Technology from the 'Berufsakademie Lörrach'.
- Members of the Study Society for Technical Physics 'Ångström' of the Rijswijk College.
- Members of the Study Society 'Stuff' for Mechanical Engineering of the Technical College of Eindhoven.
- Members of the Netherlands Royal Institute for Engineers (KIvI).
- Members of 'Volonta', the Society of Students at Hollandse Signaal Apparaten (HSA).
- Students of the Von Kármán Institute of Brussels.
- Students of Information Technology from the Technical College of Haarlem.
- Royal Netherlands Air Force officers with a background in engineering.



The stand of NLR at the Paris Air Show

Exhibitions

- The Dutch Federation of Fibre Reinforced Composites held a meeting at Ede; NLR supported the meeting by participating in an exposition.
- The International Training Equipment Conference (ITEC) was held in the Hague. In the stand of the Netherlands Industrial Simulator Platform (NISP), NLR showed its flight simulation facilities in a video film and slide show focused on the National Simulation Facility. Demonstrations were given with the Mission Support System MSS/C and with the NLR ATC Research Simulator (NARSIM).
- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) during the Paris Air Show of 1995 at le Bourget.
- In the Hague the Nederlandse Industriële Inschakeling Defensieopdrachten (NIID) organized its yearly Symposium. During this event, NLR showed its activities for defence in an exhibition and demonstrated the Mission Support System MSS/C.
- During a boat trip on the 'Jules Verne', ambassadors of the Netherlands were given a presentation of the activities of the national technological research institutes (GTI's and TNO). NLR took part in a supporting exposition.
- At the Business Days of the Delft University of Technology, NLR showed exposition panels and provided additional information.
- For the first time NLR participated in the EMC Congress and Exhibition in Zürich.
- During 'Fairwind 95' NLR presented together with Fokker exposition panels on board of Navy vessels sailing to the Far East.
- At Schiphol East a Chinese delegation visited NLR's laboratory aircraft and a small exposition on Remote Sensing in the hangar.
- During the CEAS Symposium 'Making it Real' at Delft, NLR gave a demonstration on 'Remote payload operations supported by automation and robotics'.

Events

- Well-attended New Year Receptions for the NLR staff were held in both Amsterdam and Noordoostpolder.
- Members of the Works Council and members of the Board of the Foundation NLR had their annual lunch together.
- At Amsterdam and Noordoostpolder, meetings were held for acquainting new employees with NLR's activities and procedures.
- A one-week course was held for students of the Koninklijke Militaire Academie.
- An APERT-meeting was held, attended by an Indonesian delegation.
- A workshop 'International Forum on Turbine Powered Simulation,' organized by DGLR and DNW, was held at NLR for the 15th anniversary of the German Dutch Wind Tunnel (DNW).
- Several meetings of the GARTEUR Executive Committee, Groups of Responsables and Action Groups were held at NLR.
- On 20 October the National Simulation Facility (NSF) was inaugurated by the State Secretary of Defence, Drs. J.C. Gmelich Meijling, enabling the Commander in Chief of the Royal Netherlands Air Force, Lt.Gen. B.A.C. Droste, to perform a demonstration flight. The guests attending the ceremony then visited NLR's simulation facilities.
- The new High Field Strength Test Facility was introduced to representatives of customers, the press and NLR staff.
- A FANSTIC (Future Air Traffic Control, New Systems and Technologies in the Cockpit) demonstration day was held.
- For members of the Royal Netherlands Air Force a symposium 'KLu Intel Community' was organized by Operations Research Division.

5 Scientific Committee NLR/NIVR

Advice provided to NLR and 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 1996;
- the Programme for basic research and development of facilities for 1997;

To the Boards of Directors of NLR and NIVR, on:

- the results of the work carried out by NLR in 1994 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 1995 or 1996.

Membership of the Scientific Committee

The composition of the Scientific Committee was changed by the appointments of Dr. R.J. van Duinen and Ir. F. Holwerda.
At the end of 1995 the Scientific Committee was composed as follows:

Prof.dr.ir. P.J. Zandbergen, *chairman*
Prof.ir. C.J. Hoogendoorn
Prof.ir. T. de Jong
Dr. R.J. van Duinen
Ir. F. Holwerda
Ir. P.G. Vermeulen, *secretary*

Membership of the Subcommittees

A new subcommittee, the Subcommittee for Electronics and Instrumentation, was founded.
As members were appointed:
Prof.ir. D. Bosman, *chairman*
Ir. W. Brouwer (KLM)
Ing. H. de Groot (Fokker Aircraft)
Lt.Kol.Ing. H. Horlings, (RNLAF)
Ir. J.A. van Kaam (Signaal)
Kol.Ir. E.B.H. Oling (RNLAF)
Ir. L.R. Opbroek (Fokker Aircraft)
KLTZE Ing. R.C.A. Patijn (RNLN)
Prof.ir. G.L. Reijns (DUT, Faculty of Electrical Engineering)
Dr. R.P. Slegtenhorst (Delft Instruments).

Appointments in the Existing Subcommittees

- Prof.dr.ir. J.L. van Ingen, a member of the Subcommittee for Aerodynamics, was appointed chairman;
- Prof.dr.ir. H.W.M. Hoeijmakers was appointed a member of the Subcommittee for Aerodynamics.

Resignations

- Ir. F. Holwerda resigned as a member of the Subcommittee for Structures and Materials;
- Prof.ir. D. Bosman resigned as a member of the Subcommittee for Applied Mathematics and Information Technology.

At the end of 1995 the subcommittees were composed as follows:

Subcommittee for Aerodynamics
Prof.dr.ir. J.L. van Ingen, *chairman*
Prof.dr.ir. P.G. Bakker
Dr.ir. R. Coene
Prof.dr.ir. H.W.M. Hoeijmakers
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
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*
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

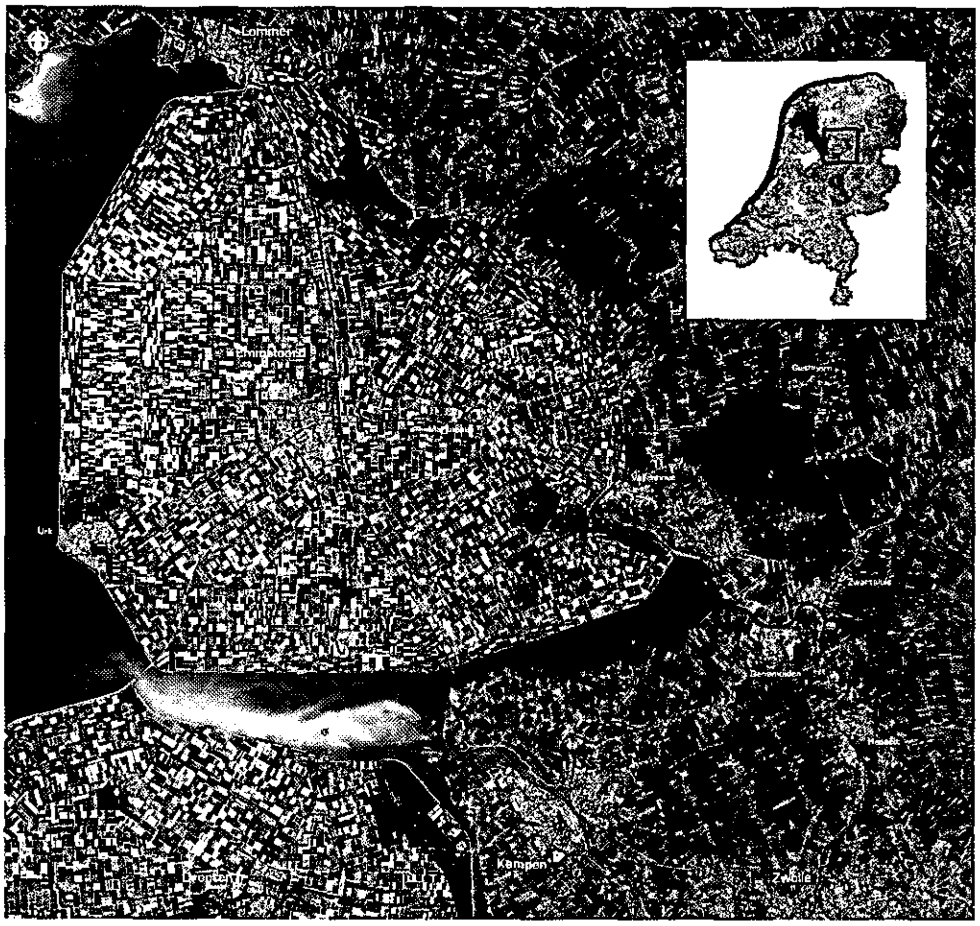
Subcommittee for Flying Qualities and Flight Operations
Prof. J.H.D. Blom, *chairman*
KTZSD ir. K. Bakker
Ir. H. Benedictus
Ir. W.G. de Boer
J. Hofstra
Ir. R.J.A.W. Hosman
Ir. H.J. Kamphuis
Maj. H.J. Koolstra
Ir. H.B. Langeraar
Prof.dr.ir. J.A. Mulder
Prof.ir. E. Obert
Lt.Kol.Vl. b.d. A.P. Okkerman
Ir.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

Subcommittee for Electronics and Instrumentation
Prof.ir. D. Bosman, *chairman*
Ir. W. Brouwer
Ing. H. de Groot
Lt.Kol.ing. H. Horlings
Ir. J.A. van Kaam
Kol.ir. E.B.H. Oling
Ir. L.R. Opbroek
KLTZE Ing. R.C.A. Patijn
Prof.ir. G.L. Reijns
Dr. R.P. Slegtenhorst

Concluding remarks

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

> The long-awaited recovery of the aircraft market materialized in 1995. This could, however, not prevent new, drastic reorganizations in the aircraft industry of the Netherlands. In the beginning of 1995, very radical measures were announced, and partly executed, that should safeguard the Dutch aircraft industry's survival in the long term. At the end of 1995, the situation of Fokker was most uncertain, in view of the heavy losses suffered in the year.
> In the space technology sector, a continued decreasing tendency in the available government budgets can be observed.
>
> In 1995 NLR carried out a large volume of work under contract, especially for national customers. NLR's favourable state is due to its advantageous market position, which is partly due to the way in which the basic research is carried out. The basic research forms the knowledge base of NLR, and besides the facilities, determines the value of NLR for customers. This is becoming more important, as customers have to be found outside the Netherlands. The co-operation with a large number of partners in the framework of the programmes of the European Union is a suitable means, but takes up a large part of the budget for basic research. The bilateral co-operation with the Deutsche Forschunganstalt für Luft- und Raumfahrt (DLR) is worth mentioning. In addition to programmatic attuning, ways of organizing the management and the exploitation of facilities, such as the wind tunnels of NLR, are studied.
>
> The Scientific Committee has expressed approval with the Work Plan for 1996. With respect to the strategy in the area of space technology, the Scientific Committee agrees with the planned policy. With respect to aviation technology, as yet the course is being pursued that NLR has to remain capable of supporting the national industry in all important fields. In the present situation, however, it is impossible to predict what will happen to Fokker in 1996. The future of Fokker will doubtlessly influence the work to be carried out by NLR in 1996.
>
> The Scientific Committee is of the opinion that it is of great importance, also in order to keep a favourable position on the world's research market, that NLR has available suitable, modern research facilities. However, a reconsideration of the services to be provided in the future may come up in this area as well. NLR has a strong position in the fields of ATM/ATC and simulation research, which may be reason to strengthen the focus on these fields.
>
> The number of reports produced by NLR was impressive, although there is a tendency to produce more reports in the form of Contract Reports rather than Technical Publications. Contract Reports are not generally submitted to the Scientific Committee, reducing its field of vision. The Committee is aware, however, that this is a result of the relatively large number of research contracts. NLR is represented at many important international congresses at invitation, permitting the conclusion that NLR manages to maintain its position in the world.



SPOT XS image of Noordoostpolder, processed to show simulated natural colours, enhanced by Laplace filtering - © NLR / Spot Image

6 International Co-operation

6.1 AGARD

Mission

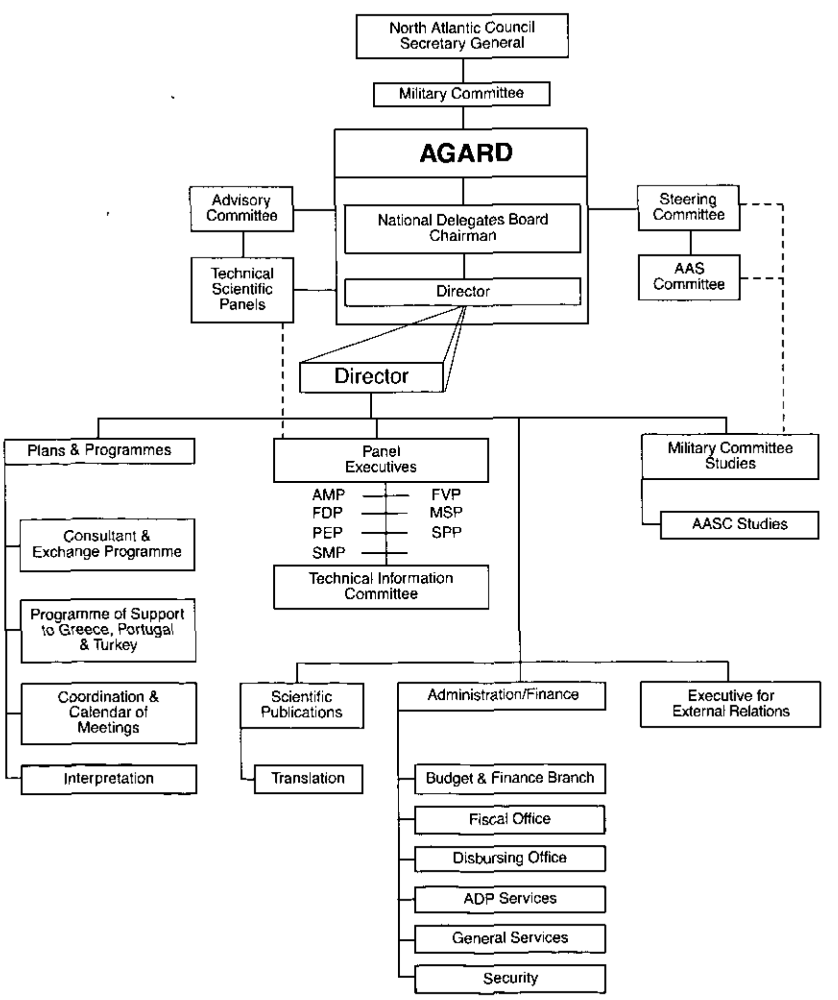
The mission of AGARD, NATO's Advisory Group for Aerospace Research and Development, is to bring together the leading personalities of the NATO member nations in the fields of sciences and technology relating to aerospace for the following purposes:

- 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

Three levels can be identified in the AGARD organization:

- The National Delegates Board, the governing body, assisted by a Steering Committee and an Advisory Committee;



Organization Diagram of the Advisory Group for Aerospace Research and Development

- The AGARD staff, the executive body;
- The Technical Panels and the Aerospace Applications Studies Committee, which together constitute the expert bodies of the Agency.

The mission of AGARD is carried out through a number of activities, including:

- Panel programmes of conferences, symposia and specialists' meetings, and meetings of subcommittees and working groups;
- Consultant and Exchange programmes embracing the provision of individual consultants to NATO member nations and the organization of Lecture Series and Special Courses;
- A programme of Military Committee studies, consisting of aerospace applications and technology studies initiated at the request of the NATO Military Committee;
- The publication of numerous reports;
- 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 1995, 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 1995, five Lecture Series have been organized.

Special Courses

In Special Courses, teams of experts present lectures in one, occasionally two or three nations on a specific topic. In 1995, four Special Courses have been organized, none of them in the Netherlands.

Support Programmes

The following numbers of support programmes were active in 1994:

Greece	15
Portugal	22
Turkey	30

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

Consultants Programme

In 1995 a total of 80 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 subjects of Aerospace Applications Studies (AAS) each year. In 1995 one study, AAS-43, on 'minimizing collateral damage during peace support operations,' has been initiated.

National Delegates Board Meetings

The National Delegates Board meets twice each year, in Spring and in Autumn. The 1995 Spring meeting was held in Brussels, whereas the Autumn meeting took place in Irving (California, USA). At both occasions a joint R & T session with the Defence Research Group (DRG) was organized. During these sessions, proposals for a more co-ordinated approach with respect to NATO defence R & T were discussed.

