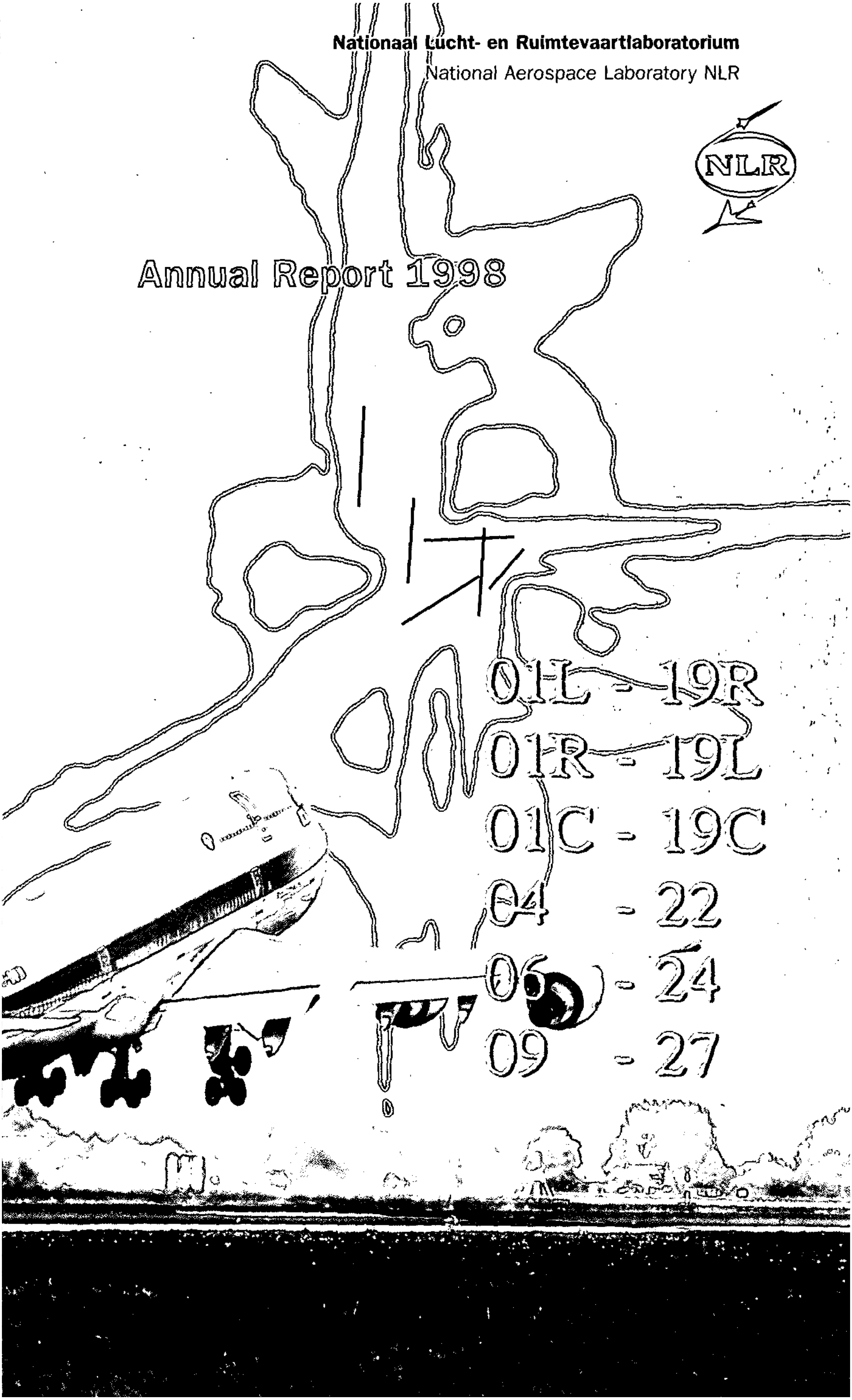
Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 1998



Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Anthony Fokkerweg 2
1059 CM Amsterdam
P.O. Box 90502
1006 BM Amsterdam
The Netherlands
Telephone +31 20 5113113
Fax +31 20 5113210
Web site: http://www.nlr.nl

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National Aerospace Laboratory NLR

Annual Report 1998

Board of the Foundation NLR*

	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)
Cdre.ir. D. van Dord	Minister of Defence
Gen.maj. ir. M.R.H. Wagevoort	Minister of Defence, for the Royal Netherlands Air Force (RNLAF)
Mr.drs. A.A.H. Teunissen	Minister of Economic Affairs
Dr. P.A.J. Tindemans	Minister of Education, Culture and Science
Ir. H.N. Wolleswinkel *(acting)*	Netherlands Agency for Aerospace Programmes (NIVR)
G.H. Kroese	Air Traffic Control the Netherlands (LVNL)
Prof.dr.ir. A.W. Veenman	Stork N.V.
Ir. C.J.M. Gresnigt	KLM Royal Dutch Airlines
Ir. R. Uijlenhoet	Amsterdam Airport Schiphol
Ir. E.I.L.D.G. Margherita	Netherlands Organization for Applied Scientific Research (TNO)
Prof.dr.ir. Th. de Jong	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

Chairman of the Scientific Committee NLR/NIVR*

Prof.dr.ir. P.J. Zandbergen

Board of Directors of NLR*

Dr.ir. B.M. Spee	General Director
Ir. F.J. Abbink	Technical Director
Drs. L.W. Esselman R.A.	Financial Director

* On 31 December 1998

Table of Contents

1 Introduction

The National Aerospace Laboratory NLR may look back on a successful year of operation. The income from contracts in1998 showed an all time high result despite the demise of Fokker Aircraft in 1996 and corresponding changes in the organization of NLR.

An important event took place on 15 January 1998, when the Netherlands' Government presented to the Parliament a paper on the 'Position of the Government regarding the Restructuring and Revitalisation of the Dutch Aviation Sector' outlining the strategy to support the industry to become a participant in Airbus programmes such as A3XX and to qualify for participation in the development of a possible successor to the Lockheed Martin F-16 of the Royal Netherlands Air Force.

The Government recognized and underlined the importance of the knowledge infrastructure of the Netherlands, in particular of NLR as the national aerospace research institute giving indispensable technological support to government agencies, industry and users. As a consequence the government decided to continue to fund NLR, to conduct research on aircraft use, safety and the environment, and to provide optimum support for the industry and the Ministry of Defence in participation in international aircraft programmes such as mentioned above.

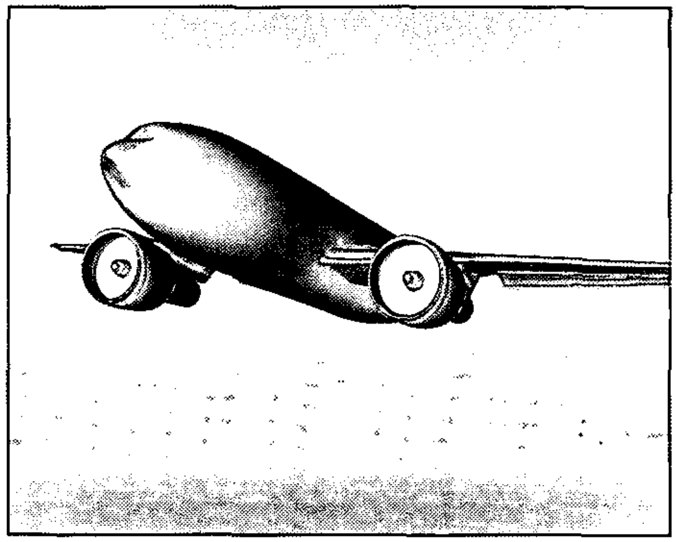
At national level the Government has incited several industrial activities, in which NLR plays a major role, to demonstrate the capabilities of the Dutch industry. The activities related to the F-16 replacement are co-ordinated by the Netherlands Industrial Fighter Aircraft Replacement Platform (NIFARP) and look rather promising. The activities related to civil aircraft were somewhat delayed (due to the repeated postponement of the formation of a Single Corporate Entity in Airbus Industries for the production of the A3XX) although discussions with DaimlerChrysler Aerospace Airbus (DCAA) about the future use of new materials such as GLARE are continuing.

The issue of the potential growth of Amsterdam Airport Schiphol formed an important element in the political discussions during the formation of the new cabinet in 1998 and successively in parliament. In close co-operation with other institutes in the Netherlands, i.e. *Rijksinstituut voor Volksgezondheid en Milieu* (RIVM) and *Centraal Plan Bureau* (CPB), NLR contributed with supporting studies to demonstrate the trade-offs in capacity, safety, noise and emissions of various runway configurations. The discussions led to the government decision to allow a significant increase in airport capacity within strict environmental and safety limits. This is expected to generate even more work for the development and implementation of advanced technical Air Traffic Management (ATM) procedures in the near future, in close co-operation with the *Rijksluchtvaartdienst* (RLD), *Luchtverkeersleiding Nederland* (LVNL), Amsterdam Airport Schiphol (AAS) and Royal Dutch Airlines (KLM).

Against this background NLR compiled the *'Strategieplan NLR 1998 – 2002'* which outlines the main directions in knowledge and facility development for the various disciplines necessary to qualify for future product/market combinations in the next five years. As a result of the reorientation process, which put more emphasis on operational aspects of civil and military aircraft, two new divisions were formed to replace the former Flight Division, i.e. the Air Transport Division and the Flight Division from 1999. The Air Transport Division deals with such issues as ATC/ATM, safety, noise and pollution, and airport operations. The Flight Division is concerned with all aspects of aircraft operations, human factors and flight simulation. Signs of change in disciplines are also reflected in renaming the former Informatics Division in Information and Communication Technology Division and the former Electronics and Instrumentation Division in Avionics Division.

In the international context NLR has strongly proceeded with technology studies in the framework of the European Union (EU), the European Space Agency (ESA), Eurocontrol and the Western European Armament Organization (WEAO). The launch of the EU Fifth Framework Programme will form a strong incentive for NLR to continue with this approach. Participation in international programmes of this kind is crucial for the development of technology for future aircraft and aircraft operations.

Emphasis on international co-operation is also reflected by NLR's continuing support to research activities within the Group for Aeronautical Research and Technology in Europe (GARTEUR) and the Association of European Research Establishments in Aeronautics (AEREA). In particular the co-operation with the Deutsches Zentrum für Luft- und Raumfahrt (DLR) was intensified by exploring the possibility for further integration of ATM research and of workshop activities. Beside the successful joint operation of the German Dutch Wind Tunnel (DNW), NLR also supports the operation of the four-nation (France, Germany, the Netherlands and the United Kingdom) European Transonic Windtunnel (ETW).



Results of computation by FASTFLO (Fully Automatic System for 3-D Flow Simulations) for aircraft with Ultra-High Bypass Ratio engines

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 and consultancy 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 funded by the Netherlands government.

With sites in Amsterdam and in the Noordoostpolder, NLR owns wind tunnels, laboratory aircraft, research flight simulators and an Air Traffic Control research simulator. 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 structures and materials, space technology, remote sensing and environmental testing. NLR's extensive computer network includes a 32-GFlops NEC SX-4 supercomputer, tools for software development and advanced software for computational fluid dynamics and for calculations of aircraft and spacecraft structures. In 1999, the NEC SX-4 will be replaced by an NEC SX-5 with eight processors, 64 GB main memory and 55 GB disk space.

NLR co-operates on an equal base with the DLR (*Deutsches Zentrum für Luft- und Raumfahrt*) in the German-Dutch Wind Tunnel (DNW), which operates the Large Low-speed Facility in the Noordoostpolder. In addition to this LLF, the Foundation DNW operates the aeronautical wind tunnels of DLR and NLR. Together with DLR, the Ministry of Defence of the United Kingdom and the *Office National d'Etudes et de Recherches Aérospatiales* (ONERA) of France, NLR also takes part in the European Transonic Windtunnel (ETW) in Cologne.

2.2 Activities in 1998

In 1998 NLR's turnover was 154 million guilders compared to 143 million in 1997. The income from contracts was 114 million guilders, fifteen million higher than in 1997. In 1998 about 40% of the total of NLR's activities were related to the development and 60% 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 38% of the work under contract was carried out for foreign customers.

Services Provided under National Contracts

Activities under contract to Dutch customers amounted to 70 million guilders. These contracts included work for the Netherlands Agency for Aerospace Programmes (NIVR) under its programmes for aeronautics and space research and technology. 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 (LVNL), Fokker Aviation and Fokker Space. 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 Aerostructures concerned among other things 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 ATC systems and on safety and environmental aspects of aeronautics. Research on present and future ATC systems was also performed under contract to the LVNL, KLM Royal Dutch Airlines and Amsterdam Airport Schiphol.

Services Provided to International Customers

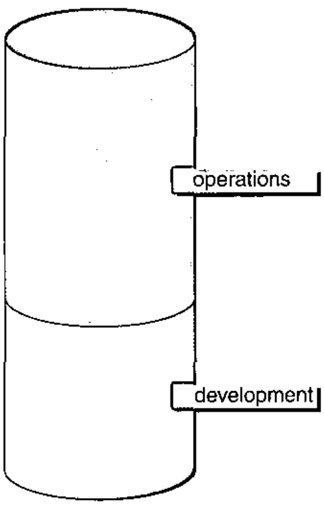
Research carried out under contract to international customers amounted to 44 million guilders. Major customers were the European Space Agency, the European Union and Eurocontrol.

Research and Equipment

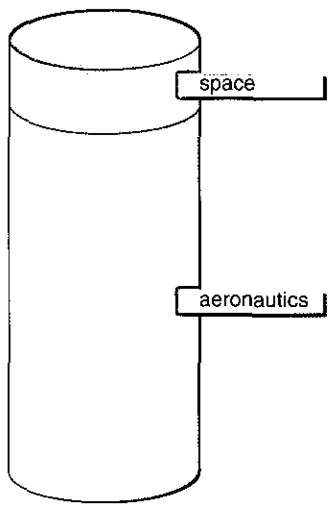
NLR spent 28 million guilders on its basic aerospace research programme supported by the government, aimed at preserving NLR's capability to support its customers in the future. Research aimed at the development and modernization of NLR's research facilities amounted to 12 million guilders. A total of 16 million guilders was used for capital investments, of which the procurement of a new cockpit for the Research Flight Simulator, the purchase of central computing facilities and investments in new systems for the DNW were the most important ones.