Netherlands Delegation to AGARD

The Netherlands Delegation consists of:

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

6.2 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 1995 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 1995

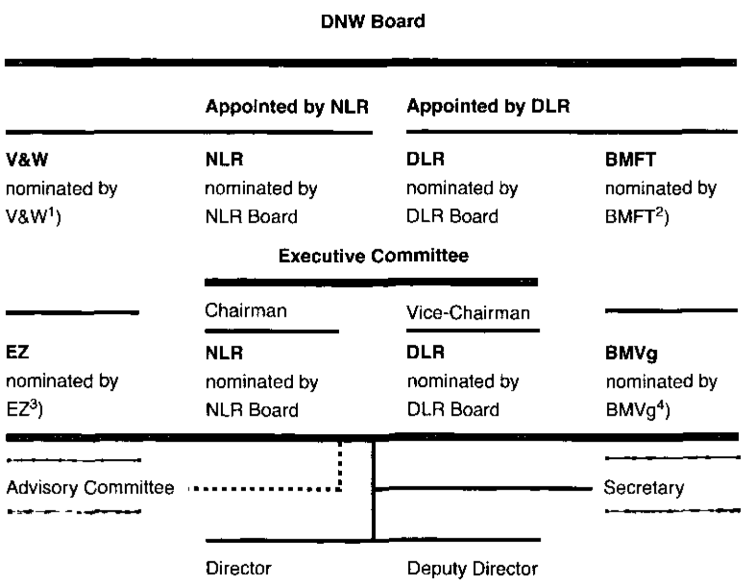
Dr.Ir. B.M. Spee, *Chairman*
NLR
Dipl.-Ing. H. Max, *Vice-Chairman*
DLR
Min.Rat R. Schreiber
Ministry of Defence of Germany (BMVg)
Min.Rat Dr. H. Diehl
Ministry for Research and Technology of Germany (BMBF)
Dr. H. Körner
DLR
J.A. Verberne R.A.
NLR
Ir. H.N. Wolleswinkel
Ministry of Transport of the Netherlands (RLD)
Secretary was Dipl.Volksw. A. Dick.

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. B. Haftmann
Deutsche Aerospace Airbus
Prof.Dr.Ir. J.L. van Ingen, *Chairman*
Delft University of Technology
Prof.Ir. E. Obert
Fokker Aircraft
Dipl.-Ing. V. von Tein
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 was Dr.-Ing. G. Lehmann.

The Board and the Advisory Committee had one joint meeting.



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)

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

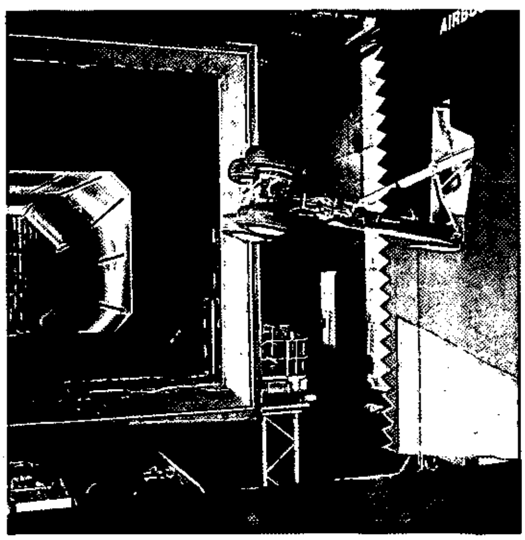
The Board of Directors

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

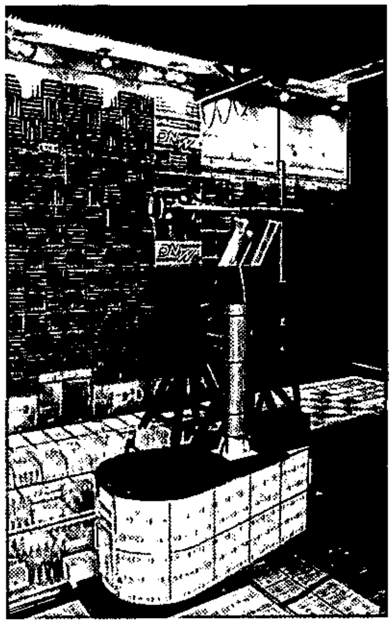
The experiences gained during the two-year trial of joint operation of the Niedergeschwindigkeits-Windkanal Braunschweig (NWB) and the Lage Snelheids Tunnel (LST) under DNW management were found to be positive, and the Board of the Foundation DNW agreed to incorporate both wind tunnels in the DNW organization as of 1 January 1996. During the year 1995, operational practices were harmonized and a basis for standardisation, primarily of data acquisition and data reduction hardware and software, was defined.

Some 1330 hours were spent on contract testing, about 240 hours of which for the automotive industry. Aircraft testing comprised sixteen 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 models of rotary wing aircraft, a high-bypass turbofan and a modern propeller configuration;
- flow field studies on high-lift configuration and helicopter rotors.



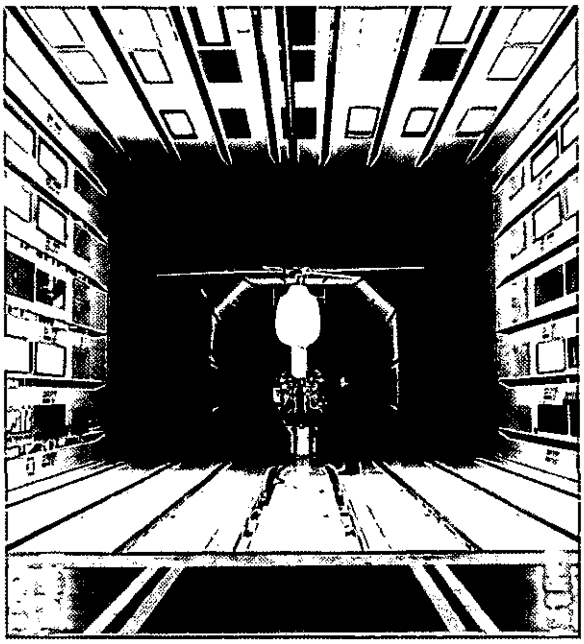
Noise test on a full-size main undercarriage leg of an Airbus A320 in the open jet test section of the DNW



Acoustic test of a Very High Bypass Ratio Turbofan Simulator in the open jet test section of the DNW

For the ground transport industry, eleven test campaigns were executed, of which six on passenger cars, four on full-sized lorries and one on a high speed train configuration. The complexity of such tests and the diversity of the problems studied is still growing. Ground simulation using a moving belt is becoming a standard requirement for most of the forces and moments tests. The simultaneous measurement and analysis of interior noise levels, car body deformation, engine compartment internal flow and cooler efficiency get ever increasing attention.

A major programme was started to increase the testing potential of the DNW. Substantial budgets were approved for improving existing test equipment and for the implementation of new techniques. In this framework, the system supplying compressed air for engine and jet simulation was significantly improved by doubling the storage capacity; preparations for refined temperature control of the outlet air were made. The computing power and speed of the data processing system were increased by a replacement of mainframe computers, and new testing equipment for flow field studies and noise testing was ordered. The update programme, which will cover several more years, is aimed at keeping the DNW at the forefront in the low-speed wind tunnel testing arena.

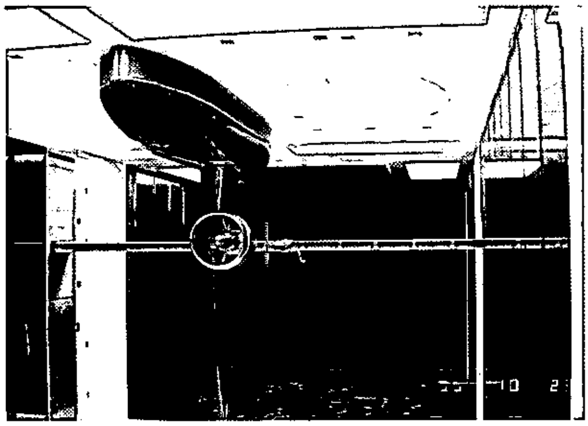


Helicopter model being used in a validation experiment for a slotted wind tunnel wall correction method

The DNW-LST received orders for 1296 hours of contract testing, half of which from the aircraft industry and half from other industrial clients. Tests for the aircraft industry included an investigation on a 1:4-scale tail rotor model of a transport helicopter. The objective of this test was to measure the efficiency of the tail rotor and to study the interaction between the tail rotor and the tail surfaces. A 1:10-scale model of the same transport helicopter was used for an investigation of the aerodynamic forces on the rear loading ramp and of the effect of opening the ramp on the stability of the helicopter.

A new development in the field of measurement techniques was the combination of a rake carrying eighteen five-hole probes with a software package for quick visualization of the results. A first application of this technique was a study of the flow downstream of the wing of a semi-span model, with emphasis on the pylon and nacelle area.

In the category of industrial aerodynamics, tests were carried out to study the formation of vortices off large buildings on airport sites. Large vortices generated by buildings may interfere with the flight path of aircraft on take-off or landing. For the visualization of vortices in the wind tunnel, the laser light sheet technique was used.
The testing of navy vessels included the investigation of the exhaust gas dispersion and the wind climate on a helicopter deck.



Front view of a semi-span aircraft model and a five-hole probe rake in the LST

6.3 The European Transonic Wind Tunnel (ETW)

On behalf of the Netherlands, NLR is a 7% shareholder in the European Transonic Windtunnel GmbH, established in 1988.

In 1995, the first Co-operative Test Programmes were executed, yielding promising results. Within the scope of these programmes, the customer industries are charged only the direct costs, whereas the ETW, learning from these programmes, is allowed to use the results for marketing purposes.

The Supervisory Board of the ETW adopted a business plan showing a delay in the start of development programmes that are expected to make use of the ETW. This prompted the preparation of a no-cost extension to the Initial Operation Period, which will allow the allocated funds to be better distributed over the years to come.

ETW Supervisory Board

At the end of 1995, the membership of the Supervisory Board was as follows:

France	
IGA G. Dorey, *Chairman*	ONERA
IGA J. Chéret	DRET/SDCE
ICA E. Lisack	DPAC
Germany	
Dr. H. Diehl	BMFT
H. Max	DLR
Dr. H. Körner	DLR
United Kingdom	
Dr. G.T. Coleman	DRA
S.I. Charik	DTI
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. He is 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

6.4 GARTEUR

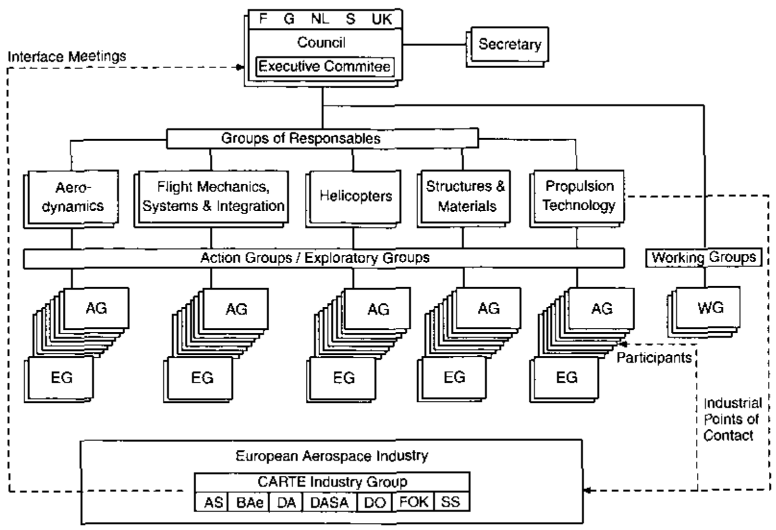
The Group for Aeronautical Research and Technology in Europe (GARTEUR) was formed in 1973 by representatives of the government departments responsible for aeronautical research in France, Germany and the United Kingdom. The Netherlands joined in 1977 and Sweden in 1992.

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.

The co-operation in GARTEUR is concentrated on pre-competitive aeronautical research. 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 parties (research establishments, industries or universities) from at least three GARTEUR countries participate.

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

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE - GERMANY - THE NETHERLANDS - SWEDEN - UNITED KINGDOM



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

Organization

The organizational 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.

GARTEUR Council and Executive Committee

At the end of 1995 the GARTEUR Council was composed as follows.

France

IGA J. Chéret	DRET/SDEP *
IGA M. Scheller	ONERA
IGA J.P. Marec	ONERA **
ICA E. Lisack	DGAC/DPAC
ICA J.L. Monlibert	DCAé/STPA

Germany

Dr. W. Döllinger	BMBF *
Dr. D. Diehl	BMBF
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 **
M. Markin	MOD

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

* Head of Delegation
** Member of the Executive Committee

From 1994, Mr. Van Houwelingen has held the chairmanship of the Council for a period of two years. Professor Abbink has held the chairmanship of the Executive Committee for the years 1994 and 1995. The Secretary of GARTEUR for the period 1994-1995 has been Mr. L. Sombroek (NLR).

Garteur Strategy

At the fifteenth Garteur Council Meeting on 29 October 1993, the Council decided that Garteur would play a stronger and more strategic role. Therefore processes have been initiated to produce the exchange of national plans and policies on aeronautical research, and overviews of US aeronautical research plans, European co-operative aeronautical research plans and Garteur research programmes, with the intention of providing information serving as a basis for the definition of further co-operative research programmes.

Furthermore, the Council established a Council Working Group to explore the possibilities for the harmonization of aeronautical research in Europe. This Group has met three times in 1995, and has prepared a draft report on its findings and recommendations. A first discussion on the draft report took place at the 19th Council Meeting on 18 October 1995.

NLR Participation

NLR participates in all five Groups of Responsables.
At the end of 1995, twenty-four Action Groups were active; NLR participates in twenty-three of these Action Groups.

6.5 Co-operation with European Research Establishments in Aeronautics

DLR/NLR Partnership

Background

A formal partnership agreement between DLR and NLR was signed in 1994. 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 was set up, consisting of representatives of DLR and NLR. The chairmanship rotates annually.

DLR/NLR Executive Board at the end of 1995

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

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

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

The Facilities Committee

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

The Programme Committee

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

Facilities

The partners stimulate joint operation and use of existing research facilities. Furthermore, the partners exchange information on planned investments and where possible embark on joint or complementary investments. Potential facilities for future co-operation are super-computers, research aircraft, flight simulation equipment and wind tunnels. An important step in the co-operation was the final incorporation of the DLR-owned NWB wind tunnel and NLR's LST wind tunnel into 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 incorporate their high-speed and supersonic wind tunnels in DNW as well. The basic agreement reached in 1995 will be followed by a formal agreement in 1996 to start a trial period of two years as from 1997.

Basic Research

The partners strengthen their collaborative efforts with respect to a number of basic research topics, such as aerodynamics (propulsion/ airframe integration, computational fluid dynamics), structures, design techniques, avionics and safety. The co-operation strengthens the co-operation within GARTEUR and forms the nucleus for proposals for research projects under the Framework Programme of the European Union and the European Co-operation for the Long Term in Defence.

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.

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 organizational 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, acquisition and personnel exchange.

Organization

Within AEREA, a Heads of Establishment Board has been set up, as the highest body within the Association.
At the end of 1995 the Heads of Establishment Board consisted of:

M. Earwicker *Chairman*	DRA
M. Scheller	ONERA
Prof. Dr. C. Golia	CIRA
J. van Houwelingen	NLR
Prof.Dr. W. Kröll	DLR
Maj.Gen. L.B. Persson	FFA
A. Giménez	INTA

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

In 1995 the Heads of Establishments Board organized a strategy workshop to evaluate the progress within AEREA and to provide the different groups with new guidelines in order to speed up the process of co-operation.

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 was established that will prepare this common policy. Prof. Abbink represents NLR in the Facilities Committee.

In the Subcommittee on Wind Tunnel Facilities, Prof. Slooff 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's activities will be finalized with a report in which recommendations will be made on: actions to be taken to facilitate pooling of wind tunnel facilities in Europe; joint development activities with respect to test techniques, test rigs, etc.; make, buy and sell options for rendering intramural services; as well as a joint marketing strategy for large wind tunnel facilities.

Other subcommittees have prepared overviews of existing simulator facilities, research aircraft, etc.