National and International Co-operation

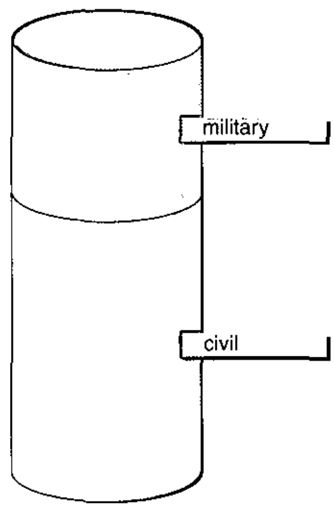
A large part of NLR's basic research is carried out as NLR's own contributions to European research projects both on the civil (European Union, Eurocontrol) and military (European Co-operation



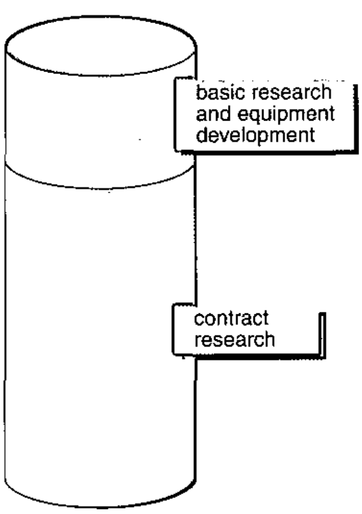
Division of the work into development and operations support



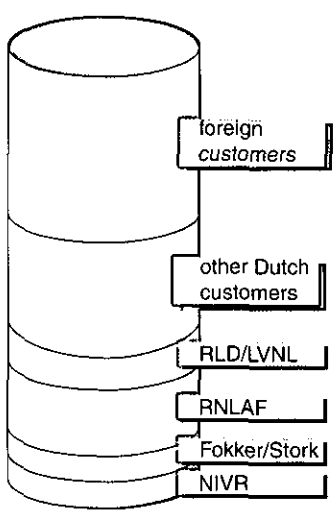
Division of the work into aeronautics and spaceflight support



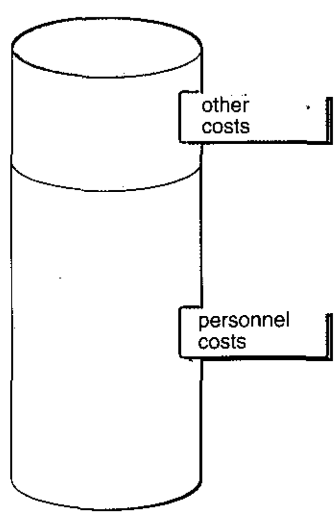
Division of the work into civil and military support



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

for the Long Term in Defence, West European Armament Organization) sides. Another significant part 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, Spain and Sweden take part.

NLR and the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) jointly govern the German-Dutch Wind Tunnel (DNW), which operates the Large Low-speed Facility in the Noordoostpolder. Since 1995 the 3-m low speed wind tunnels of DLR and NLR, located in Braunschweig and in the Noordoostpolder, respectively, are incorporated in the foundation DNW. In 1997 the transonic aeronautical wind tunnels of DLR and NLR were included in the series operated by the Foundation DNW.

Although the European Transonic Windtunnel (ETW) located near Cologne, Germany, was fully operational and performed several tests for customers, the so-called initial operation period was extended until mid-1999.

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 (AEREA). 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-operated with research institutes and universities of the Netherlands. NLR and the Delft University of Technology (DUT) jointly operate a Cessna Citation II, which is used as a research aircraft. One member of NLR's staff was a part-time professor at the DUT's faculty of Aerospace Technology. Another member was appointed professor at the Cranfield Institute of Technology.

Collaborative activities of the research institutes Aero-Gas Dynamics and Vibration Laboratory (LAGG) of Serpong and NLR, together with 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 (APERT). The co-operation is co-ordinated by NLR and by the Agency for the Assessment and Application of Technology of Indonesia.

Like in 1997, NLR was active in many Working Groups of the NATO Research and Technology Organization (RTO).

Co-operation with the US National Aeronautics and Space Administration (NASA) and Federal Aviation Administration (FAA) included research on air-ground integration for Air Traffic Control and external safety studies.

Quality Assurance

The ISO 9001/AQAP-110 quality assurance certificates of the Fluid Dynamics, Informatics and Space Divisions were extended. New certifications were obtained for the Structures and Materials Division, the Flight Division and the Electronics and Instrumentation Division. In addition, NLR holds several accreditations, for example for EMC (Electromagnetic Compatibility) testing and for the calibration of forces, pressures and electronic quantities.

Breakdown of the staff at the end of 1998

(Cat. I: university graduates, Cat. II: advanced technical college graduates, Cat. III: others; between brackets the numbers at the end of 1997)

		Cat. I		Cat. II		Cat. III		Total	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
- Support Staff		16	(16)	9	(7)	11	(11)	36	(34)
		19	(19)	9	(7)	11	(11)	39	(37)
Fluid Dynamics Division	A	4	(5)	2	(2)	2	(2)	8	(9)
- Transonic and Supersonic Wind Tunnels	AF	5	(4)	17	(17)	8	(8)	30	(29)
- Aeroacoustics	AK	8	(7)	4	(3)	1	(1)	13	(11)
- Theoretical Aerodynamics	AT	14	(15)	–	(–)	–	(–)	14	(15)
- Aerodynamic Engineering and Aeroelasticity	AE	11	(11)	3	(3)	–	(–)	14	(14)
- German-Dutch Wind Tunnel	AD	4	(4)	19	(17)	17	(19)	40	(40)
		46	(46)	45	(42)	28	(30)	119	(118)
Flight Division	V	2	(3)	1	(1)	1	(1)	4	(5)
- Flight Testing and Safety	VV	16	(15)	6	(6)	2	(1)	24	(22)
- Flight Simulation	VS	10	(12)	14	(15)	2	(1)	26	(28)
- Operations Research	VO	23	(23)	5	(5)	2	(2)	30	(30)
- Man Machine Integration	VE	23	(25)	1	(1)	2	(2)	26	(28)
- Helicopters	VH	14	(14)	1	(1)	1	(1)	16	(16)
- Airports	VA	11	(–)	1	(–)	–	(–)	12	(–)
- Air Traffic Management	VL	27	(37)	5	(5)	–	(–)	32	(42)
- Flight Mechanics	VM	12	(10)	–	(–)	1	(1)	13	(11)
- Transport and Environmental Studies	VT	9	(6)	7	(5)	1	(–)	17	(11)
		147	(145)	41	(39)	12	(9)	200	(193)
Structures and Materials Division	S	1	(2)	1	(1)	–	(–)	2	(3)
- Loads and Fatigue	SB	15	(14)	8	(7)	1	(1)	24	(22)
- Structures Technology	SC	11	(9)	4	(4)	1	(1)	16	(14)
- Laboratory Facilities	SL	1	(–)	22	(22)	19	(18)	42	(40)
		28	(25)	35	(34)	21	(20)	84	(79)
Space Division	R	2	(2)	–	(–)	2	(2)	4	(4)
- Remote Sensing	RR	6	(7)	5	(5)	–	(–)	11	(12)
- Systems	RS	17	(15)	–	(–)	–	(–)	17	(15)
- Labatories and Thermal Control	RL	10	(9)	7	(8)	–	(–)	17	(17)
		35	(33)	12	(13)	2	(2)	49	(48)
Informatics Division	I	1	(1)	1	(1)	4	(4)	6	(6)
- Mathematical Models and Methods	IW	17	(17)	–	(–)	–	(–)	17	(17)
- Software Applications	IA	19	(19)	6	(7)	1	(1)	26	(27)
- Data and Knowledge Systems	ID	27	(22)	9	(11)	–	(–)	30	(33)
- Computing Services	IC	17	(16)	12	(13)	8	(8)	37	(37)
- Embedded Systems	IS	12	(12)	7	(9)	–	(–)	19	(21)
		87	(87)	35	(41)	13	(13)	135	(141)
Electronics and Instrumentation Division	E	2	(2)	–	(–)	–	(1)	2	(3)
- Avionics	EA	18	(16)	9	(7)	–	(–)	27	(23)
- Electronics	EE	6	(6)	19	(20)	4	(4)	29	(30)
- Instrumentation	EI	8	(8)	19	(17)	5	(6)	32	(31)
		34	(32)	47	(44)	9	(11)	90	(87)
Engineering and Technical Services	T	4	(4)	–	(–)	1	(1)	5	(5)
- Technical Projects	TP	2	(2)	3	(4)	1	(1)	6	(7)
- Technical Design	TO	1	(1)	6	(8)	1	(1)	8	(10)
- Production Workshop	TW	–	(–)	7	(6)	11	(11)	18	(17)
- Production Control	TV	–	(–)	5	(5)	1	(1)	6	(6)
- Service Workshop	TS	–	(–)	3	(3)	5	(4)	8	(7)
		7	(7)	24	(26)	20	(19)	51	(52)
General Services	G	1	(1)	1	(2)	–	(–)	2	(3)
- Buildings	GG	–	(–)	–	(2)	–	(1)	–	(3)
- Electrical Engineering	GE	–	(–)	6	(4)	5	(7)	11	(11)
- General Facilities	GF	–	(–)	2	(2)	35	(36)	37	(38)
- Library and Information Services	GB	1	(2)	3	(3)	5	(5)	9	(10)
- Document Processing	GT	–	(–)	4	(3)	29	(29)	33	(32)
		2	(3)	16	(16)	74	(78)	92	(97)
Administrative Services	O								
- Administration	OA	2	(1)	20	(20)	10	(13)	32	(34)
- Stores and Dispatch	OM	–	(–)	1	(1)	4	(4)	5	(5)
- Purchasing	OI	2	(1)	5	(4)	–	(–)	7	(5)
		4	(2)	26	(25)	14	(17)	44	(44)
Grand total		409	(399)	290	(287)	204	(210)	903	(896)

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.

Mr. G.H. Kroese was appointed by Air Traffic Control the Netherlands as a member of the Board of the Foundation NLR. Mr. Kroese succeeded Mr. A. van Bochove. The Delft University of Technology's Faculty of Aerospace Engineering appointed Prof.dr.ir. Th. de Jong, who succeeded Prof.dr.ir. J.L. van Ingen.

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

As of 1 January 1998, Ir. F. Holwerda was appointed as head of the Structures and Materials Division. Mr. Holwerda succeeded Dr.ir. G. Bartelds, who retired.
As of 1 January 1998, a new department, the Airports Department, was created in the Flight Division. Ir. H.A.J.M. Offerman was appointed head of the Airports Department.
As of 1 May 1998, Mr. G.S. Wijdeveld was appointed head of the Purchasing Department, succeeding Mr. J.F. Post.
Ing. J. Sterk, head Support Staff, retired and was succeeded by Ir. J.C.A. van Ditshuizen, appointed head Marketing and Communication as of 1 May 1998.
As of 1 August 1998, Mr. R. Raterink was appointed head of the General Facilities Department in NLR Noordoostpolder. This department resulted from the merger of the previous Buildings, Domestic Services and Guarding, and Stores and Dispatch Departments.
Ir. L. Sombroek, Co-ordinator AGARD/RTO and Co-ordinator of activities concerning Indonesia, retired as of 31 December 1998.

On 31 December 1998 the Heads of Divisions and Services were:
Prof.ir. J.W. Slooff
Fluid Dynamics Division
Ir. J.T.M. van Doorn
Flight Division
Ir. F. Holwerda
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. J. van Twisk
Engineering and Technical Services
Ir. W.F. Wessels
General Services
Drs. L.W. Esselman R.A
Administrative Services

The senior staff further included E. Folkers, *Secretary* and Ir. J.C.A. van Ditshuizen, *Head Marketing and Communication*.

At the end of 1998 NLR employed a staff of 903 (compared with 896 at the end of 1997), of whom 409 (399) were university graduates. Of the total, 777 (773) were employed on a permanent basis, and 126 (123) had temporary appointments. About 60 per cent of the staff were posted in Amsterdam, 40 per cent in the Noordoostpolder. A breakdown of the staff is given on page 12.

Effective from 1 January 1999, the Flight Division has been split into an Air Transport Division, headed by Ir. J. Brüggen, and a new Flight Division, headed by Prof.drs. P.G.A.M. Jorna. E. Folkers was appointed General Secretary and was succeeded by Ms. I.P.G. Ahlers as head of the Legal Department. The name of the Informatics Division was changed into Information and Communication Technology Division; that of the Electronics and Instrumentation Division into Avionics Division, also as of 1 January 1999.

The organization of the laboratory on 31 December 1998 is shown on page 14, the organization on 1 January 1999 on page 15.

Organization Diagram

31 December 1998

Technical Director
Ir. F.J. Abbink DT

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

al Director
. Esselman R.A. DF

Associate Director	Drs. A. de Graaff	DO
Marketing and Communication	Ir. J.C.A. van Ditshuizen	DM
- *Public Relations*	Ms. J.F. van Esch	DPR
- *Publications*	Dr. B.J. Meijer	DPI
Co-ordinators:		
- *Defence Projects*	Ir. A. Gebhard	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		DJ
- *Legal*	*DJ*	
- *Filing*	*DB*	
- *Security*	*DB*	
Personnel	ɪn	DZ
Co-ord. RTO/Indonesia		DA
Company Welfare Work		

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

- **Transonic and Supersonic Wind Tunnels** — Ir. W.M. van der Poel **AF**
- **Aerodynamic Engineering and Aeroelasticity** — Ir. R. Houwink **AE**
- **Theoretical Aerodynamics** — Dr. B. Oskam **AT**
- **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**
- **Airports** — Ir. H.A.J.M. Offerman **VA**
- **Air Traffic Management** — Ir. J. Brüggen **VL**
- **Man Machine Integration** — Drs. P.G.A.M. Jorna **VE**
- **Transport and Environmental Studies** — Ir. G. Bekebrede **VT**

Structures and Materials
Ir. F. Holwerda **S**

- **Loads and Fatigue** — Ir. H.H. Ottens **SB**
- **Structures Technology** — Dr.ir. J.F.M. Wiggenraad **SC**
- **Laboratory 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. M.P.A.M. Brouwer **RL**

Informatics
Ir. W. Loeve **I**

- **Mathematical Models and Methods** — Dr. R.J.P. Groothuizen **IW**
- **Software Applications** — Ir. F.J. Heerema **IA**
- **Data and Knowledge Systems** — Ir. J.C. Donker **ID**
- **Computing Services** — Ir. U. Posthuma de Boer **IC**
- **Embedded Systems** — Drs. E. Kesseler **IS**

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**

Enginee Technic
Ir. J. van

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- **Producti** — Ing. W.A.
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- **Service** — F. Hofma

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- **cument Processing** — . D.J. Rozema **GT**

Administrative Services
Drs. L.W. Esselman R.A. **O**

- **Administration** — Drs. B.P.E. Haeck **OA**
- **Stores and Dispatch** — Drs. B.P.E. Haeck **OM**
- **Purchasing** — G.S. Wijdeveld **OI**

Organization Diagram

1 Januari 1999

Technical Director
Ir. F.J. Abbink **DT**

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

Financial Director
Drs. L.W. Esselman R.A.

eral Secretary
lkers **DA**

Associate Director	Drs. A. de Graaff	**DO**
Marketing and Communication	Ir. J.C.A. van Ditshuizen	**DM**
- *Public Relations*	Ms. J.F. van Esch	DPR
- *Publications*	Dr. B.J. Meijer	DPI
Co-ordinators:		
- *Defence Projects*	Ir. A. Gebhard	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

Legal	Ms. I.P.G. Ahlers
Personnel	Ms. W.J. van Druten
Company Welfare Work	Ms. D.L. Blazer Ms. C. Diekema

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

- **Transonic and Supersonic Wind Tunnels** — Ir. W.M. van der Poel **AF**
- **Aerodynamic Engineering and Aeroelasticity** — Ir. R. Houwink **AE**
- **Theoretical Aerodynamics** — Dr. B. Oskam **AT**
- **Aeroacoustics** — Dr. H.H. Brouwer **AK**

Flight
Drs. P.G.A.M. Jorna **V**

- **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**
- **Man Machine Integration** — Drs. P.G.A.M. Jorna *a.i.* **VE**

Air Transport
Ir. J. Brüggen **L**

- **Flight Testing and Safety** — Ing. M.A. Piers **LV**
- **Airports** — Ir. H.A.J.M. Offerman **LA**
- **Air Traffic Management** — Ir. J.C. Terlouw **LL**
- **Transport and Environmental Studies** — Ir. G. Bekebrede **LT**

Structures and Materials
Ir. F. Holwerda **S**

- **Loads and Fatigue** — Ir. H.H. Ottens **SB**
- **Structures Technology** — Dr.ir. J.F.M. Wiggenraad **SC**
- **Laboratory 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. M.P.A.M. Brouwer **RL**

Information and Communication Technology
Ir. W. Loeve **I**

- **Mathematical Models and Methods** — Dr. R.J.P. Groothuizen **IW**
- **Software Applications** — Ir. F.J. Heerema **IA**
- **Data and Knowledge Systems** — Ir. J.C. Donker **ID**
- **Information and Communication Services** — Ir. U. Posthuma de Boer **IC**
- **Embedded Systems** — Drs. E. Kesseler **IS**

Avionics
Ir. H.A.T. Timmers

- **Avionics Systems** — Ir. M.A.G. Peters
- **Electronics** — Ing. H. Slot
- **Instrumentation** — Ir. R. Krijn

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

- **Electrical Engineering** — A.M.G. Reijntjens **GE**
- **General Facilities** — R. Raterink **GF**
- **Library and Information Services** — Ir. W.F. Wessels **GB**
- **Document Processing** — Ing. D.J. Rozema **GT**

Administrative Services
Drs. L.W. Esselman R.A. **O**

- **Administration** — Drs. B.P.E. Haeck **OA**
- **Purchasing** — G.S. Wijdeveld **OI**

3 Research Activities

The research activities of NLR have been carried out by its six divisions (Fluid Dynamics, Flight, Structures and Materials, Space, Informatics, Electronics and Instrumentation) and three service groups. This Chapter, Research Activities, is subdivided along the areas of technology of these divisions and the Engineering and Technical Services. In many of the research and development projects NLR carries out, specialists of several divisions co-operate in multi-disciplinary project groups. Projects are described in the section dedicated to the technology discipline of the division responsible for project management. Inevitably, aspects of related activities in different projects may be described in different sections of this Chapter.