Research
The associates intend to develop and execute a number of joint research programmes. Therefore a Programme Committee has been set up to propose and manage strategic multidisciplinary programmes. The Programme Committee will link its activities to those of GARTEUR. In 1995 the Committee finalized a revised Long Term Technology Programme that should provide guidance for the conception of the Fifth Framework Programme of the CEC. Prof. Abbink represents NLR in the Programme Committee.

Personnel Exchange
Personnel exchange will stimulate the creation of interdependence amongst the Associates and create the right European spirit amongst the establishments. The Board decided to take a pragmatic approach towards personnel exchange and to handle initiatives on a case-by-case basis.

Relations to the CEC
Since 1989, the aeronautical research establishments have worked together in the Aeronautical Research Group (ARG) to facilitate the communication with the CEC and industry and the information exchange amongst the establishments on CEC-related issues. The ARG, chaired by Drs. A. de Graaff (NLR), is part of AEREA. In general the AEREA partners have been very successful in the tendering for the first calls of the Fourth Framework Programme.

6.6 Co-operation with Indonesia

Background

In 1980, NLR and the Agency for the Assessment and Application of Technology (BPPT) in Indonesia started a co-operation, primarily aimed at 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 1987.

The support of 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, the Institute of Technology Bandung (ITB) and the 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 technology (APERT) was started in the beginning of 1992, planned to last two years. As in the foregoing projects, NLR and BPPT are the co-ordinating bodies for APERT, of which the first part was sponsored by Fokker and NLR on the Netherlands 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 Prof.Dr.-Ing. B.J. Habibie and Drs. J.M.M. Ritzen in September 1992.

Execution of APERT

During the plenary programme meeting, held in Amsterdam on 26 April, the Joint Governing Group for APERT 95 was installed and the programme organization and memberships were established. The main objective of the programme is the continuation, if possible extension, of the long standing co-operation between the Indonesian and Netherlands participants mentioned above and others, based on the principle of mutual interest and mutual benefits, aiming at an equal partnership collaboration in all areas. This phase of APERT is planned to last three years.

The programme includes three Joint Expert Groups:

I Education. The main objective is to continue the co-operation between DUT and ITB.

II Laboratory Development. The main objective is to further improve the aerospace research capabilities and facilities in Indonesia.

III Joint Research. The main objectives are to increase the number of research subjects and to increase the number of participating institutes and industries.

Awaiting the signing of an official agreement on APERT 95 a small number of activities were started in the first half of the year, as earlier agreed by the Governing Group.

In July a delegation of DUT headed by the rector, Prof.ir. K.F. Wakker, visited Indonesia, to intensify the co-operation between ITB and DUT. The mission was sponsored by APERT 95 and attended by Dr. P.A.J. Tindemans (OCW) and Mr. J.P. Klok (NLR) during visits to several ministries in Jakarta.

In August, Dr.Ir. B.M. Spee (NLR), taking part in a trade mission which accompanied an official visit of Her Majesty Queen Beatrix to Indonesia, signed Amendment 2 to the General Co-operation Agreement on APERT, in this manner officially extending the programme with another three years until 31 December 1997. For BPPT, Prof.Dr.Ir. H. Djojodihardjo signed the document.

The stay of Ir. S.J. Boersen, project representative, was extended until the end of the year, as laid down in an N250 Test Support Agreement between NLR and IPTN.

With LAGG, an agreement was signed for 1995 to support the project representative by NLR on maintenance of equipment, supply of consumables and goods for ILST operations and backstopping activities.

By the end of 1995, IPTN announced that it saw no further need for support by NLR beyond 1995.

Other activities

Apart from the Apert Programme, NLR has a co-operation agreement with IPTN on fatigue load monitoring of the CN235 aircraft under operational circumstances.

In Indonesia, plans are being developed to realize a large transonic wind tunnel near the ILST at the site of PUSPITEK for future aircraft development programmes of IPTN. Ir. F. Jaarsma of NLR executed a mission to Serpong to advise the management of LAGG on the realization of such a project. NLR has offered to the Indonesian authorities to donate its Pilot High Speed Tunnel (PHST) for training and familiarization purposes. The tunnel will be rebuilt at the premises of IPTN.

Capita Selecta

1 Development of the National Simulation Facility

In 1995 NLR has started operating its newly developed National Simulation Facility (NSF) for research under contract to the Royal Netherlands Air Force and other customers. The NSF is an advanced full-mission research flight simulator equipped with a six-degrees-of-freedom motion base, a head-tracked visual system and currently an F-16 cockpit in Mid Life Update configuration. The development of the NSF took NLR just three years. The NSF was inaugurated by the Netherlands State Secretary of Defence, with the Supreme Commander of the Royal Netherlands Air Force demonstrating some of the capabilities of the NSF in a simulated mission.

History

Already in the late 1970s NLR conducted computer simulations of the F-16 fighter, to support the development of the fly-by-wire flight control system under contract to the manufacturer General Dynamics. NLR generated vast amounts of data by mainframe computers running flight control system and aerodynamic simulation software in a non-real-time mode. The F-16 simulation program was later transferred to faster computers. Real time simulations were then used to support the Royal Netherlands Air Force (RNLAF) in incident/accident investigations and system and concept development. In 1989 the RNLAF expressed a need for an advanced research simulation capability covering fast jet (F-16), transport and rotary wing aircraft. The budget required for the development of such a facility, however, exceeded the funds available at the RNLAF and NLR.

A feasibility study was made for the Dutch Commission for the Development of Defence Materiel (CODEMA). CODEMA agreed to contribute to the funding of the first phase of a development project, covering the F-16 simulation capability. One reason for funding this project was the work to be performed by NLR as part of the F-16 Mid Life Update co-development under contract to Lockheed Martin Tactical Aircraft Systems (formerly General Dynamics).

By the end of 1991 NLR received the go-ahead for the development of the National Simulation Facility (NSF).

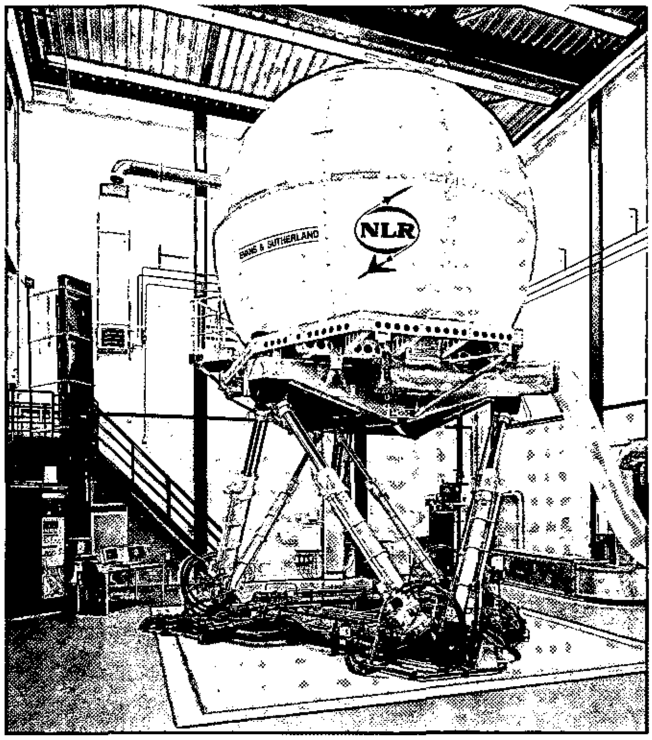


Fig. 1 - Dome and motion system of the National Simulation Facility

Capabilities of the NSF

The NSF is a full mission (research) simulator, enabling pilots to use mission-related equipment such as Electronic Warfare systems that react to simulated threats. Additionally the NSF is capable of performing mission rehearsal simulations, which enable pilots to investigate all the aspects of a particular real mission before actually carrying it out. In this case, geospecific terrain and real world imagery from satellites and reconnaissance photos feed various databases. If the NSF were classified as a trainer simulator, it would qualify as the 'ultimate' synthetic training device, ranking directly below the real aircraft (see Fig. 2).
The full mission requirement implies highly detailed simulations of the avionics, weapon systems and sensors and of the influence of weather conditions on sensors and aircraft, etc.

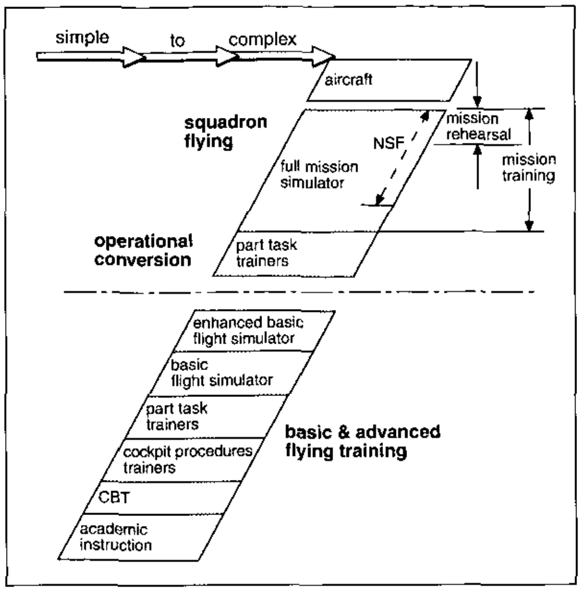


Fig. 2 - Utilization of synthetic training equipment

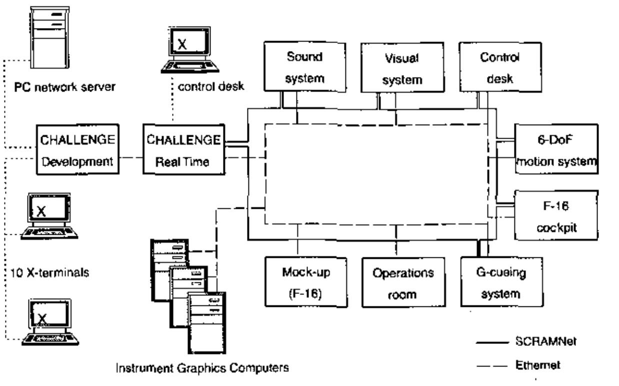


Fig. 3 - Overview of the simulator components

In contrast to NLR's existing Research Flight Simulator (RFS), which traditionally has used a generic transport or generic fighter cockpit, the NSF has a type-specific (F-16 Mid Life Update) cockpit and a complete tactical environment. The NSF immerses the pilot in a realistic synthetic environment.

Some of the top level requirements for the NSF, stated in the project definition, were:

- The NSF should be realized within three years, to allow the support of F-16 Mid Life Update (MLU) co-development work from the end of 1994;
- Simulations must support air-to-air, air-to-surface, low-altitude high-speed missions with a maximum of realism;
- A high-fidelity cockpit and the possibility to use physiological measurement equipment on the pilot are required for human factors research;
- Assessment of simulator training effectiveness and (training) simulator component requirements should be possible by selective 'degrading' of NSF components;
- Simulation of avionics should support integrating both aircraft equipment through its standard interface ('hot bench') and its functional software equivalent;
- All hardware and software components should be designed for maximum interchangeability with the Research Flight Simulator (RFS).

During the NSF development project, the existing RFS should remain fully operational, and continue to be further developed to support a multitude of different projects.

Development

The NSF project was started on 1 January 1992. In the definition phase it became clear that the expected volume of simulator experiments for the RFS and the NSF would not allow both simulators to be served by one single host computer configuration. A Request for Proposal for an additional NSF host computer system based on real-time UNIX was put out. The choice was made for two Silicon Graphics Challenge computers equipped with four MIPS R-4400 100 MHz RISC processors, one computer for software development and one for real-time operations.

Installing a new computer system was no trivial matter, since important parts of the real-time simulation software are dependent on the operating system. However, to incorporate the latest technological advances in information technology, it was considered necessary to create a completely new real-time executive and software development environment. A team consisting of engineers of the NLR Informatics Division, Fokker Space (formerly Fokker Space & Systems), BSO and the NLR Flight Simulation Department, worked on the feasibility, architecture and implementation of this very complex environment. It appeared feasible to use existing tools and software. An entire year was devoted to the initial integration and upgrading

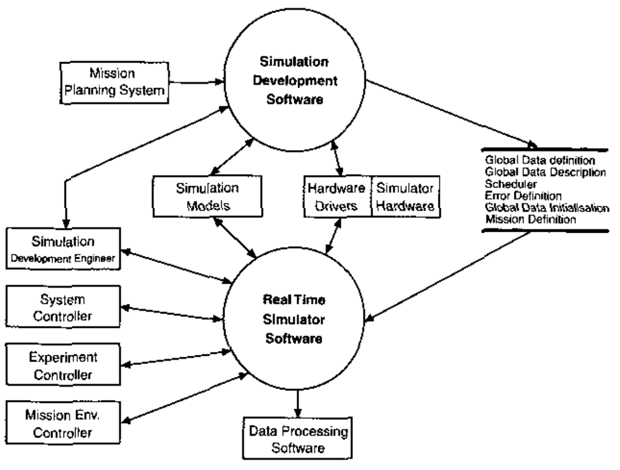


Fig. 4 - Top level architecture of the software

of these existing elements, creating the working environment for the NSF. During 1993 and 1994 some 14,000 man-hours were devoted to the development of this working environment known as PROSIM (Program and Real Time Operations Simulation Support Tool).

PROSIM consists of a development part and a simulation part (see Figure 4). The development part helps the simulation software modellers to design models in a structured way, supported by industry standard software development methods and tools. Communication between software models can be described on different levels. The majority of the software variables is placed in a Global Data Definition structure, and simulation models communicate through "shared memory". The use of this shared memory is strictly controlled by PROSIM, which, for instance, does not allow any software variable to be multiply defined. The real-time simulation part of PROSIM enables the software to run in real time, with user-defined update rates and with user-defined dependencies between models (for instance, the module generating the sum of the forces acting on the aircraft must be activated after the aerodynamics and landing gear modules have calculated their forces). As expected, the UNIX-based computers initially operated in real-time with a time uncertainty of the individual update steps of several milliseconds. This uncertainty could be reduced to two tenths of a millisecond, enabling real-time simulations to run with update rates in excess of 100 Hz.

Simulation Models

Early 1994, with the basic version of PROSIM at their disposal, simulation software engineers started transferring various models from the existing to the new host computer. These models included models of a general nature, such as atmospheric wind and turbulence models, forces and moments calculation models, and specific F-16 models such as aerodynamics, landing gear, engine, avionics and flight control system models. These already validated models were available in an early stage of the NSF development.

F-16 Avionics Simulation

The requirements of the NSF, for the greater part founded on requirements stipulated for the F-16 MLU co-development simulations by Lockheed Martin, entailed functionally simulating the new MLU avionics of the aircraft precisely. The time span available for the NSF development, however, would not allow NLR to generate all MLU avionic models from scratch, not just because of the sheer size of the software development, but mainly because of the lack of MLU documentation, as the MLU avionics was still undergoing modifications at Lockheed, even on the level of the required functionality.

The F-16 avionics software incorporates such systems as:

- the Modular Mission Computer, consisting of Fire Control Computer, Upgraded Programmable Display Generator driving the Multi Function Displays, Stores Management System and Head Up Display Electronics Unit;
- the Upfront Controls, such as Integrated Control Panel and Data Entry Display;
- the Westinghouse APG-66 V2 Fire Control Radar;
- the TERMA Electronic Warfare Management System;
- the Advanced Identification Friend or Foe;
- the Intraflight Data Link.

While much of the MLU functionality had been designed in other Lockheed Martin F-16 programmes, such as the F-16 C/D Block 50 programme, it was impossible for NLR to acquire the required documentation, owing to regulations imposed by the US Air Force and the US State Department. This hampered the development of the NSF software severely. Lockheed Martin therefore offered to share its F-16 MLU flight simulation software with NLR (with permission from the US State Department). NLR subcontracted a team from Lockheed's Flight Simulation Laboratory to integrate parts of the F-16 MLU avionics software of Lockheed in the NSF environment. This software was validated. The avionics software of the NSF conforms to the latest MLU specifications.

Interactive Tactical Environment Management System

To generate 'target-rich' tactical scenarios, NLR acquired the Interactive Tactical Environment Management System (ITEMS), a complete simulation package that provides interactive players and supports command and control authority structures.

Hardware Simulation Systems

Apart from software components, the NSF contains the following major hardware elements:

- an F-16 cockpit in MLU configuration;
- a six-degrees-of-freedom platform motion system;
- a g-cueing system for sustained acceleration cueing;
- a visual system, consisting of an image generator, a dome projection system and a database generation system;
- an audio system for voice communication and sound simulation;
- graphical workstations for display generation;
- a control desk;
- an operations room;
- a host computer system;
- a flight simulator interface system.

The NSF has a specially developed Flight Simulator Interface System (FSIS) to allow the host computer to upload data to and download data from other simulator systems. It is of utmost importance that the man in the simulator experiences the effects of his actions as he would in the real world. The FSIS therefore has to allow all cueing systems to react as quickly as possible to movements or other changes as a result of, for instance, pilot inputs.

The hardware systems of the NSF are connected by a local area network that enables distributed computer systems to communicate with each other. The high data throughput demands (about 6 Megabyte/sec or 128 Kilobyte per frame) prohibit the use of standard computer interfaces such as Ethernet. The real-time data are therefore transferred between the computer systems of the NSF by a Scramnet digital high-speed fibre-optic network on a 'reflective memory' basis. The NSF uses also multiple, non-real-time links between all hardware systems and workstations based on Ethernet, for instance for downloading configuration files before the real-time process is started. At the start-up of the simulation program, the various hardware systems are selected, and physically connected to the host computer through opto-electronic switches.

Visual System

Capabilities of commercially available visual systems were assessed in an extensive study, using detailed information on various systems obtained from manufacturers. Both helmet-mounted displays and dome display systems were evaluated. In the latter case, both fixed projection and the then newest development of head-tracked area-of-interest projection were considered. Based on the requirements for air-to-ground missions, where pilots must be able to use their normal equipment in the cockpit (including night vision goggles or helmet mounted sights), simulator-specific helmet-mounted displays were eliminated from the list.

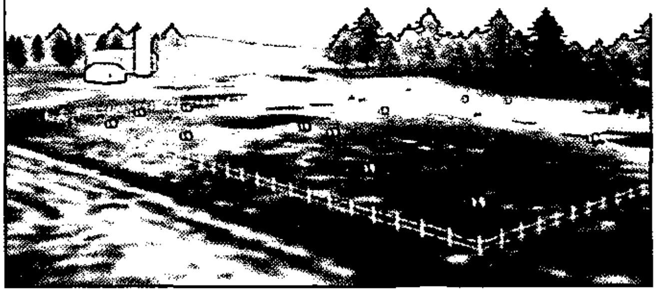


Fig. 5 - Detail of visual database: rural area

The best available combination of elements in one visual system appeared to be one of Evans & Sutherland, which was awarded the contract. The visual system of the NSF includes a 5-metre diameter dome, specially made to withstand the linear and angular accelerations of the motion platform. The dome is made of twenty-four graphite-epoxy parts, seamlessly connected to form a very stiff sphere, crucial for preventing any visual artifacts caused by platform movements. An Evans & Sutherland VistaView head-tracked servo-projection system projects both a head-tracked background image and a head-tracked inset image on the inner surface of the

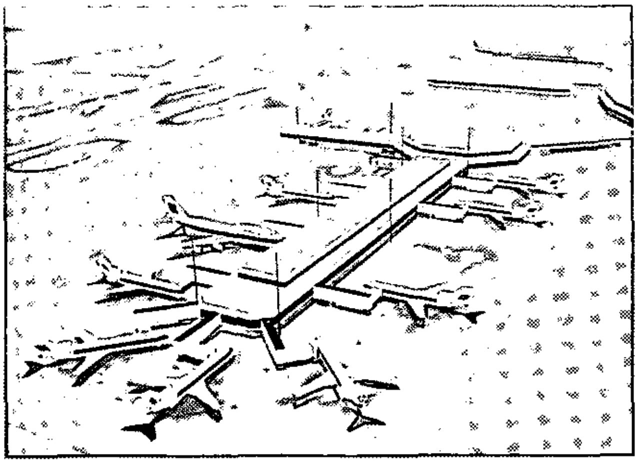


Fig. 6 - Detail of visual database: San Francisco International Airport

dome. Two high-brightness light valve projectors supply the pilot with an oval shaped image with a field of view of 142x110 degrees and an inset of 45x35 degrees. Two channels of a three-channel ESIG-3000/GT (Global Texture) image generator produce the outside world scenery as seen by the pilot; one for the background and one for the area-of-interest inset. The third channel is used to generate infra-red imagery picked up by possible F-16 or missile sensors or to generate optical video from, for instance, a Maverick missile. These images are then relayed to the cockpit to be mixed with the Multi Function Display images. The image generator can be used for mission rehearsal simulations whereby it is possible to use geospecific imagery (for instance satellite imagery) to texture terrain which in its turn is based on digital geographical terrain elevation data. To complete the visual

Fig. 7 - Simulator control desk

system, a data base generation system (DBGS) is used to implement new visual databases. In addition to databases in Evans & Sutherland formats, the system can handle visual data based on the international Standard Database Interchange Format or semi-automatically create databases from the US Defense Mapping Agency's Digital Terrain Elevation Data and Digital Features Analysis Data.

Motion System

The National Simulation Facility NSF is one of the very few fast-jet full-flight simulators equipped with a platform motion system, with six degrees of freedom. It has been argued that motion systems would not improve the value of

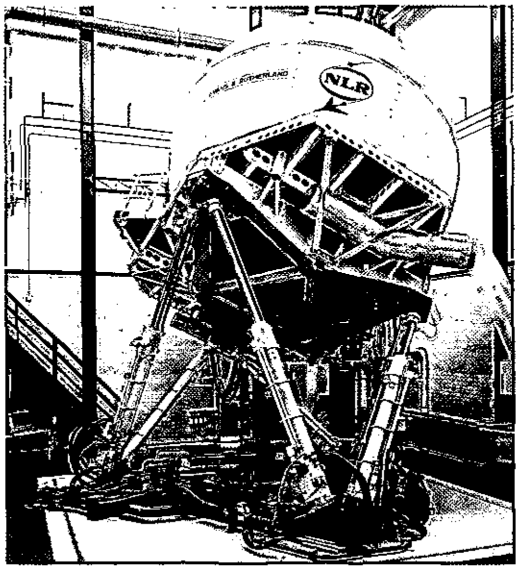
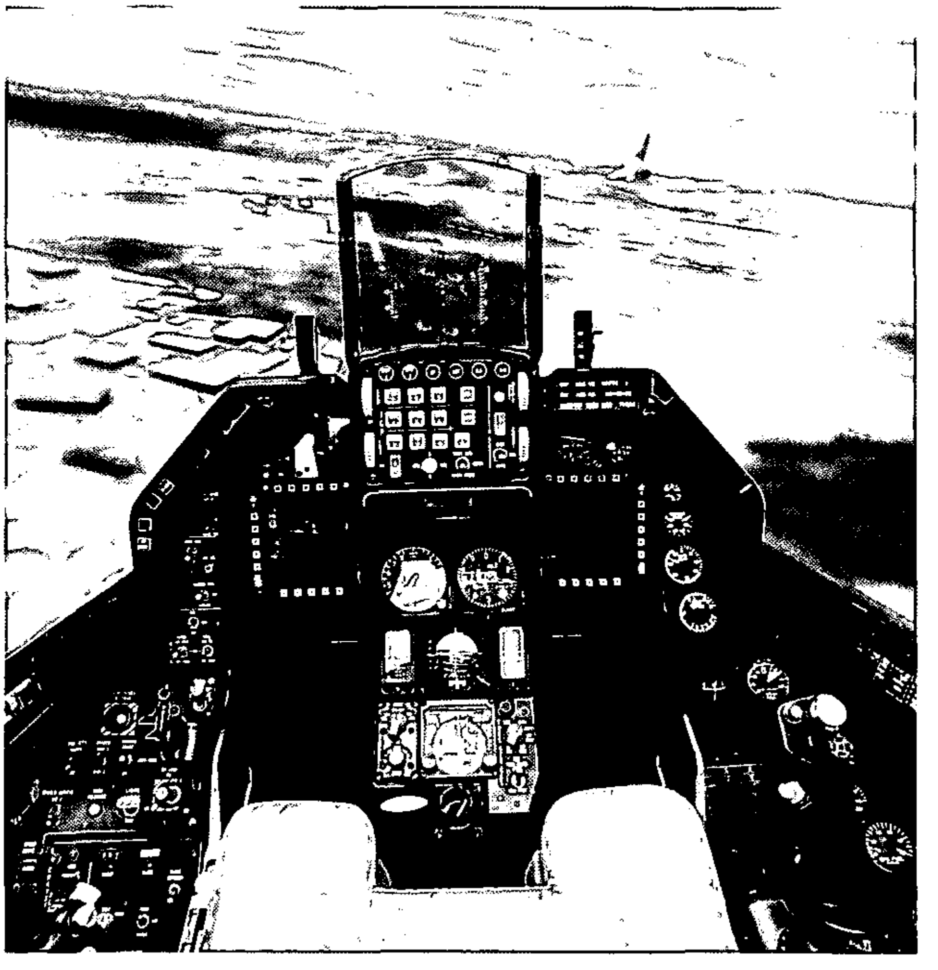


Fig. 8 - Excursion limit of motion system

Fig. 9 - F-16 Mid Life Update cockpit in the NSF



fast-jet simulators, since they are unable to generate motion cues fast enough. NLR has demonstrated the opposite to hold true in various simulation programmes such as for the Israel Aircraft Industries LAVI fighter and recently for the SAAB Military Aircraft JAS-39 Gripen fighter. The motion system of the NSF, built by the Dutch firm Hydraudyne, is the world's largest and fastest synergistic system, with a 72-inch hydraulic actuator stroke. It generates onset accelerations based on simulated aircraft accelerations. These acceleration stimuli affect the pilot's vestibular organs in his inner ear and create motion sensations. It is not the correct amplitude of the acceleration that is most important, but the phase, and therefore the time lag, of the stimulus. Because of the still limited stroke of the actuators, only short term accelerations can be generated. For long-duration acceleration cueing, the NSF will be equipped with a G-cueing device. In this device moveable seat and backpanes combined with inflatable cushions put pressure on the pilot's body. Together with strap belts which can be tightened, a system which inflates and deflates the pilot's anti-g suit and a system which pulls the helmet down in the case of positive g's will cause the pilot to believe that he is under actual g-loading.

F-16 Cockpit

The NSF is equipped with an F-16 cockpit in the Mid-Life Update (MLU) configuration. The cockpit was designed and built by Lockheed Martin Tactical Aircraft Systems to specifications from NLR. It is fully functional and provides the same look and tactile responses as a 'flyable' cockpit. The cockpit has some 500 analogue and digital inputs and outputs connected to a VME-based interface system that is linked to the host computer via Scramnet.

Communication and Control

The NSF is equipped with an advanced 'touch panel' control desk to control and monitor systems and simulation experiments. By means of touch screens, operators can activate various simulator systems, and change or record parameters. Multiple video recording channels can be addressed, for instance to record the pilot's out-of-the-window view combined with cockpit displays. Customer-specific touch screen software control can be implemented. Communication and audio generation is performed through an advanced audio system, capable of simultaneously generating 40 different sounds in real-time. Both sampled and synthesized sounds can be activated, ranging from all voice messages of the F-16 Voice Message Unit to hail clatter on the canopy and sounds of missile launches.

Official Opening

All of the NSF hardware and software were simultaneously operated on schedule, on 31 December 1994, exactly three years after the NSF project was started. In 1995 the NSF was configured for several simulation experiments, demonstrating the flexible concept.
On 20 October 1995 the NSF was officially inaugurated by the State Secretary of Defence, Drs. J.C. Gmelich Meijling, and flown by the Commander in Chief of the Royal Netherlands Air Force, LtGen B.A.C. Droste.

Current NSF Simulation Programmes

Programmes scheduled for 1996 pertain both to pure research and to system development.
A government-funded technology demonstration project will show the benefits and drawbacks of using speech recognition and commands in the F-16 MLU aircraft. This project is carried out in close co-operation with the TNO Human Factors research institute (TNO-TM) and the Royal Netherlands Air Force.

Another simulation experiment will be carried out to investigate the handling qualities of the recently developed JAS-39 Gripen fighter aircraft, for SAAB Military Aircraft. For this experiment the F-16 cockpit will be modified by the installation of Gripen flight controls, and the simulation software will be interfaced to actual Gripen models developed by SAAB.

Several experiments, mainly focused on cockpit mechanization issues, will be carried out in the Lockheed Martin F-16 MLU co-development programme.

Simulation experiments addressing human factors issues of training and simulator technology will be carried out under the EUCLID (European Cooperation for the Long term In Defence) programme.

Future Developments

Until the end of 1995, the development of the NSF has been concentrated on the F-16. Currently, efforts are undertaken to develop a similar simulation capability for rotary wing aircraft. A generic helicopter capability will be created first, to be followed by type-specific capabilities when demand arises.

2 Development of the Mission Support System MSS/C

The Mission Support System Campal (MSS/C) developed by NLR is a powerful tool for military mission planning. It enables aircraft pilots to familiarize with the battle theatre and to compose flight routes. In the planning process, MSS/C deals with current flying restrictions, weather conditions and threats in both the friendly and enemy areas. The C of MSS/C refers to an early version named Campal, Computer Aided Mission Planning at Airbase Level.

MSS/C supports several mission types: offensive missions with conventional weapons and smart missiles, reconnaissance missions, defensive missions (combat air patrol) and ferry missions. All missions are supported for peace and war times, and for times of tension. The information for the actual scenario can be retrieved from external command and control systems and/or from a database resident in MSS/C.

MSS/C at Volkel Airbase (Courtesy Volkel Airbase)

Definition and Key Objectives

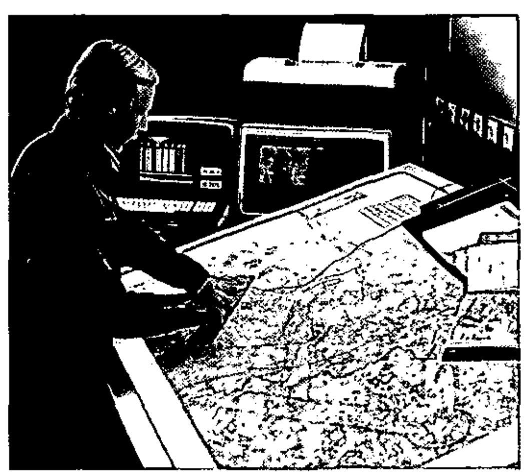
The mission support system MSS/C is a Mission Planning System, defined as 'a system that allows all the available and pertinent information to be used to plan a mission to achieve certain objectives in an optimum and near-optimum way, and also data that describes the mission to be loaded into the aircraft' in Advisory Report No. 296 of AGARD, NATO's Advisory Group for Aerospace Research and Development.

This AGARD Report lists the key objectives of mission planning systems as:

- reduce planning time and errors,
- reduce planning workload,
- improve attack effectiveness,
- increase survivability,
- improve co-ordination,
- increase safety,
- improve resource management,
- allow interoperability.

History

NLR has supported military mission preparation for a long time. An historical overview, starting in 1979, of the various state-of-the-art planning systems developed by NLR is given in Table 1. Previously, in the early 1970s, NLR had supported the development of attack templates for drawing attack manoeuvres in handmade combat mission folders. In 1975 the Royal Netherlands Air Force (RNLAF) requested NLR to investigate the technical feasibility of computer-based automation aids for military aircraft mission planning. NLR then investigated the available display systems with respect to their capabilities of displaying geographical information as background for route planning and evaluated the available 'rear port tube graphics systems.' These systems offered an optical entry at the rear of the display system, to project the geographical information on the inner side of the display screen.