3.1 Fluid Dynamics

Summary

Following the restructuring of the Fluid Dynamics Division in 1996-1997, after the termination of transport aircraft development in the Netherlands, the year 1998 can be considered as a period of consolidation and reactivation. Particularly characteristic for 1998 were:

- Participation in a large number of projects of the Fourth Framework Programme of the European Union
- A quite satisfactory occupation level, after a major modernization in 1996/1997, of the transonic wind tunnel HST (since mid-1997 under operational management of the German-Dutch Wind Tunnel organization (DNW) and named DNW-HST), together with a high occupation of the joint NLR/DLR Large Low Speed Facility (DNW-LLF)
- A significant and successful contribution to the aerothermodynamic design, by a Dutch industrial team, of the rudders of the NASA/ESA X-38 experimental space crew return vehicle

NLR contributed to as many as seventeen aerodynamic and aeroacoustic projects of the Fourth Framework Programme of the European Union (EU). Most of these projects concern research in the areas of air vehicle configuration aerodynamics (supersonic transport, wing-in-ground effect vehicles), propulsion-related aerodynamics, wake vortex aerodynamics, helicopter aerodynamics, Computational Fluid Dynamics (CFD) and aeroacoustics.

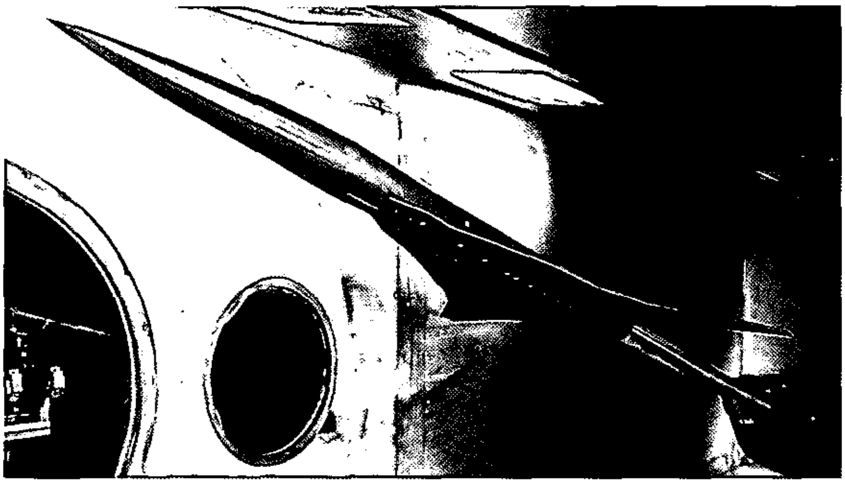
In the area of fluid dynamics NLR also contributed to six Action Groups and four Exploratory Groups of the Group for Aeronautical Research and Technology in Europe (GARTEUR), in addition to activities initiated by the Association of European Research Establishments in Aeronautics (AEREA) and collaborative programmes of the Western European Armament Organization (WEAO). These activities were in the areas of CFD code application, comparison and experimental validation, and wind tunnel testing and measurement techniques.

The bilateral collaboration with the Deutsches Zentrum für Luft- und Raumfahrt (DLR) in the areas of CFD code development and propulsion/airframe integration aerodynamics was continued.

Following the operational integration of NLR's wind tunnels DNW-HST and DNW-SST and model engine calibration facility (ECF) into the DNW organization in 1997, the existing collaborations in and tuning of activities related to wind tunnel operations and development of aerodynamic and aeroacoustic measurement techniques and instrumentation with DLR and the DNW organization were intensified.

In the framework of the collaborative Aerospace Programme for Education, Research and Technology (APERT), funded by the Royal Netherlands Academy of Sciences (KNAW), joint research with the Indonesian aircraft industry IPTN and the Institute of Technology of Bandung (ITB) was executed in the areas of high-lift systems aerodynamics and wing design for improved buffet onset.

Research was also carried out in such areas as high-lift system configuration aerodynamics and aeroacoustics, computational aeroelastics, CFD for high-lift systems, and improvement and extension of CFD methods, all partly funded by the Netherlands Agency for Aerospace Programmes (NIVR). Scale effects in the wind tunnel simulation of airport wind climates were studied, as was road tunnel ventilation aerodynamics, under contract to the Ministry of Transport. Radar cross-section prediction techniques were investigated, partly funded by the Ministry of Defence.



Model of supersonic transport aircraft, Eurosup, in the High Speed Tunnel (DNW-HST) at NLR Amsterdam

A senior aerodynamicist was stationed with the Large Aircraft Division of Airbus in Toulouse to support Fokker Aerostructures in preparing for participation in the envisaged A3XX aircraft programme.

Applied Aerodynamics

As a consequence of the demise of Fokker Aircraft in 1996, the emphasis in applied aerodynamics research continued being transferred from research supporting aerodynamic design to research supporting aircraft operations and structural design.

Aerodynamics of Civil Transport Aircraft

NLR co-ordinates the BRITE/EURAM project AIRDATA (Aircraft Drag and Thrust Analysis). This project is targeted towards improving the aerodynamic design methodology for future aircraft satisfying requirements of high aerodynamic efficiency and low fuel consumption. Four technical sub-objectives are addressed: (i) improvement of flow modelling for thrust/drag analysis, including CFD validation, (ii) demonstration of CFD grid optimisation, adaptation, and extrapolation for engine/airframe integration, (iii) development of drag breakdown diagnostics capabilities to achieve the higher level of technology demanded for future aircraft, and (iv) new knowledge on thrust, drag, and drag breakdown. In this project, use is made of data obtained in another BRITE/EURAM project (ENIFAIR, Engine Integration for Future Aircraft) for a generic aircraft configuration at various power settings, engine positions, and Mach numbers.

NLR participates in the BRITE/EURAM project EUROSUP (Reduction of Wave and Lift-Dependent Drag of Supersonic Transport Aircraft) of the EU. This project addresses the multipoint aerodynamic design and optimization of supersonic transport aircraft. The manufacturing of the EUROSUP model was completed. A multipoint design and optimization process was carried out by the *Office National d'Etudes et de Recherches Aérospatiales* (ONERA), British Aerospace and the Defence Evaluation and Research Agency (DERA). On the basis of the resulting design, three different wing shapes have been defined for supersonic and transonic cruise and a low speed take-off condition. To validate the design, a wind tunnel model with three different wings has been manufactured by NLR and tested in the transonic DNW-HST and supersonic DNW-SST wind tunnels. For transonic flow conditions, the results were compared with CFD calculations made by NLR with the Navier-Stokes ENSOLV code. Almost perfect agreement was established. For other flow conditions, good agreement with computational results provided by other partners in the programme was obtained. The EUROSUP programme has proven that CFD design and analysis methods are suitable for application to such a complex multipoint design problem, although the methods still have to be refined for low-speed flow conditions.

Participation in the GARTEUR Action Group (AD) AG-26 'Navier-Stokes Computations of Transonic Flows About Wing-Bodies with High-Aspect Wings' was continued. NLR contributed to the definition of a proposed computational grid with 2.5 million points for the AS28G wing/body configuration.

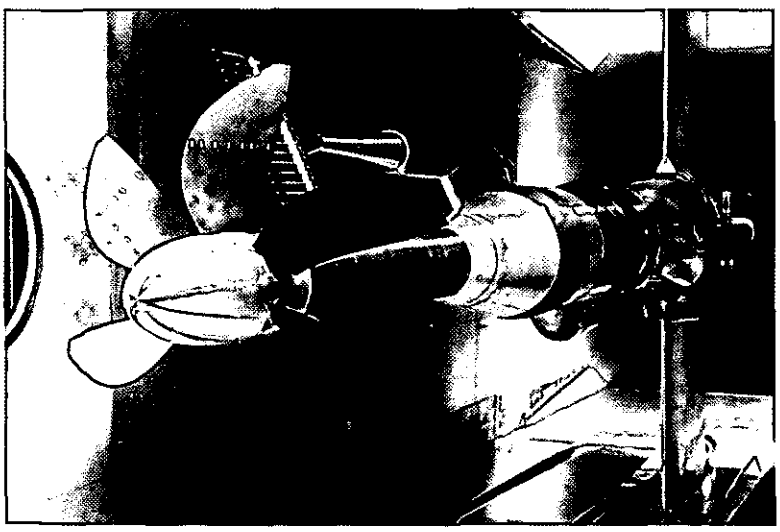
GARTEUR (AD) AG-25 'Two-Dimensional High-Lift Navier-Stokes Computations' also continued its activities. NLR contributed to the final report on task 2 and task 3 activities concerning the computational analysis of maximum lift phenomena for airfoils with slat and flap extended.

Within the scope of the collaborative Aerospace Programme for Education, Research and Technology (APERT) between the Netherlands and Indonesia, two joint research projects were continued. One project concerns transonic transport wing design for improved buffet-onset lift and the other high-lift aerodynamics of 2-D multielement airfoils. Within the framework of these projects, specialists of IPTN and ITB have visited NLR to reassess the relevance of their objectives in the light of the recent economic crisis and its effects on the aerospace activities in Indonesia. It was concluded that the two joint projects were still meaningful for both the Indonesian partners and NLR, and work on the projects was continued.

A theoretical study has been made of the effect of 'flap tip devices' on the low-speed aerodynamic and airframe noise characteristics of civil transport aircraft. The study was driven by the perception that winglet-type devices applied at the tips of trailing edge flaps might reduce airframe noise and improve the lift/drag ratio in landing and take-off configurations of possibly large aircraft. Numerical flow simulations for an Airbus A3XX-like configuration, based on the Euler equations using the FASTFLO code, confirmed a potential for induced drag reduction. The results were not fully conclusive, partly because viscous effects were not modelled. Wind tunnel tests are therefore envisaged, also to establish the effects on airframe noise and wake vortex signature. This investigation was executed in collaboration with Deutsche Airbus and partly funded by NIVR.

Propulsion-Airframe Interaction

NLR participates in the BRITE/EURAM programme APIAN (Advanced Propulsion Integration Aerodynamics and Noise). This programme is aimed at investigating the aerodynamic and aeroacoustic properties of advanced propeller propulsion. The APIAN propeller was tested in the transonic wind tunnel DNW-HST in the 'isolated' configuration. The tests comprised performance measurements with a rotating balance, pressure measurements on the blades, determination of the propeller slipstream, blade deformation measurements under load and acoustic measurements. Reynolds number or scale effects were of particular interest and most of the tests have therefore been done at three different tunnel pressures. The analysis so far indicates weak though significant scale effects.

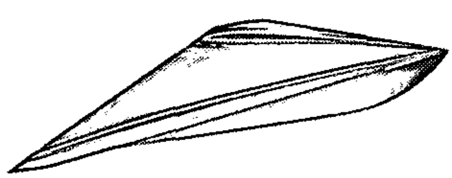


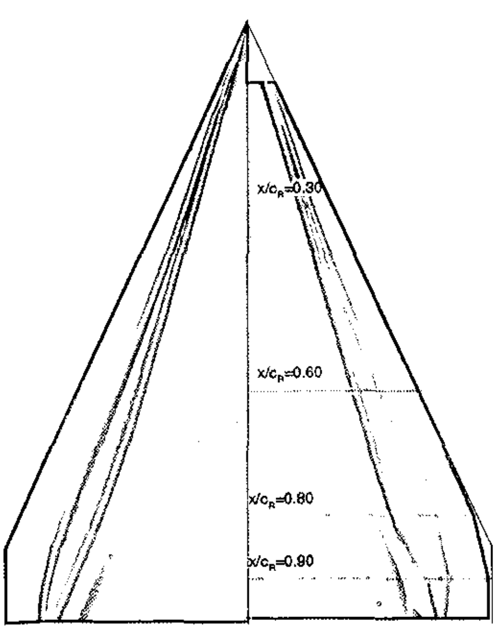
Test rig with propeller in the DNW-HST for performance and noise tests in the European project Advanced Propulsion Integration Aerodynamics and Noise (APIAN)

NLR also participated in the BRITE/EURAM project ENIFAIR (Engine Integration for Future Aircraft) which was nearing completion by the end of the year. The ENFLOW CFD system was applied to three configurations of the 'ALVAST' wind tunnel model: a clean wing/body configuration, a configuration with conventional turbofan engines and a configuration with Ultra-High By-pass Ratio (UHBR) engines. Improved CFD results, based on the Reynolds-Averaged Navier-Stokes (RANS) equations and two-equation turbulence modelling, were obtained. Experimental data for these configurations at transonic speed have been obtained in the S1 wind tunnel of ONERA.