Pilot System

Phase	a/c-tgt-mission types	Area reference	Area coverage			information	aircraft loading	attack planning	a/c perf. calculation	output	lines of code
			elec. maps	schem. maps	DLMS						
MOT&E July 79- end 81	1/1/1	UTM 32	–	–	–	–	–	–	level flights	co-ordinates, fuel info	10,000
Phase 1 End 1981- End 1982	1/1/1	UTM 32	–	Y	–	threat presentation	–	template based	level flights	co-ordinates, fuel info	40,000
Pilot system End 1982- Begin 1985	1/1/1	UTM 32	–	Y	Y	threat presentation, navigation	predefined loadings	template based	level flights, climbs	co-ordinates, fuel info, flight plan, CMF directives	70,000
S.O. CAMPAL Begin 1985- End 1988	4/2/1	UTM 32	Y	Y	Y	threat evaluation, navigation	predefined loadings	template based	level flights, climbs	co-ordinates, fuel info, flight plan, CMF	150,000
MSS/C Begin 1991- End 1994	4/3/5	World-wide	Y	Y	Y	threat/route assessment, navigation, meteo	predefined loadings, store individually loading	flexible attack: – run-in – attack – escape – stand off – deconfliction	level flights, climbs, descents, optimum flights	co-ordinates fuel info, flight plan, CMF, overview map, DTC	700,000
Pandora 1996-	4/3/5	World-wide	Y	Y	Y	threat/route assessment, navigation, meteo	predefined loadings, store individually loading	flexible attack: – run-in – attack – escape – stand off – deconfliction	level flights, climbs, descents, optimum flights	co-ordinates fuel info, flight plan, CMF, overview map	700,000

Table 1 - Historical overview of MSS/C development

The operational testing of the Lockheed Martin (then General Dynamics) F-16 fighter aircraft in Europe in 1979 required computer capacity to calculate fuel consumption and co-ordinate conversions. The main computer of NLR was applied to support the operational introduction of the F-16; a printer terminal was available to the remote user for the communication with NLR's computer. Later, the terminal was extended with an alphanumeric display. Video colour displays were introduced at the end of the 1970s. In 1982 a mission planning Pilot System was installed at Volkel Airbase. This system would serve for more than ten years.

In the beginning of the 1980s the capability of converting coloured paper maps into coloured electronic maps became available. At first the conversion could only be done by the classification of colours, a short time later by defining the red, green and blue tints of each picture element, or pixel. The large amount of information to be transferred from the main computer at NLR to the local work station at the airbase and the security requirements necessitated a computer to be included in the local work station. The experience gained in the operational introduction of the F-16 and in the development of the Phase 1 and Pilot Systems was used in the semi-

MOT&E System 1979 - 1981	Phase 1 + Pilot System 1981 - 1995	S.O. CAMPAL System 1985 - 1988	MSS/CAMPAL 1991 - 1994	Pandora 1996
• α-N display • printer	• α-N display • printer • colour graphics display • digitizer (1x1.4 m)	• α-N display • graphics printer • 2D colour image display (1024x1024 pixels) • digitizer (1x1.4 m) • colour hard copy unit (A3)	• 3D colour graphics display (1280x1024 pixels) • colour hard copy unit (A3)	• 3D colour graphics display (1280x1024 pixels) • colour hard copy unit (A4/A3)

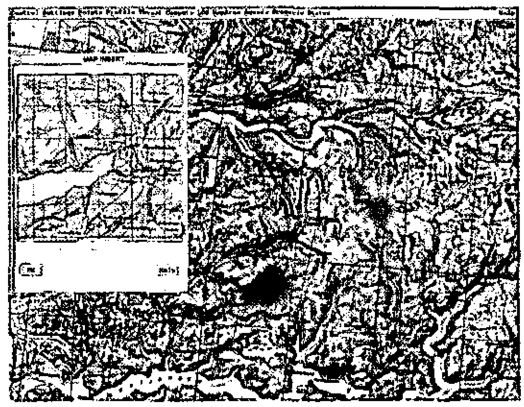
Table 2 - Evolution of CAMPAL work station

operational CAMPAL, which was to become the real prototype for the present military mission planning systems.

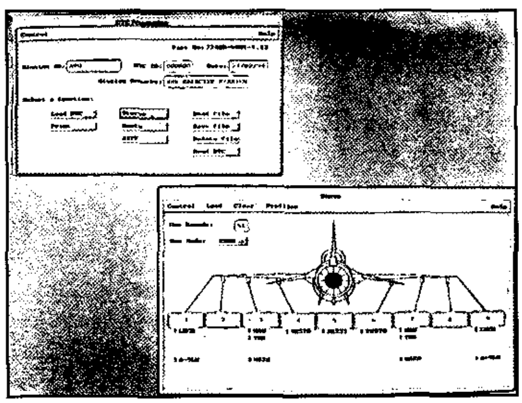
Table 2 shows the evolution of the CAMPAL work station. A digitizer was available for the input of accurate co-ordinates, a 'high-resolution' display presented maps and overlay information to the pilot, a colour hard copy unit provided the requested maps with overlays (maximum size A3, or 297x420 mm). While CAMPAL was being developed, the manufacturer of the F-16 introduced an on-line data loader, to improve the transfer of mission data via an avionics cartridge to the F-16 fire control computer.

Experience gained with the semi-operational CAMPAL workstation led the RNLAF to seek international co-operation for the development of a fully-operational mission planning system. At the end of 1990, three European Participating Air Forces (of Belgium, the Netherlands and Norway) concluded a contract for such a system with the manufacturer of the F-16 aircraft, with NLR acting as a subcontractor for the mission planning and preparation part of the software.

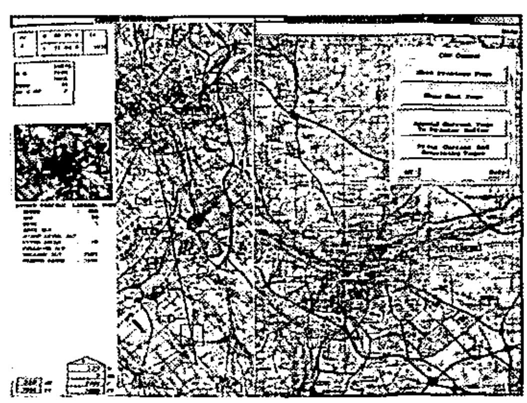
A new computer platform was selected, and the digitizer was removed. Moreover, the application was adapted to the current state-of-the-art in user interface software technology: windows. The conversion from the semi-operational CAMPAL command language to a foolproof window application, a major task, has resulted in the state-of-the-art window-driven mission preparation software package of MSS/C.



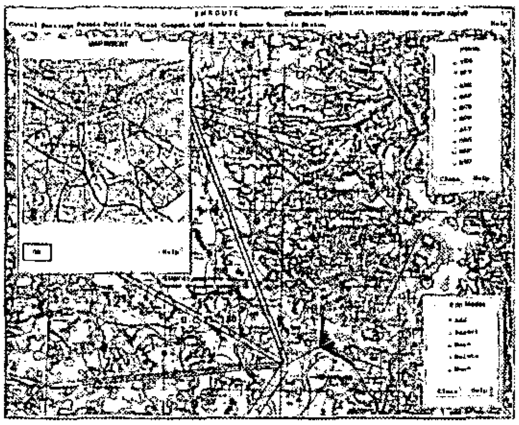
Electronic map including intel overlay



Use of windows for weapon allocation



Combat mission folder on display



Printer output with ACO overlay

Functionality

The present MSS/C consists of three main components: *scenario*, *planning* and *output*. *Scenario* presents all data related to geographical co-ordinates, formatted in overlays, on a continuous map on a scale selected by the user. The user has the option to define the contents of the overlay for his mission preparation session. Each overlay can be switched on or off easily. Figures and symbols are parameter-controlled; colour, line width, line style and fill pattern can be selected by the user.

Planning sessions start with an overall assessment of the feasibility of the mission to be executed and with the weapon loading related to the mission objectives. Weapon loading can be done very quickly by selecting a standard weapon configuration, but store-by-store selection is also possible. Advice with respect to weapon effectivity and related attack manoeuvres can be requested.

Planning supports missions with up to four aircraft and, if applicable within the mission type, up to three targets. The trajectory planning of the mission consists of three parts: the route to the destination area, the manoeuvring (e.g. attack, combat air patrol) in the destination area and the route from the destination area to the home base. Ferry missions comprise just the planning of the route from home base to destination base. In-flight refuelling can be included.

After completion of planning for the first aircraft, the total trajectory or parts of it may be copied for the benefit of planning for the other aircraft of the mission. Other features made available for a user-friendly planning process are:

- preplanned missions, part of the resident data base;
- route advice through the friendly area;
- calculation of penetration risk;
- calculation of a minimum risk route;
- warnings in case the trajectory is too close to an obstacle or crosses a low flying area;
- advice on weapon delivery and deconfliction.

The *output* component of MSS/C takes care of the transfer of route information to the aircraft via the avionics cartridge, and of the production of the flight plan, the combat mission folder and overview maps. The maximum size of the output is A3. In order to provide route and scenario information on the map, the overlay mechanism of the scenario component is available in the output also, so the user has the option to overlay the information he wishes.

Database

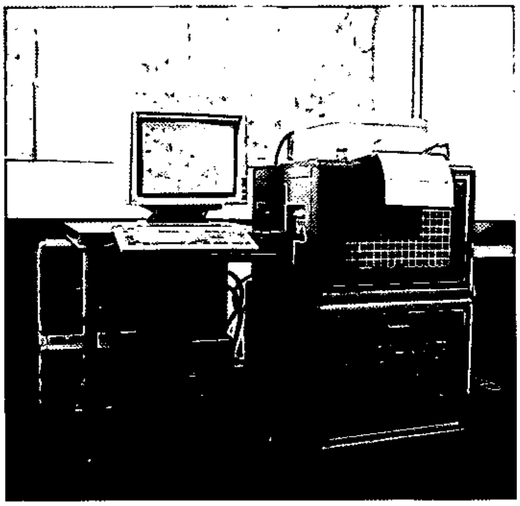
Mission planning databases contain three main types of data:

- data about geographical features and weather,
- data about friendly assets including physical data and data about their use,
- data about the enemy assets.

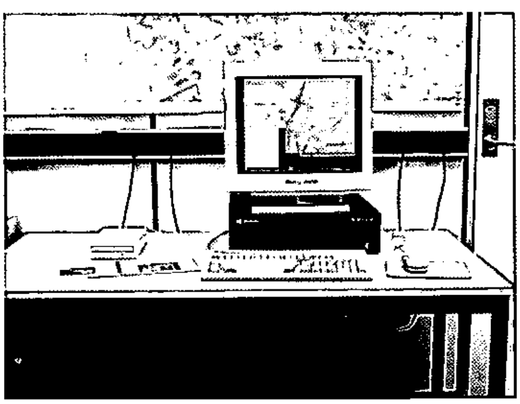
Table 3 shows an overview of the data available in the MSS/C resident data base, and indicates where data can be derived from an external command and control information system.

Mechanization

The mechanization of MSS/C is shock and vibration proof in accordance with MilStd-810D, prevents compromising electromagnetic signal emanation (AMSG 719/721) and is capable of operating in a temperature range of 10° to 34° C, in a humidity range of 20% to 80% (non-condensing) and within an altitude range of –1000 to 6000 ft. The basic computer of MSS/C is a Silicon Graphics Inc. 4D/35 workstation. The same mission types can be supported, with the same functionality, by another mission planning system of NLR, Pandora, based on a



Operational, ruggedized, MSS/C with power backup



Pandora mission support system

low-end commercial off-the-shelf workstation. With Pandora, deployability is safeguarded with transport cases only. Protection against compromising emanation is arranged in accordance with relaxed standards (AMSG 788A).

Map Scanner

In order to meet the mission planning map requirements, NLR has developed a map scanning station, because appropriate electronic maps could not with the proper flexibility be provided by the world's leading map producer, Defense Mapping Agency (DMA) of the USA, or by the Netherlands geographical services agency.

In 1991–1992 NLR developed an Information Preparation Station (IPS) Map Scanner, aiming at the three following objectives. The scanning products should correspond to the accuracy of screen display and printer (4 pixels/mm); no transformations or corrections for lens disturbance or inadequate light distribution should be necessary. Although the state of the art did not allow these objectives to be met completely, the scanner does provide continuous map areas in accordance with requirements. Scanning and postprocessing are done in one step, and the IPS Map Scanner produces Map Sheet Conformal Projection System (MSCPS) continuous maps. A high-resolution camera (8–10 pixels/mm) has been installed to ensure the readability of the electronic maps.

Comparison

A yardstick for assessing the performance of mission planning systems is the capability of manipulating maps. This capability is determined by the characteristics of the selected platforms and by the limitations of the electronic map mechanization. The three types of platforms currently used for mission planning are: workstation, PC and notebook. The two types of electronic maps used in the systems discussed below are: maps generated by DMA, in the Arc Digital Raster Graphics standard (ADRG) and maps generated by NLR by scanning paper maps, using the Map Sheet Conformal Projection System (MSCPS).

DMA, the major US producer of (electronic) maps on the scales 1:250,000 and smaller, scans with 10 pixels per millimetre. The number of map sheets that can be glued together is determined by the storage capacity of one CD-ROM (e.g. four maps of scale 1:250,000). As a consequence, scrolling is limited to a small predefined continuous area. In practice this approach limits the possibility of the user to define his continuous planning area. Electronic map data produced by DMA need postprocessing to satisfy more realistic scrolling specifications and to compose larger continuous areas.

Table 4 compares five mission planning systems representing the three platform types and two types of electronic map systems described above:

- (US) Air Force Mission Support System (AFMSS), on a workstation, all information stored on hard disk, using the DMA's ADRG method;

information	breakdown	remarks
Scenario cluster		
Geographical info.		
Digital Landmass SYSTEM	terrain elevation and feature data	
1:50/100/250,000 electr. maps	continuous areas	UTM projection
1:500,000 electronic maps	continuous areas (TPC, LFC)	Lambert projection
1:2,000,000 electronic maps	map sheets	Lambert projection
Schematic maps (WVS)		DMA product
Intelligence Info.		
Threats*	AOB, EOB, GOB, MOB, Events, Latent threat	point co-ordinates
Planning lines*	including FLOT, FSCL, EFSCL, RIPL	split up in line parts
Nuclear incidents*		for presentation only
Meteorological info.		
Airfield weather*	actual and forecast	
Significant weather chart*	lines, symbols and text	
Aircraft performance weather*	grid position, wind speed/direction, temperature, QNH	mainly for Ferry a/c performance calc.
Navigation info.		
Airspace management*	routes, zones, lines, boundaries, traverse levels	validity periods
Low flying restrictions	lines, areas, circles	validity periods
Obstacles	Elevations in AGL and MSL	limited availability for low level flights
Friendly airfields	status of ATC, runway, weather, X-serv.	necessary for diversion
Airfield ICAO codes	position and capabilities	
Standard waypoints		to support fast planning
Flight information regions	region identifiers + latitudes/longitudes	for air traffic control in peace time
Magnetic corrections		predicted for 5 years
Aircraft and weapon cluster		
Aircraft performance		implemented as software library
Aircraft configuration	tailnumber specific and generic	
Weapon Stores config.	aircraft/station/stores standard, pilot selectable	standard configurations can be predefined
Tactics cluster		
Tactical scenario	altitude bands, risk levels,EOV conditions, threat type	threat presentation and risk calculation
Weapon effectiveness	predefined by NATO, local adaptations possible	
Manoeuvres	run-in, attack, delivery	fuse arming/safe escape/fragmentation
Route (Preplanned)	air-to-ground missions, air defence sectors, CAP-pos.	
Communications	including IFF/SIF codes	
Default and control parameters		
Defaults		to speed up standard planning sessions
Control parameters	ID. of info. source, map scale/type and symbols	user friendliness

* also obtainable from other CCIS systems

Table 3 - MSS/C Database

- Mission Support System/Computer Aided Mission Preparation at Airbase Level (MSS/C), on a ruggedized workstation, map information stored on optical disks, other information on hard disk, using the MSCPS method;
- Pandora, the MSS/C successor on a Commercial Of The Shelf (COTS) workstation, with all information stored on hard disk, using the MSCPS method;
- Modular Mission Support System (M^2S^2), on a PC, all information stored on hard disk (amount of geographic information is limited due to PC storage limitations), using the ADRG method;
- Aviation Mission Planning System (AMPS), on a notebook, all information stored on hard disk, (amount of geographical information is limited due to notebook limitations), using the ADRG method.