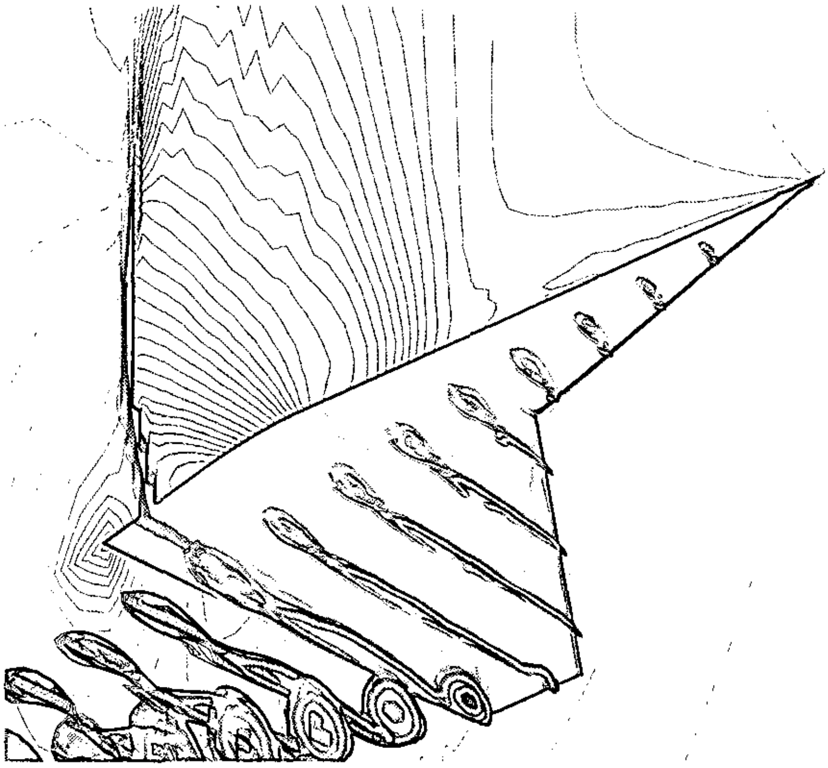
DLR and NLR co-operated in the field of turbofan propulsion-airframe interaction at low-speed flow conditions. The analysis of previously made tests in the DNW-LST and DNW-NWB wind tunnels on the 'ALVAST' model was continued. Most of the effort, however, was devoted to support in wind tunnel tests and to the analysis of results of the ALVAST complete configuration in the DNW-LLF.
Support was also provided in measurements on powered models of the Fairchild-Dornier 728 aircraft project in the DNW-NWB and the DNW-HST; both in the form of model engine (TPS) calibrations in the Engine Calibration Facility (ECF) and in the form of on-site test support in the HST. Calibrations of TPSs in the ECF were also executed for a number of tests in the DNW-LLF.

Aerodynamics of Air Combat Vehicles
CFD Technology Development for fighter aircraft applications was continued as part of the (WEAO) TA-15 programme 'Computational Methods in Aerodynamics'. Three types of activities were executed:





Computed surface pressure based on Navier-Stokes equations and two-equations turbulence model (above and left), and comparison with surface pressure measurements with pressure taps (right)



Unsteady transonic CFD result for wing with simple strake; static pressure in symmetry plane and on wing surface; strake vortex and wing tip vortex signatures in cross planes

- Computations of vortex flows about a delta wing with a rounded leading edge and a leading edge sweep of 65 degrees have been carried out to study the effect of high Reynolds numbers on turbulent boundary layer separation and vortex formation. The CFD results are being compared with experimental data for a wind tunnel model tested in the NTF wind tunnel of the US NASA, at a Reynolds number of 60 million (based on the mean aerodynamic wing chord) and a Mach number of 0.85.
- Time-accurate inviscid-flow computations for unsteady, transonic vortex flows about sharp-edged delta-wings at high angle of attack and in rolling motion were made. The first results illustrate the time-dependent behaviour of the 'vortex burst' phenomenon that is characteristic for delta wings at high angle of attack.
- A second wind tunnel entry was made in the transonic DNW-HST with the IEPG delta wing configuration. The purpose of these tests was to obtain detailed flow field information using 'Particle Image Velocimetry' (PIV). It was one of the first applications of this relatively new measuring technique in industrial wind tunnels such as the HST. The measurements concentrated on the visualization of the 'vortex burst' phenomenon, which marks a quite distinct change in the structure of the leading edge vortex above the delta wing with increasing incidence or side slip. The tests at a Mach number of 0.5 were very successful and clearly indicated vortex burst and a wave-like structure near the vortex core before vortex burst occurred. Improvements required to enhance the PIV-technique at the higher Mach number of 0.85 were identified and are being implemented.
- At DLR preparations were made for dynamic measurements on a rolling delta wing in the DNW-TWG transonic wind tunnel.

Helicopter Aerodynamics

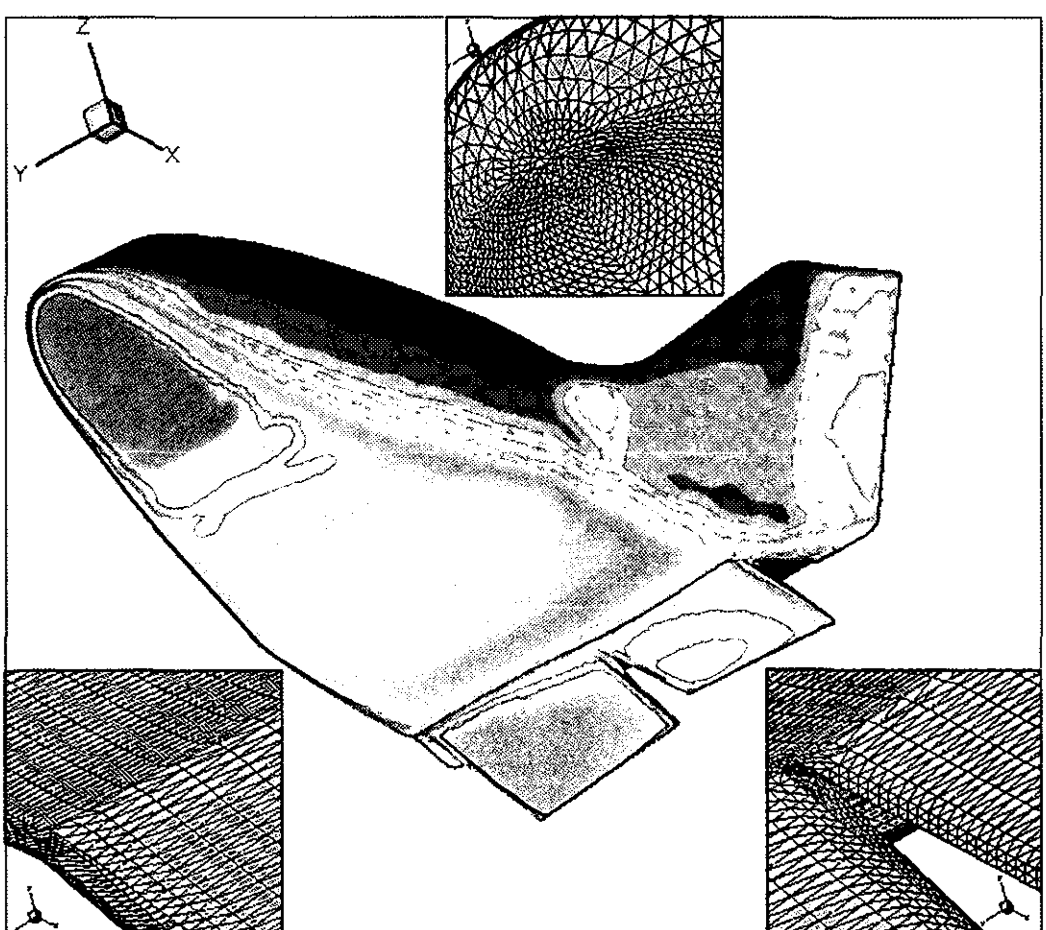
NLR participates in the EU's Fourth Framework projects EROS and ROSAA, the objective of which is to develop common European computer codes for helicopter rotor aerodynamics. In the EROS project NLR co-ordinated the grid generation effort for a method based on the Euler equations. In the ROSAA project the HELIFP method, which is based on a full potential flow model and was developed in a preceding EU project, was improved in computational efficiency and was coupled with a boundary layer method. Also, a start was made with the preparation of an interface between HELIFP and other helicopter codes used by NLR's Helicopter Department. The modelling of flexible rotor blades in the helicopter code HERO was completed.

Operations and Safety-related Aerodynamic Research

NLR co-ordinates the BRITE/EURAM programme 'WAVENC' for the identification and calculation of the effects of aircraft wake vortex encounters. In the DNW-LLF wind tunnel, tests have been executed in which a small model was positioned in the vortex wake of a simulated leading aircraft, and the aerodynamic response was measured. These results will be used to validate a theoretical method for the prediction of the response of aircraft to wake vortex encounters. Comparisons made by ONERA have indicated a very good correspondence.
NLR also participates in the BRITE/EURAM Thematic Network WAKENET on Wake Vortices. This network encompasses all disciplines relevant for wake vortex research, from basic physics to operational aspects.

Work on the modelling of the effect of water spray on a very wet runway on the lift and drag of an aircraft in the take-off run was continued as a contribution to the BRITE/EURAM project CONTAMRUNWAY (Operations on Contaminated Runways).

The wind climate, and the aircraft response to it, in the vicinity of civil airports and military airfields situated in locations with a high density of high-rise buildings represents an increasing



Navier-Stokes computation of the supersonic turbulent flow around an X-38 Crew Rescue Vehicle at a large angle of attack and asymmetric body flap deflection concern for airport and aircraft operators and for regulating authorities. Wind tunnel simulations of the phenomena involved require the representation of areas with sufficiently large horizontal dimensions and therefore model scales of the order of 1:1000 or even smaller, several times smaller than scales commonly used in wind tunnel tests of similar nature. An investigation has therefore been started into such questions as how to simulate the atmospheric boundary layer and how to measure, qualify and quantify the wake structure behind obstructing buildings on a 1:1000 model scale, using the DNW-LST wind tunnel.

Hypersonic and Space Vehicle Aerodynamics
NLR contributed to the European participation in the NASA X-38 Crew Rescue Vehicle demonstration programme. The activities were focused on the objective to produce, in the Netherlands, an advanced technology, full scale, hot metal rudder for the X-38. This objective was successfully pursued by a 'rudder team' consisting of Fokker Space, Stork Product Engineering, TNO Prins Maurits Laboratory, Delft University of Technology and NLR. NLR participated in the design team, as a sub-contractor of, and co-located at Fokker Space.
One of the roles of NLR was to provide data on the aerodynamic heating of the X-38 rudders during atmospheric re-entry. Hypersonic, supersonic and transonic CFD analyses of the X-38 rudders were provided to the rudder design team so that the team could pursue the advanced technology hot metal solution to the design problem.
Other contributions NLR made to the European participation in the programme consisted of wind tunnel tests in the DNW-HST and DNW-SST and complementary CFD analysis to complete the aerothermodynamic and aerodynamic database of the actual X-38/V210 flight vehicle. These activities, funded by the European Space Agency (ESA) and NIVR, were carried out in collaboration with Dassault Aviation.

The unsteady behaviour of the base flow of an Ariane launcher model tested earlier in one of NLR's wind tunnels has been analysed.

Non-Aerospace Aerodynamics
NLR contributed to the preliminary design of a Wing-In-Ground effect craft (SEABUS) in the framework of a BRITE/EURAM project on technology development for this type of vehicle. This research is co-ordinated by the Italian ship building firm Intermarine. The concept of the craft features aerodynamic lifting surfaces in combination with hydrodynamic control surfaces and a water jet propulsion system.
NLR develops a computational tool to investigate the static equilibrium of lift, drag and pitching moment on the complete configuration and will carry out wind tunnel tests in the DNW-LST. The computational results obtained so far indicate that at cruise speed the total drag of the proposed configuration is dominated by the hydrodynamic resistance of the submerged components, consisting of the control surfaces and the inlet to the water jet propulsion system.

NLR is increasingly involved in contract investigations of aerodynamic problems of rail and road traffic tunnels. Model experiments on scale 1:175 were executed to investigate the pressure waves generated by high-speed trains at the exit of train tunnels. A test set-up was designed, constructed, and partly commissioned, for scale model tests on road vehicle tunnel ventilation (jet fan) systems. The facility has a cross section of 0.5x1.2 m^2 and a length of 19 m, and enables flow velocities of up to 15 m/sec to be attained. A scale model jet fan to generate jet velocities up to 50 m/sec is also available.

In co-operation with the Netherlands Organization for Applied Scientific Research (TNO) and the city of Rotterdam, the vibration behaviour of the Erasmus bridge has been monitored and analysed. The results indicate that the rain/wind induced vibration problems that became apparent in 1997 have been cured by the installation of appropriate dampers in the suspension cables.

In collaboration with the Netherlands Energy Research Foundation (ECN) and the Delft University of Technology (DUT), an analysis was made of the mechanisms to be modelled in methods for the prediction of the characteristics and the design of stall-regulated horizontal axis wind turbines.

Basic Aerodynamic Research and Computational Fluid Dynamics

Reynolds-Averaged Navier-Stokes Methods

The development of the unstructured-grid Navier-Stokes solver FANS for multicomponent aerofoils was continued, partly under contract to NIVR. The underlying hybrid grid generation algorithm has been refined to make possible detailed resolution of viscous flow on small scales, for example near trailing edges. This CFD code has been applied to high-lift flows in the framework of the APERT Joint Research Programme with IPTN. One of the findings of this study into the physics of divergent trailing edge flow is its potential unsteadiness, similar to vortex shedding behind circular cylinders, but on a smaller scale. This observation has led to the insight that one needs to compute the unsteady flow if one wishes to capture all the flow physics, indicating the desirability to extend the FANS flow solver to time-accurate computations.

The three-dimensional equivalent of the FANS flow solver is FASTFLO (Fully Automatic System for 3-D Flow Simulations), which is being developed in the framework of the BRITE/EURAM project FASTFLO II. This project is the successor to the earlier BRITE/EURAM project FASTFLO I, which was based on an inviscid Euler flow model. The objective is to reduce the CFD problem-turnaround time by an order of magnitude in comparison with block-structured grid methods, for complex geometries. An example of a complex geometry in this respect is a civil transport aircraft with turbofan engines and slats and flaps in extended positions.
The FASTFLO system contains the following functionalities:

- geometry definition, including geometry repair to arrive at well-defined aerodynamic geometries;
- surface triangulation on the basis of user-specified surface resolution;
- 3D hybrid grid generation (prisms/tetrahedral);
- pre-processing to identify grid partitions for parallel computing, and flow computation;
- grid adaptation based on user specified sensors;
- aerodynamic post-processing to allow force and moment distributions to be analysed;
- visualization to explore three-dimensional flow fields to explain the aerodynamic forces and moments.

The starting point is the master geometry, which is represented either by multiblock-based curves and surfaces, or by so-called IGES 5.1 entities in standard Computer Aided Design (CAD) format. Initial experience with the FASTFLO system has shown that, in general, one needs to spend a substantial amount of time on the representation of geometries in the case of complex shapes. This time is spent using CAD systems such as CATIA or ICEM-CFD, which do not belong to the FASTFLO system proper. This aerodynamic geometry preparation time for complex three-dimensional models is similar in nature to CATIA geometry modelling for wind tunnel model manufacturing, but different in detailed objectives and results. Another observation is that the aerodynamic post-processing functionality needs to be extended.
A number of FASTFLO demonstration calculations on the level of the Reynolds-Averaged Navier-Stokes (RANS) equations have been initiated.

Work on the well-established ENFLOW system of computer codes, based on the concept of multiblock structured grids, was directed towards completing the improvement of the graphical user interface of ENGRID, the multiblock grid generation code of the ENFLOW system. Another improvement concerns turbulence modelling for applications to aircraft configurations with leading-edge vortex flow. The two-equation turbulence models included in the ENFLOW system were adapted for this purpose. The adaptation was made because the extension of the two-equation turbulence models, which are based on eddy-viscosity type linear relationships between turbulent stress and rate-of-strain tensor, fills a widespread need in CFD applications since the fundamental advantages of full-Reynolds-stress turbulence models cannot be harvested as yet. Further developments were deferred.

NLR participated in the BRITE/EURAM project AVTAC 97 (Advanced Viscous Flow Simulation Tools for Complete Civil Aircraft Design). One of the contributions of NLR is an initial RANS solution and the associated multiblock computational grid for the AS28G wing/body configuration, including underwing pylon-mounted through-flow nacelles.

NLR and DLR continued their collaboration in the area of CFD-tools for complete aircraft. One of the activities of NLR in this bilateral project concerns the demonstration of unstructured grid-based CFD simulations for a wing-body configuration with high-lift devices extended and Ultra-High By-pass Ratio (UHBR) engine simulators installed. For this complex configuration with its large variety of geometrical scales and multiple bodies, the unstructured-grid-based CFD technology did yield computational results in a short time compared with the time that would be needed for the multiblock grid approach. The computational results were compared with experimental results obtained in the DNW-LLF wind tunnel in previous years in the framework of the BRITE/EURAM Ducted Propfan Investigation (DUPRIN)-II.

Turbulence Modelling

The development and implementation of full-Reynolds-stress turbulence models for Reynolds-Averaged Navier-Stokes codes is dealt with in a collaborative effort. NLR has participated in an AEREA initiative to establish a Working Group on 'Transition and Turbulence Modelling' for collaboration on the development of advanced turbulence models, including explicit algebraic Reynolds-stress and full-Reynolds-stress transport models. NLR also participated in the establishment of the new GARTEUR Action Group (AD) AG-29 'Navier-Stokes Computations on the AG-07 Wing' for the evaluation of turbulence models on the basis of extensive Reynolds-stress data measured by GARTEUR (AD) AG-07 'Experimental Investigation of the Turbulent Shear Layers of a Swept Wing' in the DNW-LST and ONERA/CERT F2 low speed wind tunnels. The activities of (AD) AG-29 will be carried out at the level of the RANS equations, as a succession to the activities of GARTEUR (AD) AG-23 where the experimental data from (AD) AG-07 was employed to evaluate turbulence models when used at the level of three-dimensional boundary layer equations.

Euler Methods

The BRITE/EURAM project FASTFLO-I, co-ordinated by NLR, was finalised. The common product is an unstructured grid CFD code system based on the Euler equations. The FASTFLO development was continued at the level of the Reynolds-Averaged Navier-Stokes equations in a follow-up BRITE/EURAM project, FASTFLO-II, also co-ordinated by NLR.

The development of a time-accurate Euler solver HEXADAP, based on a discontinuous Galerkin finite-element method, was continued. The mathematical formulation of the flow solver algorithm was extended to a unified space-time discretization of the Euler equations to enable vortex wakes of helicopter rotors in forward flight to be modelled. Such a unified discretization allows dynamically deforming geometries such as helicopter rotors with individual blade movements representing pitch schedules, lead-lag motion and flapping motion to be treated. This work was partly funded by the Ministry of Defence.

The HEXADAP code was also applied to generic fighter aircraft configurations in pitching motion. Favourable comparisons with wind tunnel data at transonic speed (Mach = 0.90) confirmed the expectation that the ability of Euler equations to simulate vortex dynamics can be carried over to the transonic speed regime, as was concluded earlier from comparisons with experimental data at low speeds. The basic limitation, inherent to the Euler equations, is that adverse pressure gradients should remain weak enough to prevent three-dimensional turbulent boundary layer separation from occurring.

CFD Code Validation Experiments

Work in the GARTEUR Action Group AD (AG-28) 'Transonic Wing-Body Validation Experiment' included the definition of the test set-ups for wind tunnel measurements on a semi-span model of the AS-28 configuration in the S1 tunnel of ONERA and for a full-span model to be tested in the ETW and DNW-HST wind tunnels. The manufacturing of a cryogenic full-span model by DLR was started. The wind tunnel tests are being planned for 1999.

Scale Effects

NLR participates with AEREA partners CIRA, DERA, DLR, INTA and ONERA in a joint wind tunnel test in the European Transonic Wind Tunnel (ETW) to study the effects of Reynolds number variation on the aerodynamics of subsonic transport aircraft. The wind tunnel tests performed earlier in the ETW on the cryogenic F-4 model have been completed with a second, short test campaign. Analysis of the results indicates that a consistent set of data has been obtained. Reynolds number trends could be clearly identified and separated from the effects of wing deformation. Drag data indicated the existence of natural laminar flow at Reynolds numbers well beyond 10 million based on wing chord, an indication supported by boundary layer transition measurements by means of the infra-red camera technique. The evaluation of wall interference effects (expected to be very small) is in progress.

Aeroelasticity

The computational aeroelastic simulation system AESIM-BASIC has been completed with a user manual and manuals for the geometry and grid preprocessors, FOLDIT and BLOWUP. This system has been made to predict flutter, loads and other aeroelastic phenomena by time-accurate simulation of the interaction between the aircraft structure and the unsteady, full-potential, flow. It makes possible time-accurate prediction of unsteady airloads, aeroelastic stability and gust loads for aircraft configurations that can be modelled on a mono-block computational grid. As a response to interest in leasing the current version of the system, expressed by a customer, the applicability of the code for loads prediction has been demonstrated for a requested representative test case.

Support has been given to Fokker Services, to the Royal Netherlands Air Force and the Royal Netherlands Navy in solving operational problems with aeroelastic and vibration aspects.

Potential limit cycle oscillation problems of fighter aircraft were analysed using a semi-empirical method.

NLR also participated in the preparation of joint European activities in the area of aeroelasticity and unsteady aerodynamics in the framework of the GARTEUR Intermediate Programme Initiative.

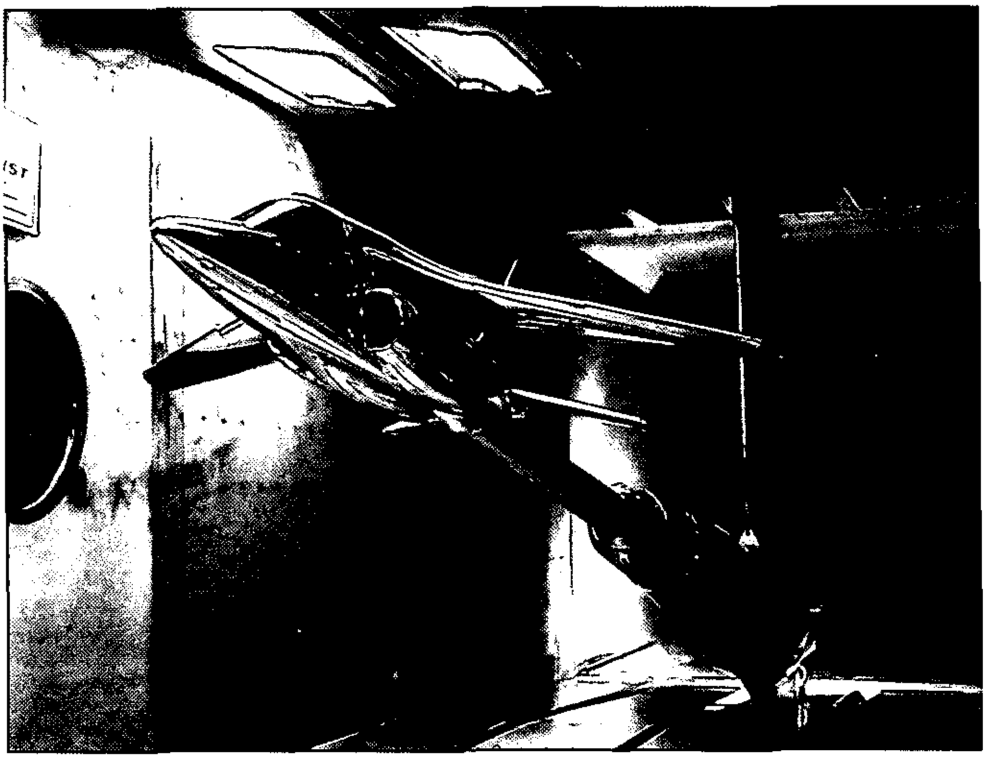
Aeroacoustics

In January the 'kick-off' took place of four BRITE/EURAM projects addressing the problem of noise reduction of turbofan-powered aircraft. NLR has been involved in all four projects.

The DUCAT (Basic Research on Duct Acoustics and Radiation) project, co-ordinated by NLR, focuses on the development and validation of computational tools for the propagation of sound in engine ducts. The development and extension of a number of prediction models were initiated. The first predictions compare favourably with analytical benchmark solutions.

In the RESOUND (Reduction of Engine Source Noise through Understanding and Novel Design) project, NLR is involved with the optimization with respect to noise generation of the design of a rotor/stator combination. Application of NLR's computer model for interaction noise suggests a possible reduction of the downstream sound power level in a by-pass duct by reducing the number of the by-pass Outlet Guide Vanes (OGVs). Furthermore, the effect of OGV sweep on the sound power level was calculated for several configurations. Significant reduction of noise was predicted at sufficient backward sweep. As a new element, the problem of modelling the sound diffraction on the 'splitter' between the by-pass duct and the core engine was solved by using the Wiener-Hopf procedure. A computer program was written, and numerical results obtained with this program show that the inclusion of splitter diffraction significantly improves the modelling of fan-ESS (Engine Section Stator) interaction. The results of all these calculations are taken into account in the design of a low-noise model fan, to be tested in a Rolls-Royce facility.

NLR's participation in the RANNTAC (Reduction of Aircraft Noise by Nacelle Treatment and Active Control) project mainly consisted of the theoretical and experimental analysis of two innovative, non-locally reacting liner concepts. For the experiments, two cylindrical liner barrels have been designed and manufactured. The experiments were carried out in the Small Anechoic Wind Tunnel (KAT) of NLR. Fan noise with a maximum level of about 135 dB was generated, and the incident and transmitted acoustic fields in the flow duct were determined.



Model of DaimlerChrysler in the High Speed Tunnel (DNW-HST) at NLR Amsterdam

In the RAIN (Reduction of Airframe and Installation Noise) project, NLR is responsible for the subtask Fan Noise Installation Effects. One activity concerns the development and validation of a computational model for the propagation of sound through a vortical flow. A pilot version of the computer program for this problem, based on ray acoustics, was completed.

Research on propeller noise was continued in the BRITE/EURAM project APIAN (Advanced Propulsion Integration Aerodynamics and Noise) in which the sound field of installed, advanced propellers is investigated. The contribution of NLR to this project includes an extension of the computer program DIFREF, which models the scattering of propeller noise by an aircraft fuselage and its boundary layer. The development of the program advanced to the computing of the scattering of noise by a cylinder of non-circular cross-section, as yet without incorporation of the boundary layer. Comparison with results of a two-dimensional model based on a Finite Element Method yielded good agreement.

In the field of wind turbine noise a new European JOULE project was launched: DATA (Design and Testing of Acoustically Optimized Airfoils for Wind Turbines). In this project NLR will test new wind turbine airfoils in the KAT, and a complete wind turbine model in the DNW-LLF. Preparatory work was done.

Radar Cross-Section (RCS) Prediction Methods

NLR continued the development of RCS prediction techniques. The mathematical formulation of a hybrid prediction technique based on a combination of high-frequency approximations, as in physical optics, and the exact electric field integral equation were finalised, and the implementation of an algorithm was continued. This work is executed in collaboration with TNO Physics Electronics Laboratory and partly funded by the Ministry of Defence. It relies heavily on the infrastructure for Computational Fluid Dynamics at NLR.

Facilities and Equipment

Wind Tunnels

Since the transfer to DNW, as of July 1997, of the responsibility for the operation of the transonic and supersonic wind tunnels (DNW-HST and DNW-SST) and of the model engine calibration facility (ECF), all wind tunnels of NLR are under operational control of the German-Dutch Wind Tunnel organization DNW. These facilities are planned to become fully integrated with DNW by 1 January 2000.

After the completion of the second phase of the modernization of the DNW-HST, in 1997, the year 1998 was characterized by a rapid increase of use for industrial customers.

Development activities were limited to a further validation test for space launcher-type configurations and the construction plus installation of a new movable working floor for the test section. Also, some minor adjustments of the tunnel pressure control system were implemented and an analysis was made of mechanisms causing model vibrations under certain combinations of model/support configuration and (extreme) flow conditions. A rig for high-speed propeller testing was completed and used in the BRITE/EURAM project APIAN.

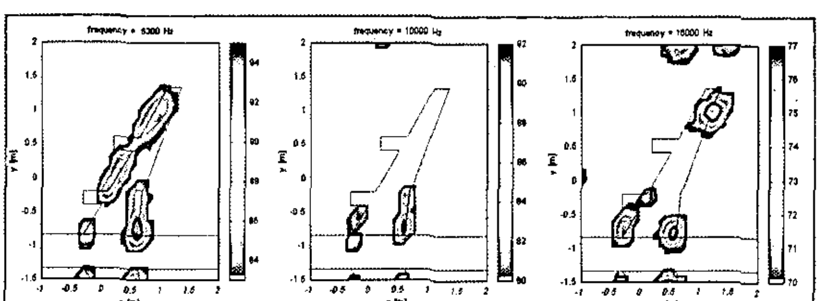
Instrumentation and Measurement Systems
The development of a new generation of strain gauge balances for the DNW-HST and DNW-SST was continued. A slender high-load balance was manufactured for force measurements on supersonic transport type models. After successful calibration, the new balance was tested under wind-on conditions on a reference model in the DNW-HST. Analysis of the results, on the basis of repeat runs and balance-to-balance comparison, showed that it satisfied the accuracy requirements that had been specified on the basis of requirements for the BRITE/EURAM EUROSUP project.

A new data reduction program for balance calibration has been developed, based on the concept of 'transfinite interpolation'. It will replace the existing software, which is based on the conventional method of matrix conversion. The conventional method exhibits shortcomings when applied to modern monobloc-type balances, with inherent non-linearity and relatively strong interactions. The new software package became ready to be tested.

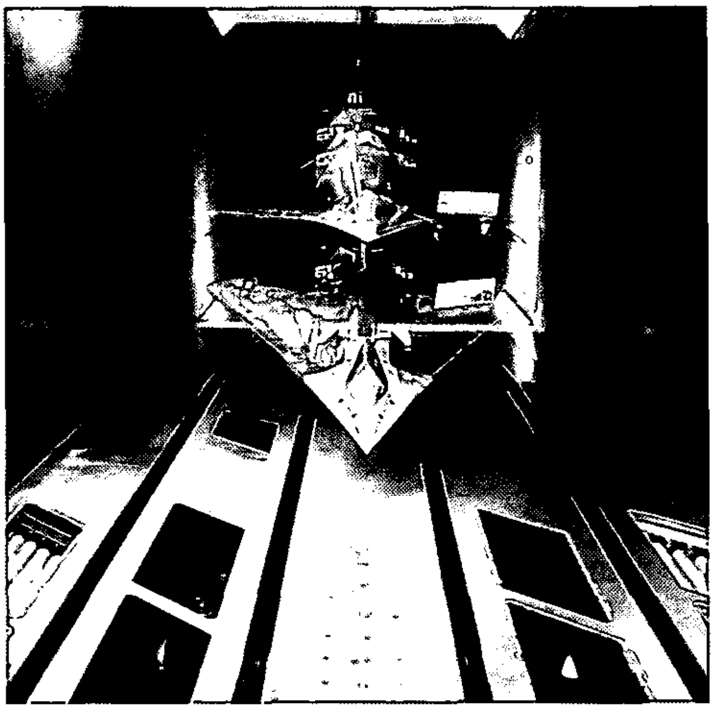
The existing optical surface pressure measurement system, based on the application of Pressure Sensitive Paint (PSP), was further improved and tested. With these activities NLR also contributed to the work of GARTEUR Action Group AG-21, an action group with the objective of demonstrating the possibilities for applying accurate and productive PSP techniques.