Perspectives

In addition to supporting actual mission planning, MSS/C and the IPS map scanner can be used as a development environment for similar applications:

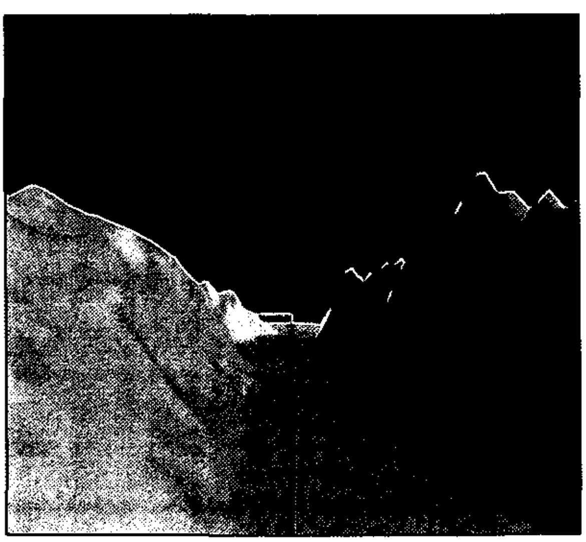
- intelligence system, to assess the friendly and enemy scenario's, and to improve the assessment method;
- planning system for other fixed wing aircraft;
- planning system for rotor wing aircraft;
- adding peripherals, such as a digitizer, to have a better overview over the area and to enter a route for quick and dirty mission planning;
- transformations of DMA's ADRG areas into NLR's MSCPS areas;
- preview (rehearsal) of planned missions.

mission planning system	platform	1:500,000 & 1:250,000 en route maps	1:50,000 detailed maps	retrieve time 1:500,000 map 600x600 km	scrolling capability	scrolling speed	area size on screen 1:500,000 continuous map
AFMSS	workstation	Y	N	some seconds	within standard predefined DMA areas	8 times/sec	150x120 km
MSS/C	workstation	Y	Y	2 minutes	full	8 times/sec	150x120 km
Pandora	workstation	Y	Y	some seconds	full	16 times/sec	150x120 km
Fairchild M^2S^2	PC	Y	N	10-15 minutes	within standard *predefined* DMA areas	2 times/sec	90x60 km
AMPS (Apache)	notebook	Y	N	10-15 minutes	within standard predefined DMA areas	once/minute	60x60 km

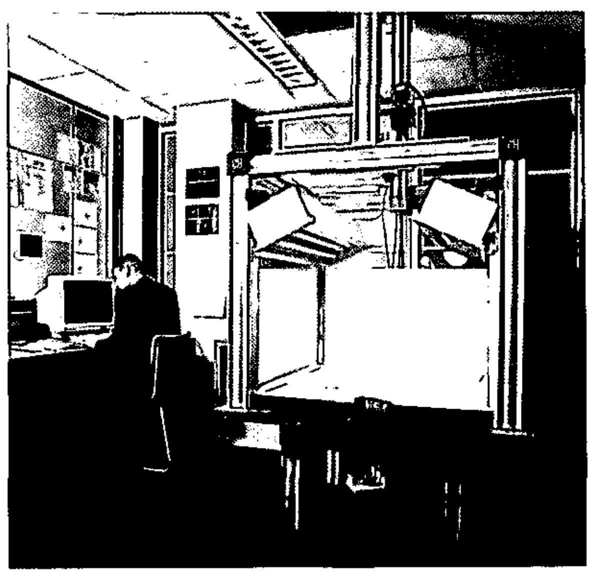
Table 4 - Comparison of mission planning systems

Concluding Remark

The Mission Support System Campal (MSS/C) has been designed and developed in a close co-operation between experts in the field of military operations and in the field of automation. In addition to frequent consultations with staff of Lockheed Martin, the Royal Netherlands Air Force and others, this co-operation appeared to be crucial to the production of a system with the quality requested by the customers.



Mission preview



Information Preparation Station map scanner

3 Development of the Airborne Remote Sensing Radar PHARUS

PHARUS (Phased Array Universal SAR) is an airborne SAR (Synthetic Aperture Radar) developed in the Netherlands. The concept of PHARUS allows airborne SAR systems to be built on a common generic basis but tailored to specific user needs. The concept is aimed at providing an economic and yet technically sophisticated solution to remote sensing or surveying needs of a specific user. The PHARUS system differs from other airborne SARs by the use of an active phased array antenna, which provides flexibility in the design of compact, light-weight instruments that can be carried on small aircraft. At the end of a period of ten years of studying, planning, designing and developing, the PHARUS system made its first test flight in September 1995.

Radar Remote Sensing

Remote sensing using radar is one technique of acquiring information on the surface of the earth from a remote location such as an aircraft or a satellite. A radar system is an active system; it transmits microwave energy which 'illuminates' the surface to be studied. Clouds are transparent to microwaves, which gives the radar the advantage of a day and night all weather capability, in contrast to optical remote sensing.

Microwave remote sensing is in the process of being developed into a large scale observation technique that, owing to the use of space technology, offers global coverage. Rather than making other observation techniques outdated, satellites such as ESA's ERS-1 and ERS-2 are expected to stimulate the interest in supporting observations from ground-based or airborne sensors. As far as spaceborne sensors are concerned, the coverage of large areas will have priority in the present and the next decade. Airborne sensors have a supporting operational task in observations with high resolution and/or high observation frequencies. In contrast to the rigid observation schemes of satellites, airborne systems can provide observations on request at any time.
From a technological point of view, airborne systems can also be used to study and test instrumental principles to be applied in future spaceborne systems.

The PHARUS Project

The PHARUS project started in 1988, after preparatory studies in previous years. The initiative came from the Dutch remote sensing community, which, in the decade before, performed extensive studies using ground-based radars, an X-band Sideways Looking Airborne Radar (SLAR) and an airborne scatterometer on the NLR's Queen Air and Fairchild Metro II research aircraft.

The PHARUS project is being carried out in a co-operation between the Physics and Electronics Laboratory of TNO (TNO-FEL), the National Aerospace Laboratory NLR and the Delft University of Technology's Laboratory for Telecommunication and Remote Sensing Technology (DUT). Financial support is provided by the Ministry of Defence and by the Netherlands Remote Sensing Board (BCRS). The programme management on behalf of these partners is carried out by the Netherlands Agency for Aerospace Programs (NIVR).

The PHARUS project consists of two parts, a definition study and a realization phase.

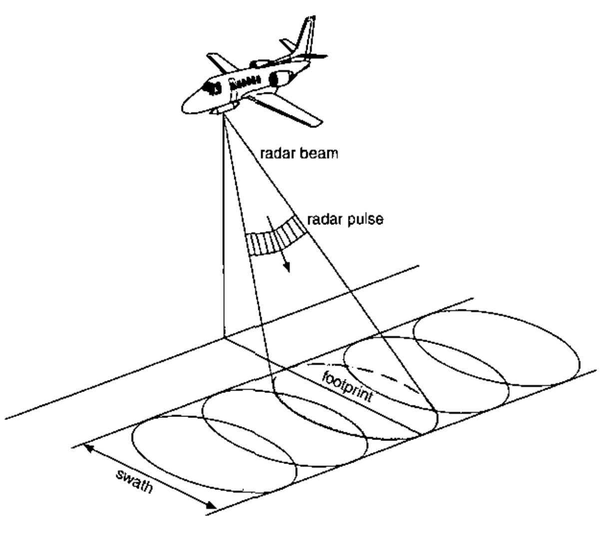
The definition study was made to study the problems before the final system was designed and to gain experience with Synthetic Aperture Radar (SAR) technology and airborne SAR problems. The study was rewarded with a successful test flight of the Phased Array Research SAR (PHARS) system on 8 November 1990.

This pilot system has been extensively used for research and application projects in Europe, for purposes of mapping, land use inventory, change detection, coastal bathometry, ship detection and ocean wave measurement.

The realization of the final PHARUS system started in april 1991 and is expected to be complete in 1996. PHARUS is a fully polarimetric C-band system, with a very flexible configuration. Some key figures are: swath width up to 20 km, resolution up to 3 m, altitude up to 12 km, instantaneous electronic beam steering up to 15°.

The first flight with an operating PHARUS was flown, with success, in September 1995.

A SLAR (Sideways Looking Airborne Radar) has a real aperture antenna carried by an aircraft. The beam of the antenna is fan-shaped and directed sideways to the earth.



A single microwave pulse generates a short time series of echoes originating from the 'illuminated' strip of terrain. While the aircraft is moving forward, successive pulses hit successive strips and generate successive series of echoes. These are measured and are transformed into successive lines of a radar image.

For images with more detail, narrower strips are required, which can be achieved by using longer antennas. Obviously, the length of the aircraft limits the length of the antenna.

In the Synthetic Aperture technique, signals are produced that appear as if they originate from very long antennas, although the data are taken with a rather short antenna. The aircraft now carries a radar with a small antenna, with a wide beam. While the aircraft is moving forward, the radar measures the radar echoes very often and very accurately. All measurements are combined into a synthesized signal by calculations. This signal represents the signal of an antenna with a synthesized aperture of the length of the distance flown in the acquisition time.

The resolution of a SAR is independent of the distance, which makes SARs well suited for long distance remote sensing systems such as spaceborne radars and systems providing stand-off capability. For a given object on the ground the 'in view' time is a function of local strip width and aircraft velocity. The maximal obtainable effective synthetic aperture for the object is equal to the local strip width. For an object at twice the distance, the 'in view' time is doubled, so the synthetic aperture can be doubled, which makes the synthetic beam twice narrower, just compensating for the double 'looking' distance.

Results from the Pilot System PHARS

The radar of the pilot system PHARS is carried in a small pod by NLR's Fairchild Metro II research aircraft (see Fig. 1). The digitizing electronics, control panel, navigation system and recording equipment are situated inside the aircraft.

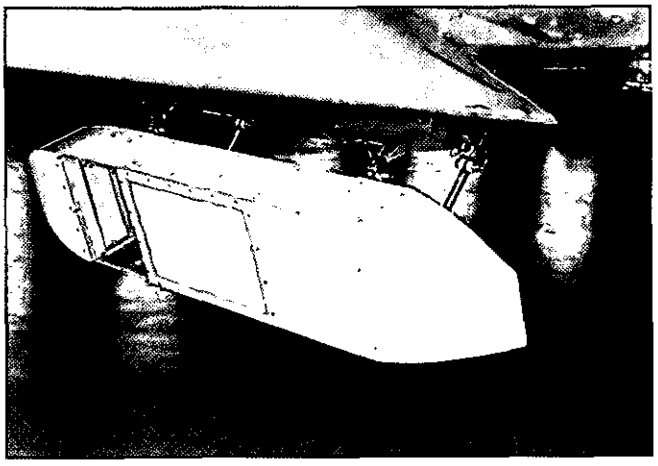


Fig. 1 - Radar pod of pilot system PHARS on Metro II research aircraft

The second test flight with the pilot system PHARS resulted in data of good quality over a mixed sea/urban/rural area in the surroundings of the Hague in the Netherlands. The measured resolution turned out to be close to 3 m in along-track direction and 5 m in cross-track direction.

Fig. 3 - Flooding of the river Waal near Tiel recorded by PHARS, resolution 4 x 4 m

Fig. 2 - Radar image of Amsterdam recorded by PHARS, resolution 6 x 6 m

In late 1991, PHARS was employed in the international calibration/validation campaign for the ESA Remote Sensing Satellite ERS-1 carried out off the coast of Norway. In three missions fourteen ocean scenes were recorded, from which directional ocean wave spectra were calculated. These spectra compared well with spectra derived from simultaneously measured data from the ERS-1 SAR and other radar sensors and from buoys.

During later test flights, several scenes such as the cities of Amsterdam (see Fig. 2) and the Hague and of the North Sea locks near IJmuiden were recorded.

Since then, PHARS has acquired data for many purposes, including the production of bathometric maps, the detection of sea traffic, the mapping of land use and infrastructure, and studies comparing PHARS with other systems such as the NASA's JPL AIRSAR and the ESA's ERS-1.

On 1 February 1995, PHARS was flown over some of the flooded areas in the Netherlands. The image (Fig. 3) shows the river Waal near Tiel. Dark areas indicate water, and the width of the river is tripled. Note the brick works now surrounded by water, the Tiel bridge and the entrance of the Amsterdam-Rhine channel.

The PHARUS System

Experimental systems such as PHARUS have to be as flexible as possible. This was achieved by making PHARUS easily programmable, even in flight.

In the single polarization mode, PHARUS is capable of producing high resolution images over long ranges. In dual and quad polarization (polarimetric) modes, the range and/or the resolution is reduced because of the limited recording capacity.

The PHARUS system is carried by the Cessna Citation II research aircraft. This twin jet business aircraft was chosen for high resolution SAR imagery because of its high speed, between 150 and 250 m/s, and its high maximum altitude of 12 km, which allows large swath widths to be used. The aircraft is equipped with various sensors to acquire aircraft attitude and position, including an inertial navigation system using laser gyros and a Global Positioning System (GPS).

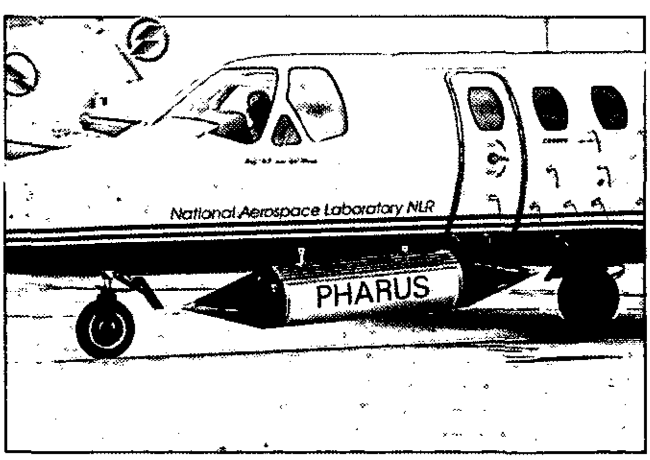


Fig. 4 - PHARUS pod on Cessna Citation II

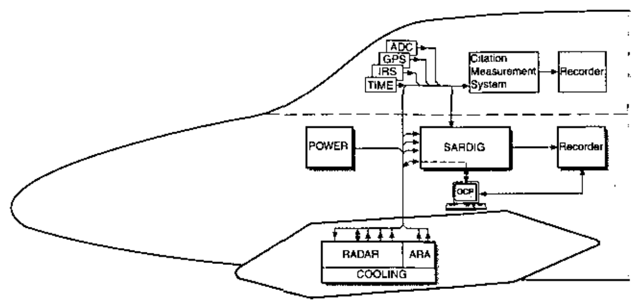


Fig. 5 - Functional diagram of PHARUS and equipment for the measurement of the aircraft path

The airborne segment of PHARUS consists of four main parts (see Fig. 5):

- External pod with Radar, Cooling system and Motion sensor
- Digitizing and Preprocessing Electronics, High speed Recorder
- Operators Control and System logging
- Aircraft navigation systems and recording.

The ground-based segment of PHARUS consists of two main parts:

- replay facilities for retrieval of radar data and aircraft data
- high precision trajectory and attitude processor.

External Pod

The external pod contains the complete radar system and a separate motion sensor to measure fast movements of the pod. A cooling system is integrated in the mechanical construction.

Transmit/Receive Modules

The most important parts of the radar are the microwave modules. Each module contains a small 20-Watt radar with a selectable transmit polarisation and two parallel receivers for the two receive polarisations. Two rows of 24 modules (expandable to four rows) form a distributed active phased array radar. By individual control of phase and amplitude of the transmitted and received signals of the modules, the antenna pattern can be formed and directed both in azimuth and elevation in a process called electronic beam steering. Outputs of the radar system are two receiver signals and a coded timing reference signal.

Mechanical/Thermal Design

In full operation about 3 to 4 kW of heat has to be removed from the pod. The mechanical support and the cooling system are integrated. The container for the plug-in Transmit/Receive modules, machined from one piece of metal, consists of a 116 x 25 x 14 cm^3 box, divided into 24 segments by thin inner walls. In the 22-mm thick outer walls, four 15-mm diameter holes were drilled with a length of over 1 m. In each 5.4-mm thick inner wall, four 3-mm diameter holes were drilled. The holes in the outer walls are connected to the holes in the inner walls. Cooling liquid is pumped through this internal piping system to transport the heat from the modules to the exchangers on the outside of the pod (see Fig. 6).