The Particle Image Velocimetry (PIV) system, which measures the two components of the velocity vector in the plane of a laser sheet, was successfully applied during experiments on a generic fighter aircraft model with leading edge vortex flow. Further developments of the PIV system concerned the improvement of the data reduction software and of the controls of the seeding system in the DNW-HST. NLR experts participated in the BRITE/EURAM project EUROPIV dealing with the PIV technique, completed in 1998, and in the Thematic Network PIVNET, started in 1998.

On the subject of wind tunnel wall interference a contribution on 'Adaptive Walls' was made to the final report of the GARTEUR Action Group (AD)



Acoustic sources at three frequencies, determined using a microphone array



Lockheed fighter configuration in the High Speed Tunnel (DNW-HST) at NLR Amsterdam

AG-18. Software for on-line application of wind tunnel wall corrections for helicopter tail rotor measurements was adapted in support of the DNW organization.

The hydraulic part of the unsteady aerodynamic measurement system HYDRA was overhauled and its documentation updated and extended. Existing unsteady aerodynamics data files, to be used in the future, were reformatted, partly as a contribution to NATO's RTO AVT Working Group 003 'Test cases for validation of computational unsteady aerodynamics codes'.
Equipment for vibration testing, acquired from the former Fokker Aircraft BV, was made operational at NLR.
Other activities in the area of unsteady aerodynamic measurement systems included the development and testing of sensors for extremely low pressure fluctuations.

The development of a microphone array system for DNW, for the determination of the locations of acoustic sources, was continued with the design and testing of a system for application in a closed wind tunnel test section without acoustic lining. Preliminary results from measurements in the DNW-LLF on an aircraft model in landing configuration were promising.

Infrastructure for Computational Fluid Dynamics

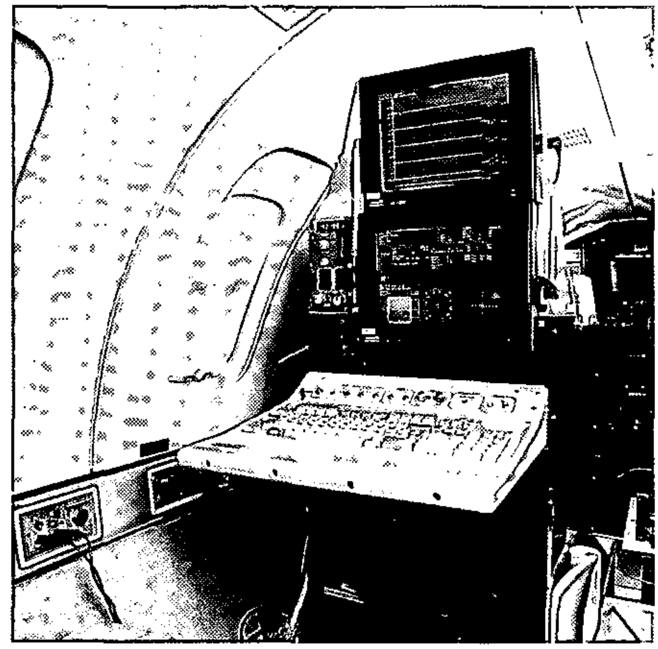
To explore the three-dimensional flow fields associated with delta wings in dynamic pitch/roll motion further, and to explain the non-periodic behaviour of aerodynamic forces and moments associated with the dynamics of vortex burst, NLR has collaborated with Computational Engineering International to implement the EnSight flow visualisation code on the NEC SX-4/16 supercomputer of NLR. Concurrent scheduling of the flow solver and the flow visualizer on the supercomputer has allowed CFD applications specialists to create 3-D animations on a GSI Octane workstation (with special compression/decompression hardware) within two hours after completion of the simulation on the supercomputer. At the same time the animation can also be recorded for future playback using standard movie player software tools.

3.2 Flight

Summary

The total volume of activities comprising contract research, basic research and development of facilities related to flight operations showed a slight growth, compared to 1997. Research work was executed in the areas of flight qualities and flight control systems, air traffic management, airport support, human factors, military support, helicopters and transport and environmental studies.

In the area of flying qualities and flight control systems, NLR chaired the Exploratory Group of GARTEUR 'Robust Flight Control 2'. NLR was also active in the EU Fourth Framework Programme projects REAL (Robust and Efficient Autopilot Control Laws Design), chaired by NLR, and ADFCS (Affordable Digital FBW Control System for Small Commercial Aircraft), which started their activities in 1998.



Equipment in the Fairchild Metro II research aircraft used in Flight Inspection of navigation and landing aids

With respect to air traffic management (ATM), efforts of NLR are focused on finding near and long term solutions in order to increase the capacity at the airport as well as in the airspace while improving the safety level and workload. Activity areas were: communication, navigation, surveillance, ATM modelling and ATM concept validation, airport automation and airport and airspace capacity analysis in Eurocontrol programmes (the Programme for Harmonised Air traffic management Research in Eurocontrol, PHARE, and the European ATC Harmonisation Integration Programme, EATCHIP), EU projects (European Pre-operational Data Link Applications, EOLIA; ATM Systems Safety Criticality Raises Issues in Balancing Actors Responsibility, ARIBA; and Testing Operational Scenarios for Concepts in ATM, TOSCA) and in programmes of LVNL and RLD.

Work on human factors was carried our with respect to the development of ATC/ATM controller Human Machine Interface (HMI), the design of military crew stations, training of pilots and controllers, and free flight research. Research into human factors of aircraft maintenance was continued on national and European levels. Research on the development of a set of measures for evaluating operator performance, workload and situational awareness was continued.

Military support was provided to the Royal Netherlands Air Force (RNLAF) during various flight tests, with the analysis of threat weapon systems for fighters and helicopters, on the tactical and operational use of the Lockheed Martin F-16, concerning the requirements for and the selection of a successor for the F-16, on the certification of pods for the F-16 MLU and on the investigation and demonstration of applications of networked simulations.

In the area of helicopters, NLR participated in the activities of three GARTEUR Helicopter Action Groups and in the EU Fourth Framework projects HELIFLOW, RESPECT and ROSAA (Improved Tools for Helicopter Aeromechanic and Aeroacoustic Interaction, Rotorcraft Efficient and Safe Procedures for Critical Trajectories and Integration of Advanced Aerodynamics in Comprehensive Rotorcraft Analysis, respectively).

In co-operation with Fokker Aerostructures and SP Aerospace and Vehicle Systems, NLR continued its participation in the Design and Development phase of the NH90 programme.
NLR supported the RNLAF in the area of the CH47-D Chinook Avionics Control & Management System improvement, and the Royal Netherlands Navy (RNLN) in the execution of flight tests with Westland Lynx helicopters onboard the new Amphibious Transport Ship.

Aircraft operations included intensive use of NLR's Fairchild Metro II research aircraft for flight inspections of the radio navigation and landing aids in the Netherlands.
Flight tests with the Cessna Citation II have been performed in support of the PHARE Demonstration project PD/3. Major progress was made in the development of the Citation Future Aircraft Systems Testbed (FAST).

In the field of transport and environmental studies, noise evaluations were carried out for a number of short term noise abatement measures under contract to the RLD and within the scope of Technical Operational Measures Schiphol (TOMS). Noise exposure was calculated for actual and future situations of several airfields in the Netherlands.

NLR contributed in several international studies on the identification and reduction of aviation emissions.

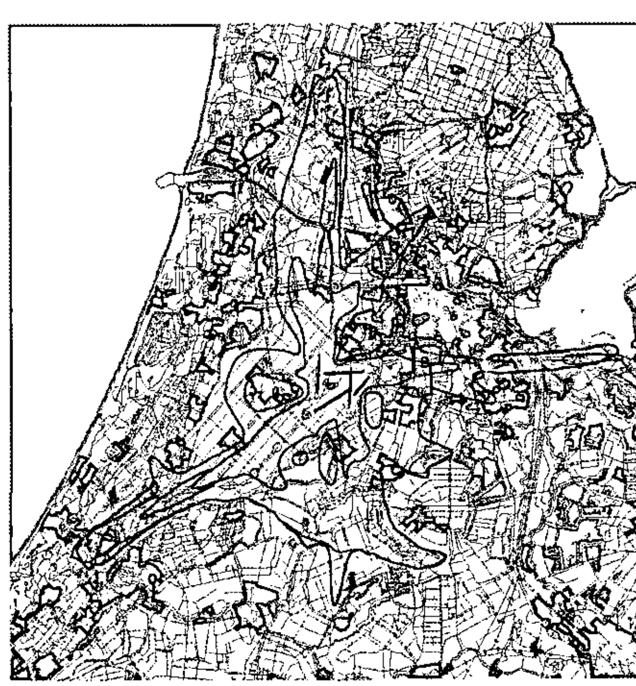
A considerable number of risk calculations were carried out for future airport locations as part of the Future Netherlands Air Transport Infrastructure (TNLI).

With regard to facilities and equipment, both software and hardware of the NLR ATC Research Simulator (NARSIM) were extended in order to run the PD/3 demonstrations.

The development of a Tower Research Simulator (TRS) was continued with the fixation of the user and the system requirements.

The Traffic Organization and Perturbation Analyzer (TOPAZ) facility continued to be used in safety assessment and model-based concept validation studies. Work with the Total Airspace & Airport Modeller (TAAM), a workstation tool for the simulation of airspace and airport operations, was conducted to support policy decisions for the TNLI and for studies for foreign airports.

To enable a multitude of simulation experiments to be performed in several configurations, modifications were made to the NLR Research Flight Simulator (RFS) and the National Simulation Facility (NSF). An upgrade of the RFS started with the procurement of a generic simulator cab. In a distributed environment the NSF was coupled with an F-16 MLU mock-up, an F-16 MLU desktop simulator and a mission environment simulation software package enabling man-in-the-loop flight simulations to be performed with different levels of fidelity in combination with several generated forces.
To enable pilot in-the-loop evaluations of helicopter models to be carried out, it has been decided to develop a helicopter mock-up.



Runways and calculated noise contours superimposed on a map of the area around Amsterdam Airport Schiphol

Flying Qualities and Flight Control Systems

Robust Flight Control 2

The GARTEUR Exploratory Group (FM) EG 17, 'Robust Flight Control 2', chaired by NLR, has started activities. Three meetings were organized, in which partners from industry and the scientific community exchanged views on possible research topics for a follow-up of the project of Action Group (FM) AG 08, 'Robust Flight Control', which was successfully completed in 1997. The Exploratory Group decided to recommend the Executive Committee to establish a new Action Group (FM) AG 11 on New Analysis Techniques for clearance of flight control laws (NEAT), starting activities in April 1999.

Robust and Efficient Autopilot Control Law Design

The BRITE/EURAM IV project REAL (Robust and Efficient Autopilot Control Law Design) was started, chaired by NLR. In the project, a procedure for autoland control law design will be developed on the basis of advanced control techniques. A problem definition has been fixed and a benchmark aircraft model developed. The current autoland design process was described and potential improvements identified.

Affordable Digital Fly By Wire Flight Control System

NLR started participation in the BRITE/EURAM project ADFCS (Affordable Digital Fly By Wire Flight Control System for Small Commercial Aircraft) on advanced technologies in fly-by-wire flight control system design, headed by Israel Aircraft Industries (IAI). In addition to NLR, the project consortium includes Alenia Aerospazio, *Centro Italiano Ricerche Aerospaziali* (CIRA), Delft University of Technology, Israel Institute of Technology (Technion) and GEC-Marconi Avionics as participating organizations. The goal of the project is to develop an architecture for an affordable fly-by-wire (FBW) digital flight control system (DFCS) for small commercial aircraft where advanced technologies such as Fuzzy/Neural and robust control algorithms will be used to reduce the cost of system development and the operational cost of the aircraft. Currently, FBW-FCS technologies are used mainly in fighter aircraft and large civil transport and cargo jets. The objective of the project is to evaluate the affordability and cost effectiveness of incorporating these technologies in small civil aircraft.
The major contribution of NLR is the implementation and final evaluation of the developed FBW flight control system on the NLR Research Flight Simulator (RFS).

Integrated Flight Propulsion and Control Systems

As part of a National Technology Project carried out for the Ministry of Defence, NLR successfully demonstrated its technical capabilities for research in the areas of thrust vectoring, high angle of attack operations and agile manoeuvring of future military fighter aircraft such as the Joint Strike Fighter (JSF). The F-16's flight control system (FCS) was redesigned in both the longitudinal and lateral/directional axes and integrated with the newly developed PW-220 engine model. The engine model was simulated on a thermodynamic basis. This advanced Integrated Flight Propulsion and Control (IFPC) system controlled the movable engine nozzles in two dimensions, to make possible thrust vectoring. A prototype of this IFPC system was implemented and successfully tested on NLR's NSF. To improve and facilitate the process from design to online testing, a sophisticated interface was set up between the remote design environments and the software environment of the NSF.

Pilot-in-the-Loop Oscillations

Because of the advent of fly-by-wire technology, Aircraft Pilot Coupling (APC), more commonly known as Pilot-in-the-Loop Oscillations (PIO), is a research area with an increasing importance in both civil and military operations. GARTEUR established the Exploratory Group (FM) EG 18 'Aeroelasticity and Dynamics of Tilt Rotor Aircraft', in which NLR participated, for the definition of the terms of reference for a future Action Group. This Action Group will focus on the analysis of pilot-in-the-loop oscillations and on test techniques for their prevention.

Fault Tolerant Control

Reconfiguration of control effects gives the possibility to enhance aircraft operation under difficult control situations. Initially stemming from military applications, reconfiguration, or more broadly fault tolerant control, is slowly migrating to civil applications. For instance the Propulsion-only Controlled Aircraft (PCA), seems to be a promising concept. In 1998 GARTEUR set up Flight Mechanics Exploratory Group FM-EG19. The interest of European industry for research on fault tolerant control was explored via various meetings and via a questionnaire in which areas of interest were defined. The results were discussed with the industry, and the scope of the research for a future Action Group was limited and defined.

Autopilot disconnect transients during crosswind approach

An exploratory study was carried out on the transient effects occurring when a transition is made from automatic flight to manual control during approach/landing at very low altitude during strong crosswind conditions. At the same time a brief review was made of the current certification requirements on the transient subject. A limited number of approaches have been flown on the RFS in order to obtain pilot opinions and comments on the subject. Autopilot disconnects were made at heights varying between 100 ft and 30 ft. For the purpose of reference also a number of complete manual approach/landings was performed.

The overall conclusion is that possibly existing JAR-AWO requirements (for automatic landing systems) have to be amended. Based on the preliminary results it was recommended to carry out more detailed simulation trials on certified flight-training simulators.

Windshear

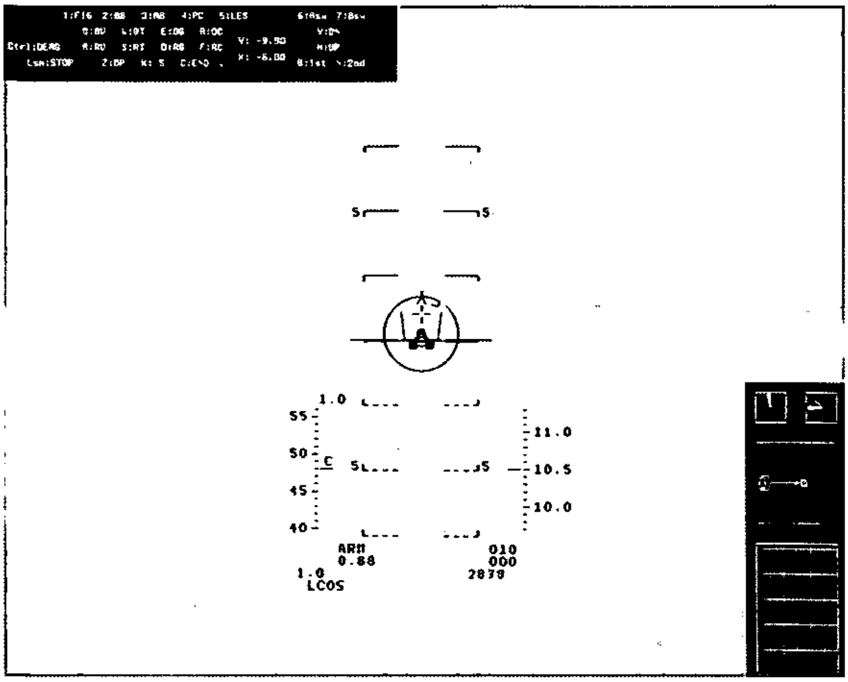
In the area of windshear research, the work on the Phase-II experiment within the WINDSTREAM (WINDShear Technology REsearch Advances Masterplan) project was finalised. The project was co-funded by the RLD and the NIVR. Data analysis was concluded, the test plan was published and the final report was completed. Results of the work showed that the use of an airborne Doppler windshear radar system improved flight safety substantially when compared to operating a normal weather radar system in conjunction with a reactive windshear detection system. Results were presented at the 21st ICAS conference in Melbourne. In the aftermath of GARTEUR (FM) AG-07 activities on windshear, papers on the WINDSTREAM Phase-Ib experiment were presented at the AIAA 1998 Atmospheric Flight Mechanics Conference in Boston and the European Geophysical Society Conference in Nice.

WAVENC

The WAVENC (Wake Vortex evolution in the far wake region and wake vortex ENCounter) project was continued. This EU Fourth Framework project, led by NLR, is aimed at increasing the knowledge in the areas of wake vortex behaviour and wake vortex encounter simulation, to investigate the wake effects of very heavy aircraft (MTOW>1,100,000 lbs) on the safety and separation distances of following aircraft. Work at NLR is performed in a co-operation between the Aerodynamics and Flight Divisions. It included aerodynamic measurements in the DNW-LLF and Computational Fluid Dynamics calculations. Flight mechanics activities consisted of the drafting of an aerodynamic interaction model to simulate the effect of the wake on a following aircraft, and the review of a two-dimensional wake vortex model. Both models will be enhanced further for parametric 'off line' simulations.

ISAWARE

The EU Fourth Framework project 'Increasing Safety through collision Avoidance WARning intEgration' (ISAWARE) was started. This project, led by thomson Detexis, has the objective to develop an Integrated Situational Awareness System (ISAS) by integrating the functionality of various warning systems such as GPWS, TCAS, ACAS, weather/windshear radar, wake vortex detector, and by using advanced technologies such as ADS-B, SMGCS and digital obstacle and terrain databases. Top level requirements were defined and the system concept definition phase, including the Man Machine Interface (MMI) definition, was started. Collaborations with other EU Fourth Framework programmes, 3FMS, DIVA and WAVENC, were set up.



Display for human centrifuge at the Aeromedical Centre of Soesterberg

Human Centrifuge

The Netherlands Aeromedical Centre, of Soesterberg, operates a Human Centrifuge for high-G training of national and international fighter pilots. The trainee is located in a cockpit-like gondola, hinged at the end of a long arm, which is mounted on a powerful electric drive system. The centrifuge has a computer system for F-16 aircraft simulation, outside view generation including HUD, and drive system control. The computer application software was developed by NLR.

The previous computer system has been replaced by NLR by a Silicon Graphics Octane computer. The signal interfacing and application software has been upgraded by NLR. To improve the quality of the outside view the resolution was increased.

Mathematical Models of Aircraft and Helicopters

Mathematical models of aircraft are essential parts of research flight simulators. The Boeing 747-200/400 model has been implemented on the new real-time Unix computer system and has been extensively tested and validated. Several laboratory pilots and Boeing 747 airline pilots have flown piloted checkouts on the motion based B747 research flight simulator, resulting in an accepted Boeing B747 200/400 simulation model.

Air Traffic Management

Air transport is growing every year and major airports are trying to keep up with the demand for more capacity. This often results in congested airports and terminal airspace. NLR focuses on finding near and long term solutions in order to increase the capacity at the airport as well as in the airspace, while the safety level and workload improve. Poor visibility conditions form another constraint for airport capacity, and therefore an additional requirement is that those solutions must be applicable for all weather conditions. The near term solutions include gradual transition into the future concepts, while at the same time providing support during implementation and guidance to the clients to set out their future policy in Air Traffic Management. The projects that have been conducted so far not only concern recommendations for improvements in the field of communication, navigation and surveillance, but also their operational impact and benefits to be accrued.

Communications

In the European pre-Operational Data Link Applications (EOLIA) project, co-funded by the European Commission (DG-13), Eurocontrol and the consortium members, initial verification trials were hosted on the NLR ATC Research Simulator (NARSIM). Demonstrations were attended by project members and Eurocontrol staff, who provided feedback on the Human Machine Interface (HMI) for the air traffic controller. In close co-ordination with the ProATN project, the EOLIA and ProATN software development teams entered the software integration and testing phase to be followed by flight trials.

The 'Airborne Air Traffic Management System' (AATMS) project focuses on data-link realisation and communication management and onboard CNS/ATM functions that are compatible with the future European air traffic environment. For this experiment, a Flight Management System demonstrator was installed in the Cessna Citation II laboratory aircraft. NARSIM supports the controller interface within the simulated ATM ground system for the actual flight trials and the data-link applications required for Automatic Dependent Surveillance and controller pilot data link communication. Data communication with the Cessna Citation was performed through the PHARE Aeronautical Telecommunications Network (PATN) providing VHF Digital Link (VDL) and Satellite Communication subnetworks.

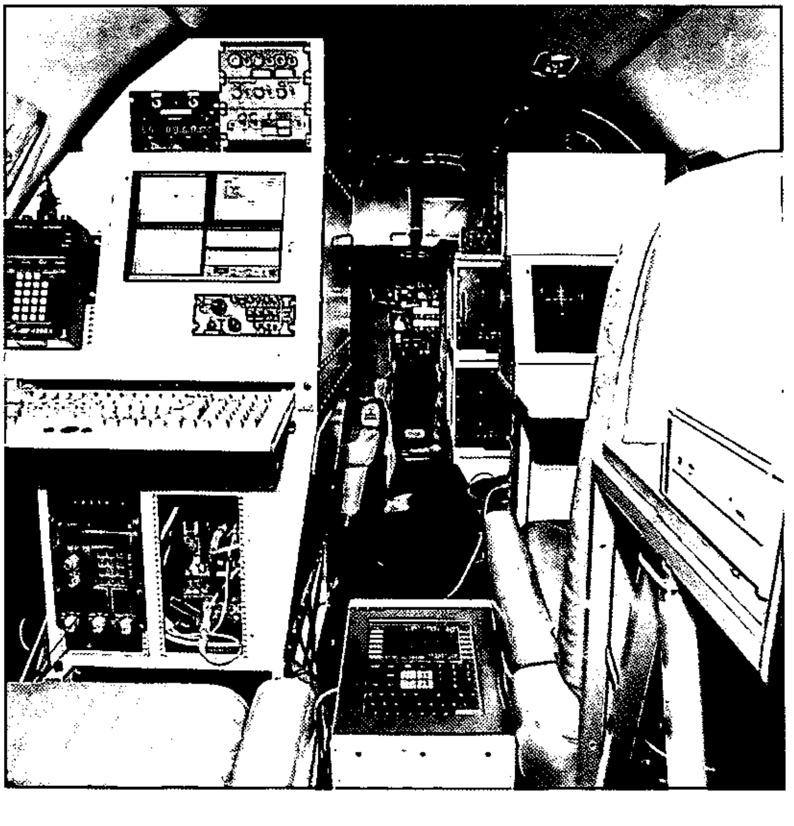
Navigation

In the project 'GNSS Performance Validation' (GPV) of Eurocontrol, led by NLR, a simulation environment for overall system validation of the future Global Navigation Satellite System in combination with any augmentation was analysed. The activities were limited to civil aviation.

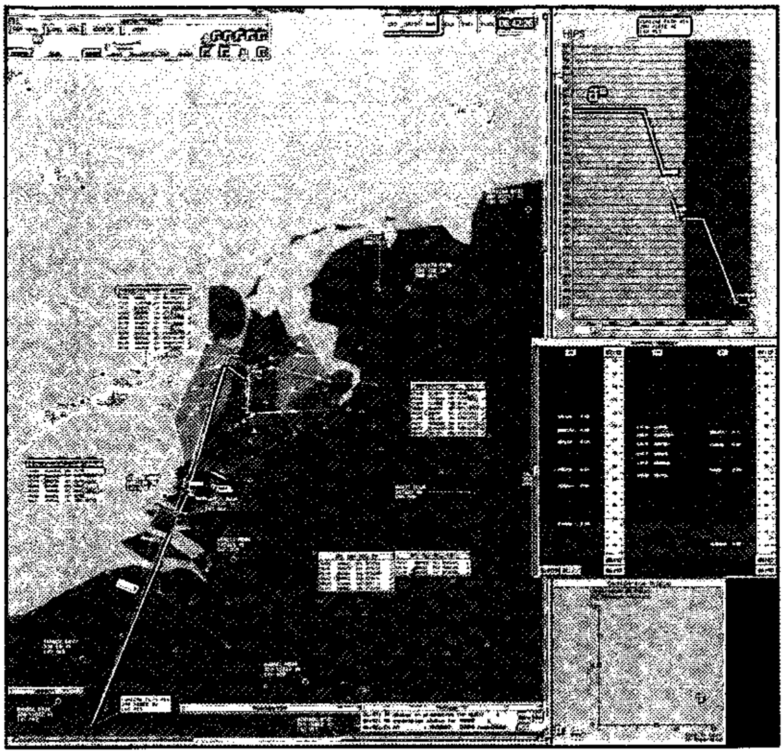
In anticipation to European ATC Harmonisation Integration Programme (EATCHIP) navigation programmes such as Reduced Vertical Separation Minima (RVSM), Area Navigation (RNAV) and 4-D navigation, the project 'Support to the Navigation domain' (SupNav) identified the operational air traffic capacity constraints for a large area of Europe. Steps towards improved airport operations have been made by defining operational requirements in support of enhanced navigation capabilities of aircraft and outlining the functional and technical architecture compliant with the navigation requirements.

Surveillance

Technical support was provided in the Mode-S surveillance programme of the LVNL. The 'Datalinking of Aircraft Derived Information'



Flight Test Console in Citation II used in PHARE PD/3 tests



Air Traffic Controller display used in the PHARE Demonstration 3 for Eurocontrol

(DADI) project of the European Union aims to design, develop and verify the capability of using downlinked aircraft-derived data for ATC ground system applications. The expected benefits are improvement in air traffic controller situational awareness and workload reduction as well as accuracy enhancement of controller support tools.

ATM

The Programme for Harmonised Air Traffic Management Research in Eurocontrol (PHARE) saw its final year. Having started in 1989, the programme in which NLR co-operated with Civil Aviation Authorities, Air Traffic Control Authorities and research establishments of France, Germany, the United Kingdom and Eurocontrol, PHARE culminated in 1998 in its third demonstration (PD/3). This demonstration was a joint project by the Eurocontrol experimental centre (EEC), the Centre d'Études de la Navigation Aérienne (CENA) and NLR, with contributions from National Air Traffic Services (NATS) and the Deutsches Zentrum für Luft- und Raumfahrt (DLR).

In PD/3 the PHARE partners developed and demonstrated an advanced Air Traffic Management concept aimed at providing solutions for the traffic demand of 2015. The basis of this concept is 4D advanced planning combined with trajectory negotiation. PHARE Advanced Tools (PATs) have been developed to support the air traffic controllers. Advanced airborne systems (an Experimental Flight Management System and an Airborne Human Machine Interface) have been developed for the airside. The PHARE Aeronautical Telecommunications Network (PATN) was used for communicating between air and ground by a satellite sub-network.
In PD/3 NLR in particular investigated the integration of arrival management with en-route traffic handling. The planning horizon for arrival management was effectively extended to around 200 NM. Significant progress was made in the refinement of the 4D arrival management concept.
Two large-scale real-time simulations were performed on NARSIM. The first took place at the end of May and demonstrated a baseline concept. In November the final public demonstration took place, which demonstrated the advanced concept in a simulated airspace covering three measured sectors and five feeder sectors. This represented twice the traffic load of today's operations. Fourteen air traffic controllers and fifteen pilots were involved simultane-

ously in each simulation, controlling up to four hundred aircraft in the simulated airspace over periods of ninety minutes. For this public demonstration representatives from European and American players in the field of ATM were invited. Over a period of three days, ninety visitors attended these demonstrations. Both the participating air traffic controllers and the visitors were generally positive about the demonstrated concept.

Free Flight

Although technological advances in communication, navigation and surveillance have made the Free Flight concept feasible, a number of human factors questions with regard to the impact that such a drastic change in air traffic services would have on the human controller remain. The controller would be expected to intervene tactically only when necessary to ensure separation. Based on the results of earlier experiments at NLR, an enhanced ATC display was developed that incorporated airborne-derived conflict detection and resolution information. Trials with controllers demonstrated benefits in terms of monitoring time and performance as well as in general acceptance. Future work will focus on Free Flight training requirements and controller responses to abnormal system modes.

ATM in the Netherlands

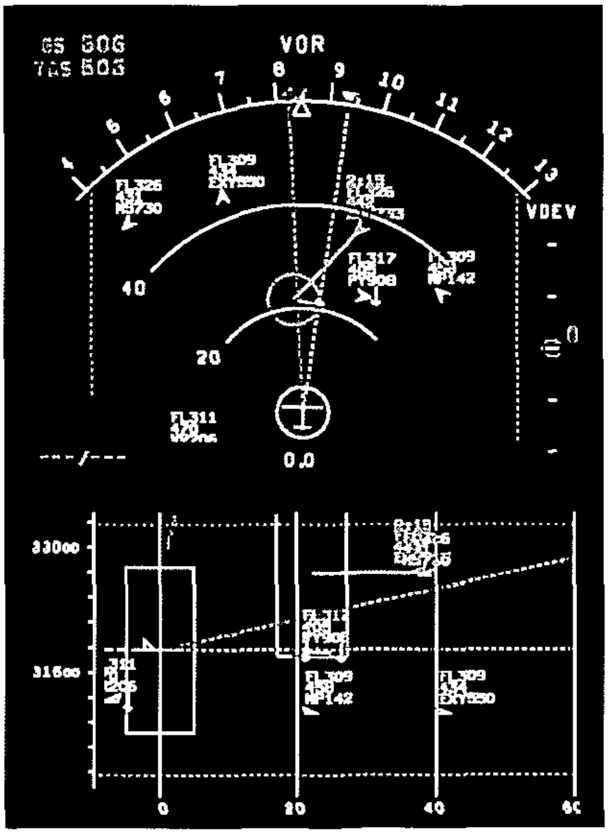
NLR has supported the RLD with the development of a policy on ATM in the Netherlands. The activities comprised interviews with ATM users on operational requirements and a report on the current status of the operational ATM system in the Netherlands as well as on ongoing R&D activities in a national, European and world-wide context. The study also highlights a converging trend in European R&D to focus on an implementation of an extended and layered planning concept, which can only be realized with full support of all actors and integration of their planning activities.