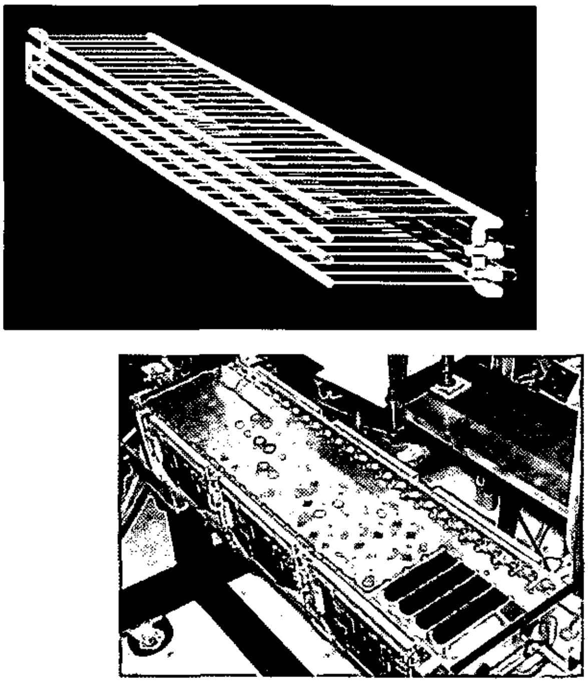


Fig. 6 - Aluminium box (bottom) made of one piece, with integrated liquid cooling channels (top) to accept 24 groups of four T/R modules (courtesy TNO-FEL)

Radar Window

The section of the structure in front of the radar antenna has to be transparent to microwave signals. This radar window of 1.5 x 0.5 m has to withstand a differential pressure of 0.75 bar, while outside temperatures range from +40°C at sea level to -60°C at high altitudes. The application of the polyethylene product Dyneema (trademark of DSM), has resulted in a light weight, strong and very 'radar-friendly' window.

Flight Testing of the Pod

A business jet with a 3 m long, 0.5 m diameter container weighing 240 kg mounted to the fuselage is no standard configuration.
Prior to the flight testing of the radar an extensive flight test programme was executed to verify the proper behaviour of the aircraft/pod combination. Important issues in the flight test programme were the aerodynamic drag and possible vortex flows into the aircraft engine.

Measurement Modes

In the single polarization mode only one radar output signal is needed to form one output channel. PHARUS can measure in four different modes simultaneously, resulting in four output channels. One of these four channel modes is the fully polarimetric mode; in another configuration, for instance, the radar beam can point to different directions.

Up to four different signals are generated in the radar by alternating from pulse to pulse the source of the signals at each of the two analog radar outputs, labelling their status via the coded time reference signal. So the two analog radar signals together can represent 2 x 2 channels in a time-multiplex operation.

Digitizing

The Horizontal-received and Vertical-received analog radar output signals are digitized in parallel at a speed of 100 MHz into 8-bit values. For each of the four channels digitized data acquired during a programmable time window are stored in memories to be processed.

Data Processing and Recording

Processing of the data is done in several steps, organized as a pipeline process. The sequential processing of the data stored in the memories can be configured in number and order.

The first processing step consists of the demodulation of the digitized, stored data and their recalculation to the selected (cross-track) resolution, which means digital filtering and resampling.

The second processing step is pre-summing, the weighted adding of a number of (multichannel) lines. Four pre-summers are available to process the data of complete lines on a line basis, in order to optimize the line output frequency to the selected along-track resolution. After the pre-summing, the data rate is reduced but still high. The limit of currently available data recorders (100 Mbit/sec) requires the compression of the data as much as possible, especially in the polarimetric mode, which requires extremely high data rates.

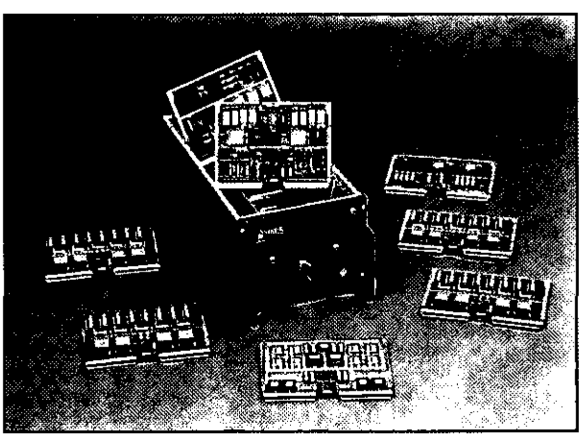


Fig. 7 - SARDIG digitizing and preprocessing electronics and box

The third processing step is the preparation of a pre-summed line for recording. A header, containing a synchronisation pattern, all status and settings information of PHARUS, aircraft navigation data and a very precise time tag is added to the line. The line data is reformatted to a format accepted by the recorder system and sent to the recorder, at 100,000,000 bits per second.

The electronics for the digitizing, preprocessing, preparation to record and the internal control is built in a box named SARDIG (SAR Digital Station) (see Fig. 7).

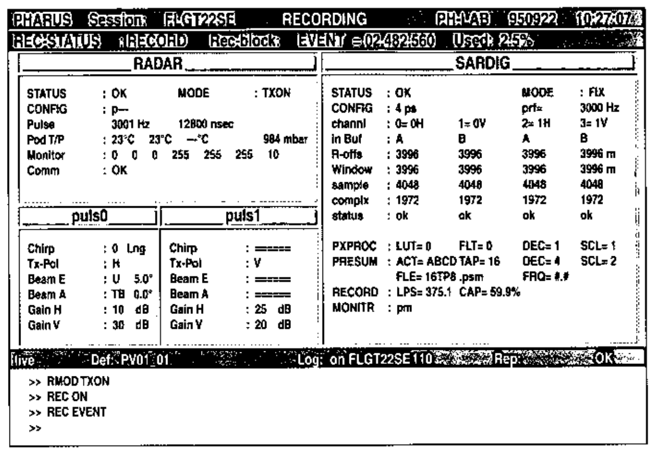


Fig. 8 - Operator Control Panel display for monitoring, reporting and commanding

Operator Control and System Logging

In the PHARUS system more than 50 settings can be controlled and over 30 variables are available for monitoring. A portable personal computer is used as an Operator Control Panel (OCP).

The OCP is linked to SARDIG and to the recording system. SARDIG is linked to the Radar. Communication between OCP and Radar is passed through SARDIG. Communication over the links is committed to a strict protocol. The Radar reports to SARDIG its current status; SARDIG reports to OCP the current status of the Radar and Sardig. SARDIG reports also the current value of aircraft navigation parameters.

The OCP displays an up-to-date overview of setting and status of PHARUS (see Fig. 8).

Logging

All inputs given via the keyboard and all responses of the system are reported, with a time tag, in a log file on the hard disk. All remarks, errors and tape addresses reported by the recording system are also added to this log file. The log file is used to evaluate the flight and to assist in the selection of the radar data to be replayed for processing.

In another file, the reports from Radar and SARDIG on settings and status are logged.
A special feature of the OCP software is that this file can be replayed, showing the display sequence of the flight.

Applications

The first project for PHARUS in 1996 will be the Familiarisation Phase, funded by the Remote Sensing Board (BCRS), to provide future users with 'hands-on' experience.

In 1998, the Advanced Synthetic Aperture Radar (ASAR), a spaceborne high-resolution, wide-swath imaging radar instrument, is to be launched on the ENVISAT-1. ASAR will provide up to 400-km wide swaths using ScanSAR techniques, or will provide simultaneously dual polarisation signals using alternating polarisation configurations.
Owing to its high flexibility and the high altitude of the aircraft carrying it, PHARUS can provide ASAR look-alike data both in ScanSAR and in dual polarisation mode, prior to the launch of ENVISAT.

Co-operation

PHARUS is an example of a successful project carried out jointly by specialists on various fields from NLR and other organizations.

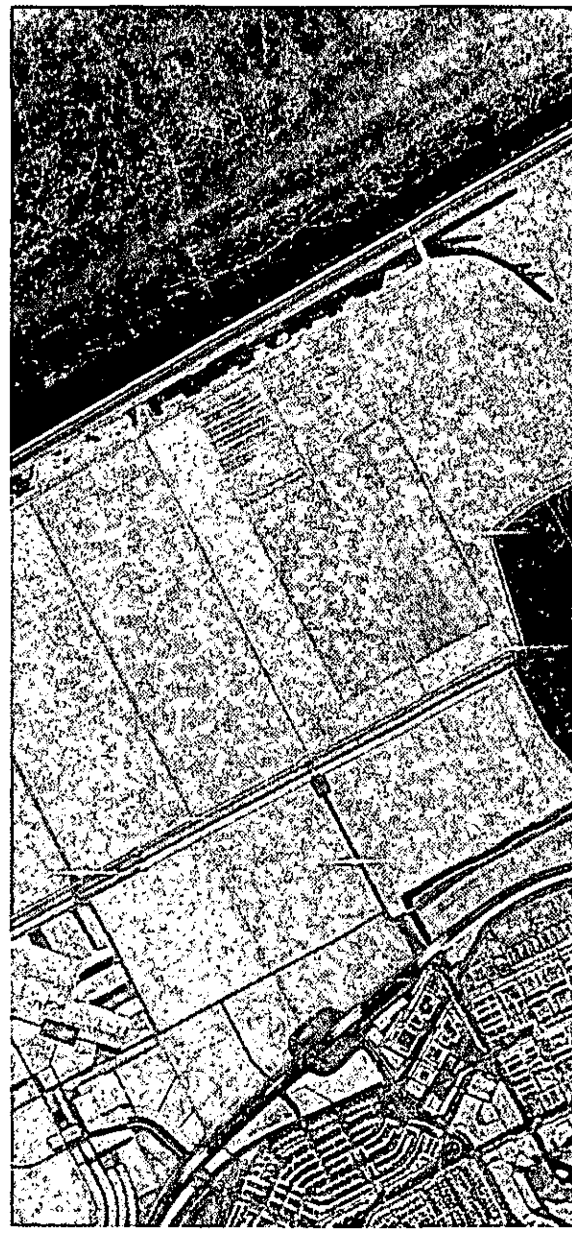


Fig. 9 - Fully polarimetric radar image acquired by PHARUS of an area North of Almere. Polarizations HH, HV+VH and VV are coded in red, green and blue, respectively. Resolution 3 x 3 m

Appendices

Appendices

1 Publications

In 1995, NLR produced a total of 692 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

TP 92267 U

Surface grid generation for multi-block structured grids
Spekreijse, S.P.; Boerstoel, J.W.; Kuijvenhoven, J.L.; Marel, M. v.d.

TP 93095 U

A study on methods to compare measured and calculated model data
Boer, A. de; Ellenbroek, M.H.M.

TP 93231 U

A database system concept to support flight test measurement system design and operation
Oosthoek, P.B.

TP 93237 U

A unified framework for the performability evaluation of fault-tolerant computer systems
Published in IEEE Transactions of Computers, Vol. 42
Pattipati, K.R.; Li, Y.; Blom, H.A.P.

TP 93244 U

A stripyield model including effects of hold periods at constant load
Richmond, M.J.; Koning, A.U. de

TP 93292 U

Air traffic collision modelling
Bakker, G.J.; Blom, H.A.P.

TP 93497 U

An airborne flight test data multiplexing and real-time processing system
Brandt, P.

TP 93536 U

On speaking terms with the EFMS through digital datalink
Brüggen, J.

TP 93561 U

In-flight velocity measurements using laser Doppler anemometry
AIAA Journal of Aircraft, **31** No. 2 (1993) 444–446
Jentink, H.W.; Stieglmeier, M. (LSTM); Tropea, C. (LSTM)

TP 94011 U

A flight test avionics acquisition system for future Fokker aircraft
Presented at the 'Aircraft Integrated Monitoring Systems Symposium' in Bonn, Germany, 21–23 September 1993 and at the 'Open Bus Systems' conference in Munchen, Germany, 29–30 November 1993.
Bogers, C.J.M.; Manders, P.J.H.M.

TP 94020 U

Trajectory reconstitution programs MURATREC I and MURATREC II
Presented at the 'Eurocontrol workshop on RASS', Luxembourg, 14–16 December 1992
Neven, W.H.L.; Blom, H.A.P.; Hogendoorn, R.A.

TP 94028 U

Control synthesis for linear parametric varying systems
Terlouw, J.C.; Bennani, S.

TP 94036 U

Experiences with rotating shaft balances for measurement of total propeller force and moment
Presented at the Indonesian Aircraft Propulsion Symposium at Bandung, Indonesia, 9–11 February 1994
Custers, L.G.M.

TP 94075 U

Effect of TiN/Ti gas turbine compressor coatings on the fatigue strength of Ti-6Al-4V base metal
Surface and Coating Technology **72**(1995)30–36
Kolkman, H.J.

TP 94100 U

Flexible data acquisition and control system for TPX/6557

Presented at 'The 5th European symposium on space environmental systems' and 'The 24th International conference on environmental systems', Friedrichshafen, Germany, 20–23 June 1994

Versteeg, M.H.J.B.; Monkel, A.; Verpoorte, J. and Jaarsma, J.

TP 94110 U

Anisotropic grid adaptation based on diffusion equations

Presented at the 4th International Conference on Numerical Grid Generation in Computational Dynamics and Related Fields, Swansea, United Kingdom, 6–8 April 1994

Hagmeijer, R.

TP 94125 U

Fatigue and residual strength behaviour of ARALL2 panels with bonded-on doublers

Hoeven, W. van der

TP 94142 U

A new generation test and verification equipment for attitude control systems

Presented at the second ESA International Conference on Spacecraft Guidance, Navigation and Control Systems, ESTEC, Noordwijk, 12–15 April 1994

Sonnenschein, F.J.; Nicolai, R.J.; Versteeg, M.H.J.B.; etc.

TP 94150 U

NASA-NLR long-line experiment

Bos, J.C. van den

TP 94152 U

Recent advances in the modelling of fatigue crack growth

Presented at the FAA/NASA International Symposium on 'Advanced Structural Integrity Methods for Airframe Durability and Damage Tolerance', Hampton, U.S.A., 4–6 May 1994

Koning, A.U. de; Hendriksen, T.K.; Hoeve, H.J. ten

TP 94157 U

Optical diagnostics for a fluid science core facility in microgravity

Presented at the International Symposium on Space Optics, Garmisch-Partenkirchen, Germany, 17–22 April 1994

Assem, D. van den; Kramer, A.J.; Briccarello, M.; Capuano. M.; Solitro, F.; Haugstätter, R.

TP 94158 U

Parallelization of a 3d multi-block NAVIER-STOKES flow solver on a distributed memory MIMD machine

Presented at the HPCN Europe '94 Conference, Munich, 18–20 April 1994

Beek, G. van; Geschiere, J.P.; Sukul, A.R.

TP 94161 U

Flow analysis and drag prediction for transonic transport wing/body configurations using a viscous-inviscid interaction type method

Presented at the 19th Congress of ICAS, 18–23 September 1994, Anaheim, California, U.S.A.

Muijden, J. van; Broekhuizen, A.J.; Wees, A.J. van der; Vooren, J. van der

TP 94167 U

The mission of the European aeronautical research and high performance computing and networking

Presented at the International Conference and Exhibition on High-Performance Computing and Networking, HPCN Europe 1994, Munich

Loeve, W.

TP 94175 U

Acquisition and assessment of fatigue loads in the CN-235 airplane

Presented at the 19th Congress of the International Council of the Aeronautical Sciences in Anaheim, U.S.A., 18–23 September 1994

Kamil, S.; Suryo, D.; Sudrajat, A.R.; Laméris, J.; Dominicus, J.A.J.A.

TP 94180 U

Flight Simulator evaluation of take-offs conducted with and without a take-off performance monitor (TOPM)
Presented at the 19th Congress of the International Council of Aeronautical Sciences, Anaheim, California, U.S.A, 19–24 September 1994
Khatwa, R.; Verspay, J.J.L.H.

TP 94183 U

Multi-sensor data fusion in command and control and the merit of artificial intelligence
Presented at the AGARD Mission Systems Panel's 1st Symposium on Guidance and Control Techniques for Future Air-Defence Systems, Copenhagen, 17–20 May 1994
Zuidgeest, R.G.

TP 94196 U

The wet satellite model experiment
Published in 'ESA-SP-1132, Vol. 4'
Vreeburg, J.P.B.

TP 94199 U

Grid adaption based on modified anisotropic diffusion equations formulated in the parametric domain
Journal of Computational Physics, **115** No.1 (1995) 169–182
Hagmeijer, R.

TP 94203 U

Aircraft propeller noise
Presented at the VKI Lecture Series 'Applied Aero-Acoustics', Rhode-Saint-Genèse, Belgium, 7–11 March 1994
Brouwer, H.H.

TP 94217 U

A linear programming algorithm for invariant polyhedral sets of discrete-time linear systems
Systems & Control Letters, **25** (1995) 337–341
Dam, A.A. ten; Nieuwenhuis, J.W.

TP 94220 U

Modelling measurement systems: putting views together
Presented at the 14th European Telemetry Conference, 17–19 May 1994, Garmisch-Partenkirchen, Germany
Oosthoek, P.B.

TP 94221 U

Integration, automation and human factors in future aviation
Presented at the ICAO Flight Safety and Human Factors Seminar, Amsterdam, The Netherlands, 16–19 May 1994
Abbink, F.J.

TP 94223 U

Human reliability in civil aviation
Presented at the 13th European Annual Conference on Human Decision Making and Manual Control, Espoo, Finland, 13–14 June 1994
Bos, J.F.T.; Hooijer, J.S.; Macwan, A.; Peek, F.; Wieringa, P.

TP 94227 U

The effect of wing sweep on the flow around a slat and its performance
Presented at the 19th ICAS Congress, Anaheim, U.S.A., 1994
Djatimoko, B.; Sudira, I.G.N.; Caktawala, A.; Chintamani, S.H.; Mack, M.D.; Berg, B. van den

TP 94234 U

Development of the Dutch national simulation facility NSF, The world's premier motion-based F-16 MLU simulator
Presented at the "1994 AIAA Flight Simulation Technologies Conference", Scottsdale, Arizona, U.S.A.
Offerman, H.A.J.M.

TP 94239 U

Parallelizing a large scale 3D multi-block Navier-Stokes solver
Presented at the 'Supercomputing '94 Conference', Washington D.C., U.S.A., 14–18 November 1994
Geschiere, J.P.; Mourik, P.A. van

TP 94241 U

On transforming accelerometer data to angular rate

Vreeburg, J.P.B.

TP 94250 U

Results of uniaxial and Biaxial tests on riveted fuselage lap joint specimens

Presented at the FAA/NASA International Symposium 'Advanced Structural Integrity Methods for Airframe Durability and Damage Tolerance', Hampton, U.S.A., 4–6 May 1994

Vlieger, H.

TP 94265 U

Communication characteristics of the VHF datalink subnetwork

Esser, R.G.W.J.

TP 94268 U

Coupled analysis in acoustics on the dynamical behaviour of solar arrays

Presented at the 19th International Seminar on Modal Analysis (ISMA), KUL, Leuven, Belgium, 12–14 September 1994

Grooteman, F.P.; Schippers, H.

TP 94269 U

In-orbit demonstration of two-phase heat transport technology: TPX/G557 flight results

Presented at the Thermal Control Technology / Two-Phase Technology Session of the combined 24th International Conference on Environmental Systems and 5th International Symposium on Space Environment, Friedrichshafen, Germany, 20–23 June 1994

Delil, A.A.M.

TP 94272 U

Reduction of noise using tuned dampers

Presented at the 19th International Seminar on Modal Analysis (ISMA), 12–14 September 1994

Boer, A. de; Derksen, J.

TP 94275 U

Eddy current detection of pitting corrosion around fastener holes

Presented at the AGARD Specialists' Meeting on 'Corrosion Detection and Management of Advanced Airframe Materials', Sevilla, Spain, 5–6 October 1994

Heida, J.H.; Hart, W.G.J. 't

TP 94303 U

The modernization program of the transonic windtunnel HST of NLR – Lessons from the past, prospects for the future

Presented at the 19th Congress of the International Council of Aeronautical Sciences, Anaheim, California, U.S.A., 18–23 September 1994

Elsenaar, A.; Jaarsma, F.J.

TP 94312 U

Aircraft environmental studies: a need for flexible information processing

Presented at the Fifth International Conference on the Development and Application of Computer Techniques to Environmental Studies, ENVIROSOFT 94, 16–18 November 1994, San Francisco Bay, U.S.A.

Veerbeek, H.W.

TP 94314 U

Validation of the computational methods used for the design of the canopy of the Hermes spaceplane

Presented at the 12th AIAA Applied Aerodynamics Conference, Colorado Springs, CO, 20–22 June, 1994

Hagmeijer, R.; Oskam, B; Cock, K.M.J. de,

TP 94319 U

Development of a trigger mechanism to reduce peak forces in crash loaded composite sine-wave spars

Presented at the 20th European Rotorcraft Forum, Amsterdam, 4–7 October 1994

Lestari, W.; Thuis, H.G.S.J.; Wiggenraad, J.F.M.

TP 94324 U

Principles for software management of mathematical software

Presented at the European Simulation Symposium (ESS '94) 9–12 October 1994, Istanbul

Vogels, M.E.S.

TP 94330 U

Spacecraft altitude and orbit control systems testing

Presented at the AGARD Flight Vehicle Integration Panel Symposium Space Systems Design and Development Testing, 3–6 October 1994, Cannes, France

Sonnenschein, F.J.; Schoonmade, M.; Zwartbol, T.

TP 94345 U

***The lower-dynamic data acquisition system* as part of the MRVS-90 instrumentation system**

Presented at the SFTE 25th Annual Symposium, Washington D.C., U.S.A., 1–5 August 1994

Robben, M.A.M.

TP 94351 U

Fractographic examination of specimens from IEPG TA-31 creep tests

Wanhill, R.J.H.

TP 94356 U

On the importance of corrections for velocity components and flow gradients normal to the wire plane of an x hot-wire

Presented at the Second International Conference on Experimental Fluid Mechanics (I.C.E.F.M.), Torino, Italy, 4–8 July 1994

Gooden, J.H.M.

TP 94359 U

SPINE: Software platform for computer supported co-operative work in heterogeneous computer and software environments

Baalbergen, E.H.; Loeve, W.

TP 94363 U

Air traffic management as a multi-agent stochastic dynamic game under partial state observation

Presented at the ICAF 7th Symposium on Transportation Systems: 'Theory and application of advanced technology', Tianjin, China, 24–26 August 1994

Blom, H.A.P.; Klompstra, M.B.; Bakker, G.J.

TP 94364 U

Structured parallelization of a multi-block Navier-Stokes solver targeting distributed memory platforms

Geschiere, J.P.

TP 94365 U

A PC-based real-time multimedia tele-*education system*

Presented at the IEEE Global Telecommunications Conference GLOBECOM '94, San Francisco, U.S.A., 27 November–1 December 1994

Algra, T.

TP 94366 U

Evaluation of the parallelization of a 3D multi-block Navier-Stokes solver for the RISC-based IBM parallel systems

Published in IBM News

Geschiere, J.P.

TP 94368 U

Evaluation of deterministic spectral gust methods

Presented at the 79th AGARD SMP Meeting, Seville, October 1994

Jonge, J.B. de; Vink, W.J.

TP 94378 U

A prediction method of transonic limit cycle oscillation characteristics of fighter aircraft using adapted steady wind tunnel data

Presented at the 19th ICAS Congress, Anaheim, U.S.A., 18–23 September 1994

Meijer, J.J.; Cunningham, A.M.

TP 94379 U

On the invertibility of mappings arising in 2D grid generation problems

Presented in technical report 94–20 of the Faculty of Technical Mathematics and Informatics, Delft University of Technology and submitted to the journal Numerische Matematik.

Hagmeijer, R.; Clement, Ph.; Sweers, G.

TP 94383 U

The effect of the environment on the fatigue properties of ARALL-3

Laméris, J.

TP 94390 U

Developing algorithms for efficient simulation of flexible space manupulator operations

Presentation as IAF paper no. 94-032 at the Astrodynamics Symposium in the 45th Congress of the International Astronautical Federation, Jerusalem, Israel, 9–14 October 1994

Woerkom, P.Th.L.M. van; Boer, A. de; Ellenbroek, M.H.M.; Wijker, J.J.

TP 94401 U

Aircraft corrosion and fatigue damage assessment

Contribution to the Corrosion Working Group in the NAARP (National Ageing Aircraft Research Programme) of the U.S. Department of Transportation, Federal Aviation Administration.

Wanhill, R.J.H.

TP 94412 U

Sound transmission measurements on curved panels with plane wave excitation

Presented at the 19th International Seminar on Modal Analysis (ISMA), KUL, Leuven, Belgium, 12–14 September 1994

Wal, H.M.M. van der

TP 94422 U

Outline and application of the NLR aeroelastic simulation method

Presented as paper ICAS-94-9.4.2 at the 19th ICAS Conference, Anaheim, Ca, 18–23 September 1994

Hounjet, M.H.L.; Eussen, B.J.G.

TP 94424 U

Ground execution of micro-gravity experiment scenarios using an end-to-end manned payload operations concept

Presented under number IAF-94-T.4.457 at the 45th Congress of the International Astronautical Federation (IAF), Jerusalam, 9–14 October 1994

Pronk, Z.; Roefs, H.F.A.; Hoop, D. de

TP 94438 U

Wind tunnel measurements of the aerodynamic noise of blade sections

Presented as EWEC paper J3-2 at the European Wind Energy Association Conference and Exhibition, Thessaloniki, Greece, 10–14 October 1994

Dassen, A.; Parchen, R.; Bruggeman, J.; Hagg, F.

TP 94450 U

Finite-element based preliminary design procedures for wing structures

Presented at the 19th Congress of the International Council of Aeronautical Sciences, Los Angeles, U.S.A., September 1994

Arendsen, P.; Dalen, F. van; Rothwell, A.R.

TP 94459 U

Full mission simulator for research and development

Presented at the 1995 International Conference and Exhibition on Training and Simulation (ITEC), The Hague, The Netherlands, 25–27 April 1995

Offerman, H.A.J.M.

TP 94476 U

Transmissieverlies van rompwandpanelen

(in Dutch) Presented at the scientific meeting 'Luchtvaartlawaai' organized by the Nederlands Akoestisch Genootschap, Utrecht, 13 September 1994. Text appeared in NAG Journal nr. 124.

Demmenie E.A.F.A.

TP 94486 U

On the radar cross section prediction of aerospace platforms

Presented at the 2nd International Conference on Approximations and Numerical Methods for the Solution of the Maxwell Equations, Washington, U.S.A., 25–29 October 1993

Schippers, H.; Brandt, P.; Maseland J.E.J.; Heijstek, J.J.

TP 94511 U

A comparison of standards for software engineering based on DO-178B for certification of avionics system

Presented at the 'ERA 1994 Avionics Conference and Exhibition (Systems Integration - is the sky the limit?)' 1 December 1994

Hesselink, H.H.

TP 94516 U

A family of LES filters with nonuniform filter widths

Published in 'Physics of Fluids', no. 7 (5), May 1995, pp. 1171–1172

Ven, H. van der

TP 94524 U

Programme and real-time operations support tool prosim – The simulation program of the dutch national simulation facility NSF

Presented at the Simulators for European Space Programmes - 3rd workshop - , 15–17 November 1994, ESTEC, the Netherlands

Dam, A.A. ten; Schrap, P.; Brouwer, W.

TP 94532 U

Preliminary model for the blunt notch behaviour of fibre metal laminates

Rijn, J.C.F.N. van

TP 94560 U

Structural concepts in composite materials for crashworthiness of helicopters

Presented at the International Symposium 'Crashworthiness and Design 95', organised by the University of Valenciennes and Hainaut-Cambrésis, 3–4 May 1995

Wiggenraad, J.F.M.

TP 94570 U

Network Interface unit: Artemis product dissemination by E-Mail

Dorp, A.L.C. van

TP 94587 U

Automatic Code generation for parallel finite element solvers

Presented at the 7th SIAM Conference on Parallel Processing for Scientific Computing, San Francisco, 15–17 February 1995

Heijstek, J.J.; Slothouber, F.N.C.; Goldman, V.V.

TP 94606 U

The effect of fatigue crack length on the residual strength of ARALL 3 panels with fingertip doublers

Hoeven, H. van der

TP 95017 U

The development of two tooling concepts for the production of composite sine-wave beams

Paper presented at the 8th International Conference on Composite Structures, Paisley, September 1995

Thuis, H.G.S.J.; Vries, H.P.J. de

TP 95049 U

Multiple crack initiation and crack growth in riveted lap joint specimens

Presented at the 18th ICAF symposium, Melbourne, Australia, 3–5 May 1995

Ottens, H.H.

TP 95068 U

Damage tolerance property comparisons for 2000 and 8000 series aluminium plate alloys

Wanhill, R.J.H.; Schra, L.; Hart, W.G.J. 't

TP 95082 U

Sub-floor skin panels for improved crashworthiness of helicopters in case of water impact

Presented at the American Helicopter Society 51st Annual Forum, American Helicopter Society, Fort Worth, TX, 9–11 May 1995

Thuis, H.G.S.J.; Vries, H.P.J. de; Wiggenraad, D.F.M.

TP 95087 U

Applications of aeroelastic methods to predict flutter characteristics of fighter aircraft in the transonic speed range
Presented at the 35th Israel Annual Conference on Aerospace Sciences, Tel Aviv/Haifa, Israel, 15–16 February 1995
Meijer, J.J.

TP 95102 U

Review of aeronautical fatigue investigations in the Netherlands during the period March 1993 - March 1995
Presented at the 24th ICAF Conference, Melbourne, Australia, 1–2 May 1995
Jonge, J.B. de

TP 95106 U

Reynolds - and Mach - number effects and 2D-3D correlation based on measurements and computer results for the Garteur take-off configuration
Presented at the High Lift and Separation Control - CEAS European Forum, 29–31 March 1995
University of Bath, U.K.
Termes, A.P.P. et al

TP 95107 U

Wind tunnel tests and aerodynamic analysis of the wind loads on the Erasmus Bascule Bridge at Rotterdam
Paper presented at the ninth International Conference on Wind Engineering, New Delhi, India, 9–13 January 1995
Willemsen, E.; Reusink J.H.

TP 95120 U

Demonstration of an automated CFD system for three-dimensional flow simulations
Burg, J.W. van der; Maseland, J.E.J.; Hagmeijer, R.; Cock, K.M.J. de

TP 95125 U

A hybrid computational model for noise propagation through a fuselage boundary layer
Paper presented at the First Joint CEAS/AIAA Aeroacoustics Conference, 12–15 June 1995, Munich, Germany
Schippers, H.; Wensing, J.A.

TP 95127 U

The influence of starter notches on flight simulation fatigue crack growth
Wanhill, R.J.H.; Schra, L.

TP 95136 U

Effects of asymmetric inflow on near-field propeller noise
Presented at the 1st Joint CEAS/AIAA Aeronautics Conference, Munich, 12–15 June 1995
Schulten, J.B.H.M.

TP 95154 U

Prevention of Buzz-saw noise by acoustic lining
Presented at the First Joint CEAS/AIAA Aeroacoustics Conference (16th AIAA Aeroacoustics Conference), 12–15 June 1995
Sijtsma, P.

TP 95155 U

Potential safety benefits of take-off performance monitors (TOPM) – A review of NLR TOPM research
Presented at the Flight Safety Foundation, European Aviation Safety Seminar (EASS) 'Safe Flight – The Enduring Challenge', 28 February–March 1995
Khatwa, R.; Verspay, J.J.L.H.

TP 95207 U

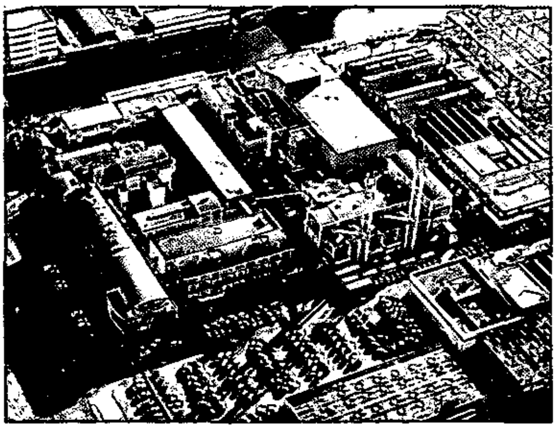
Advanced propeller performance calculation by a lifting surface method
Presented at the 31st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, San Diego, CA, 10–12 July 1995
Schulten, J.B.H.M.

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)
RLNAF	Royal Netherlands Air Force
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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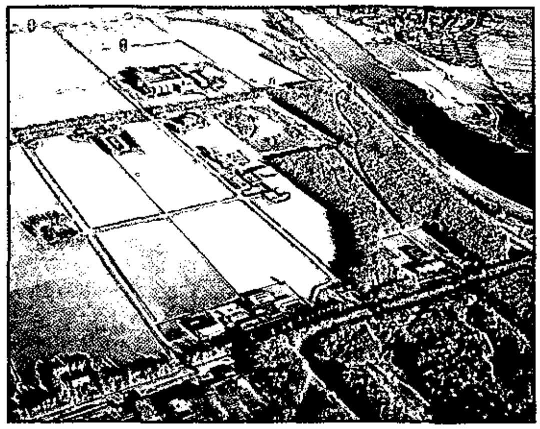

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