Operational requirements have been established for a feasibility study for the LVNL regarding the increase of landing capacity at Amsterdam Airport Schiphol.

Modelling and ATM concept validation

Many projects funded by the European Union are conducted by consortia in which NLR participates. The project 'ATM safety criticality Raises Issues in Balancing Actors responsibility' (ARIBA), which is led by NLR, has the aim to develop a cost-effective methodology for ATM safety validation and a harmonisation approach towards certification issues, based on the principle that there should be a balance between human operators' responsibilities and their controllability of evolving traffic situations. In another project led by NLR, 'Testing Operational Scenarios for Concepts in ATM' (TOSCA), the collision risk of new procedures is assessed, the potential impact of multisector planning is considered and the improving of the EATMS concept is studied.

Other projects in this field focus primarily on activities concerning the development and demonstration of model-based validation of concepts, in combination with a consistent description of the validation methodology.



Cockpit navigation display for Free Flight research

Panel activities

NLR continued to participate with research and technological development activities in various Panels of the International Civil Aviation Organization (ICAO), thereby representing the LVNL and RLD. These panels are the SSR Improvement and Collision Avoidance Systems (SICAS) Panel, the Aeronautical Telecommunications Panel (ATNP), the All Weather Operations Group (AWOG), the Global Navigation Satellite System (GNSS) Panel and the EATMS Validation Strategy working group. The findings and recommendations of the panels are reported to the LVNL and RLD, serving as input for their policy in the specific technical areas, while the technical details can be further used by NLR to maintain its knowledge.

Airports

Airport and TMA Operations

Assistance was given to Air Traffic Control the Netherlands (LVNL) defining a future methodology to meet ATM requirements of its stakeholders. This methodology enables common denominators to be derived from a great number of apparently different requirements, leading to a coherent set of operational requirements and system requirements. Under contract to the LVNL a study was carried out on measures to increase the landing capacity of Amsterdam Airport Schiphol.

Airport Automation

The LVNL received assistance concerning the introduction of an Advanced Surface Management Guidance & Control System (A-SMGCS) for Amsterdam Airport Schiphol. Also, for the Steering group on the Optimisation of the Capacity of Schiphol (SOCS), the possibilities and the techniques to be implemented for the Schiphol A-SMGCS system were explored. To meet the demand of capacity at Amsterdam Airport Schiphol, the existing infrastructure has to be further optimized, and new Air Traffic Control procedures and infrastructure use have to be considered for implementation as of 2003.

Airport and Airspace Capacity Analysis

To support policy analysis, NLR contributed to the Future Netherlands Air Transport Infrastructure (TNLI) project led by the Ministries of Economic Affairs, Environment and Transport. Capacity, punctuality and air traffic controller workload were investigated for future locations of Schiphol alternates, reconfigured layouts of Schiphol and completely new locations. For the Spanish organization AENA, under contract to INECO, studies were carried out on re-sectoring of parts of the Spanish airspace.

Human Factors

Civil Flight Deck

Within the FOCUS project, aimed at the development and evaluation of new technology for System Control, a literature study into human factor aspects and initial design and development work has been carried out. The project is being carried out under contract to NIVR and is supporting technology development at Fokker Elmo. The main driver is that new designs for System Control are based on the application of LCD technology.

Within the scope of the AWARD (All Weather Arrival and Departure) project, an Enhanced Vision System (EVS) evaluation was carried out at Sextant Avionique's part-task flight simulator in Bordeaux. For this purpose, NLR's eye-tracker and physiological data recorder were successfully integrated on-site in Bordeaux. Six airline pilots participated.

Controlled Flight Into Terrain

Under contract to the RLD, the results of a flight simulator evaluation on the use of advanced terrain displays and warning systems, carried out in 1997, were analysed. This evaluation programme concerned the operational aspects related to the introduction of such terrain displays and warning systems in the civil transport cockpit. The evaluation concentrated on the ease of use of such systems and crew reactions both during normal operation and during abnormal situations. The evaluation programme was completed.

ATC/ATM Controller HMI

In collaboration with Eurocontrol, National Air Traffic Services Ltd (NATS), CENA and LVNL, the PHARE Ground Human Machine Interface

(GHMI) number 3 was finished and partly implemented. The PHARE PD/3 system is an experimental controller working position designed for the period 2010-2020. Compared with earlier PHARE demonstrations (PD/1 and PD/2), a multisector planner working position was added. Working procedures and Computer Based Training (CBT) were made to familiarize the controllers with the new concepts.

In collaboration with DERA and EEC, an advanced Airborne HMI, based upon the PHARE 4D ATM concept, was developed and demonstrated. The Airborne HMI consisted of an interactive navigation display with a tracker ball, a CDU with enhanced datalink capabilities and a 4D tunnel-in-the-sky PFD. The AHMI was demonstrated by NLR in the Citation II research aircraft with a real data-link to the NLR ATC Research Simulator (NARSIM).

In collaboration with NASA, prototype ATM HMIs were developed for a future ATM scenario characterized by higher traffic load and greater aircraft autonomy (in terms of route selection). The prototype HMI incorporated tools to help the controller both in probing separation conflicts and in monitoring for losses of separation. Preliminary results suggested benefits in controller acceptance and usability.

Within the DEmonstration Facilities for Airport Movement Management (DEFAMM) project, a consortium explored the introduction of an integrated system for airport surface traffic management. Assistance of NLR centred on the operational testing of the DEFAMM system at Cologne-Bonn airport, and included helping to develop a controller manual for using the DEFAMM HMI and developing analysis methods for the trials.

Military Crew Station Design

The RNLAF was supported by studies aimed at a man-machine systems definition of a 'pilot-oriented mission-analysis method' and reviewing determinants of pilot workload. The studies gathered information from a pilot's point of view, and the results are to be used in the evaluation of future training design and interfaces. Further activities involved reviewing the international NH90 training proposal, and presenting an alternative national training-design for both ground crew and aircrew.

In collaboration with DERA, the RLNAF and TNO, the POWER (Pilot Oriented Workload Evaluation and Redistribution) programme is carried out for investigating the development of advanced display and pilot support tools, which aim to incorporate Advanced Information Processing and decision support techniques into the modern cockpit. Experiments in the F-16 Mock-up and NSF were carried out as part of an F-16 Mid Life Update (MLU) contract from Lockheed Martin. In these experiments, the effects of colour coding configurations for cockpit displays were investigated.

For the Netherlands Ministry of Defence, the effects of feedback on Pilot performance and safety were assessed in an F-16 Mock-up, a Slingsby aircraft and a centrifuge. The project was performed in collaboration with the Polish Air Force Institute of Aviation Medicine and the Netherlands Aeromedical Institute. The main goal in this second year of the collaboration was to assess the effects of feedback on flight performance, provided by a prototype debriefing aid. These measurements include assessing the potential benefits of Eye-Point-of-Gaze (EPOG), Electro-OculoGram (EOG) and EarPulse Waveform (EPW) as debriefing information in the mock-up (EPOG), in flight (EOG), and during anti-G-straining training (EPW).

A study performed for the Royal Netherlands Navy analysed industry proposals for NFH90 helicopter crew stations. Several proposed modifications concerning cockpit lay out, design of flight display formats and mission system design were accepted by both officials and industry. Experiments on TACCO (tactical co-ordinator) workload were performed in the ORION tactical simulator to identify bottlenecks in existing operations including the role of HMI limitations. The lessons learnt are incorporated in proposed modifications and/or requirements for future naval helicopters.

Operational and HMI requirements related to Advanced Vision Systems (AVS) for helicopters and fixed wing aircraft were analysed in the RETINAV project. The RETINAV project deals with AVS for military applications. It was concluded that a system with both imaging sensors and computer-generated imagery displayed on a head-down display and a helmet-mounted display (HMD) would offer the most benefits for both platforms.

Effectiveness G-cueing Devices

A trial was conducted on the National Simulation Facility to assess the effects of a dynamic seat in flight simulation. In total ten subjects participated and performed the longitudinal and lateral disturbance tasks. The effects of the seat were compared to conditions with and without platform motion. Preliminary results show effects from the seat cues on task performance and control behaviour. Analysis of the results will continue, and will focus on the frequency domain.

Training and Performance

The ECOTTRIS (European Collaboration on Transition TRaining for Improved Safety) project delivered its final results proposing priorities and strategies in pilot conversion training to glass cockpits. The ECOTTRIS concept was demonstrated with a training for conversion to the Airbus A340.

In co-operation with DLR, the University of Aberdeen and Imassa, a proposal was made for an evaluation method to assess pilot proficiency on Non-Technical Skills. The NOTECHS project, conducted at the request of RLD and the JAA Project Advisory Group on Human Factors, indicates a possible way to comply with the new JAA Flight Crew Licensing requirements (JAR-FCL).

Under the EU Fourth Framework the JAR-TEL (Joint Aviation Requirements - Translation and Evaluation of Legislation) started. JAR-TEL will conduct field studies to test the robustness and validity of the proposed NOTECHS method.

In the EU CAST (Consequences of Future ATM on Selection and Training) project, research continued into the identification of consequences for controller selection and training deriving from the new ATM working environment due to new functions and system automation strategy. Achieved results included amongst other things a training design framework that can be used by the individual air traffic control services to design their own tailor-made controller training.

Human Factors in Aircraft Maintenance

Research into human factors of aircraft maintenance was continued both on a national (RLD) and a European (EU) level. The ADAMS (Aircraft Dispatch And Maintenance Safety) consortium further developed its Maintenance Incident Analysis Tool, which was proven to be compatible with ADREP-2000 (of the ICAO Accident Data Reporting Study Group). Together with the European Human Factors Guide for Aircraft Maintenance the tool is now ready for use by the industry. A new concept of maintenance information presentation and use was developed, the goal being to improve procedural compliance while reducing aircraft turn-around times. Within the ADAMS consortium a JAR-66 compliant training curriculum was drafted based on the inventory of existing Human Factors issues in the current maintenance system. Under the Leonardo da Vinci programme of the European Union, the STAMINA (Safety Training in the Aircraft Maintenance Industry) project started. STAMINA will implement the curriculum proposed by ADAMS into an actual Human Factors module for JAR-66 (Joint Airworthiness Regulations) training.
The maintenance-related work for the RLD concentrated this year on human factors in base maintenance. An automated questionnaire was developed and subsequently data was collected in a maintenance hangar at Amsterdam Airport Schiphol. The questionnaire concentrated on the use of information and maintenance procedures in base maintenance, to investigate reasons behind procedural non-compliance and to estimate the frequency of occurrence.

Operator Performance and Workload Measurement

Research continued on the development of a practical, sensitive and reliable set of measures for evaluating operator performance, workload, and situation awareness. Psychophysiological measurements were fully integrated with data collection and analysis techniques. Such measures as Eye Point-of-Gaze (EPOG), Heart Rate Variability (HRV), and pupil diameter were collected in both flight deck and ATC trials.

As part of the VINTHEC (Visual INTeraction and Human Effectiveness in the Cockpit) project of the EU, a simulator study was conducted in which the dual Eye-Point-Of-Gaze (EPOG) recording system was used to gather pilot eye scanning data in normal and abnormal situations. The EPOG data was combined with other physiological and with performance data to assess pilot Situation Awareness in civil flight operations.

As part of an investigation into prototype ATC HMIs, EPOG and pupil diameter data were useful in revealing both the potential workload and strategy shifts associated with the use of new controller displays.

Free Flight Research

The feasibility of Free Flight concepts was explored using integrated air-ground simulations, in which pilots and controllers were free to interact in real time. The goals of this research were to explore procedures for accommodating mixed equipage (even under high traffic densities), and to analyse the effects of evolutionary display upgrades and Airborne Separation Assurance Systems (ASAS) equipment enhancements. Trials showed positive results, with both pilots and controllers, regarding the feasibility of a Free Flight concept using ASAS.

Additional work in the area of Free Flight involved (1) testing the robustness of the conflict resolution method, by testing it on critical conflict geometries; (2) investigating whether the performance of contemporary avionics technology for navigation and ADS-B is sufficient for the Free Flight concept; (3) developing and testing prototype HMIs for both pilots and controllers.

Military Support

Human Operator Training and Familiarization

The EUCLID (RTP 11.1) MASTER project was completed. The effects of platform motion cues on training effectiveness, using the NSF, were reported. Motion cueing appeared to facilitate control input strategies more realistically, but this was not reflected in better performance, learning or transfer. The 'Handbook of Simulator Training', made in collaboration with DERA and TNO-TM (TNO Human Factors Research Institute), was delivered.

Accident Investigations

NLR supports the Royal Netherlands Air Force (RNLAF) in the investigation of aircraft accidents. NLR staff forms an integral part of the investigation team, in particular to investigate technical and operational factors. NLR also supports the RNLAF in the investigation of smaller accidents, or incidents, then mainly advising in technical matters.

The RNLAF did not experience any serious aircraft accidents. Therefore the support was aimed at the preparation for possible accident investigations. This mainly involved maintaining the necessary level of basic technical skills and further developing Accident Investigation Manuals. NLR also supported the RNLAF in the selection of a vendor for read-out and analysis equipment for the new crash-survivable flight data recorders of the Lockheed Martin F-16 MLU. A number of new aircraft and helicopter types have become operational with the RNLAF in recent years. Therefore, the collection of a basic level of type-specific information on these platforms was initiated. NLR assisted the Royal Netherlands Navy (RNLN) in the investigation of a helicopter accident. The assistance mainly concerned the analysis of wreckage and the investigation of a main rotorhead fracture.

Flight Test Support

NLR assisted the RNLAF during various flight tests. Existing instrumentation for the Lockheed Martin F-16 was maintained. The on-site quick look facility for the F-16 instrumentation was improved. For the F-16 MLU new instrumentation is developed. The new instrumentation will become operational in 1999.

Field Trial Support

A series of Electronic Countermeasure effectiveness trials with RNLAF, RNLN and NATO assets was supported. The capabilities of the facilities for field trials, STF (IR Seeker Test Facility) and ETF (ECM Effectiveness Test Facility), were extended.

Support of Military Operations
NLR supported the RNLAF with the analysis of the performance of own and threat weapon systems for fighters and helicopters. The models and tools used for these analyses were extended. Support was provided in operational exercises for fighter aircraft and ground based air defence systems, including RED FLAG, and in instruction of RNLAF operational personnel, to the Netherlands Royal Military Academy, in the NATO Tactical Leadership Programme (TLP), and to the NATO School in Oberammergau.

Tactical Recce System Replacement
Support was provided on the evaluation of potential sensor and other subsystem candidates. The rapid developments in the area of recce equipment allowed f the requirements for most of the subsystems such as the sensors and recording systems to be tightened. A short programme was started to detail the ground station requirements based on hands-on experience by the photo interpreters. For this purpose an exploratory imagery exploitation system with stereo display capabilities was installed at Volkel airbase. The results of the evaluations will be used in the final version of the request for quotation of the RNLAF.

New Equipment for RNLAF Aircraft
NLR supported various studies with regard to the requirements for and the selection of new equipment for operational aircraft.

F-16 Replacement
Support was provided to the RNLAF concerning the requirements for and the selection of a successor for the F-16.

Certification of Military Aircraft
Work on the certification of targeting and navigation pods for the F-16 MLU continued. The Royal Netherlands Army was supported with the certification of the Sperwer Remotely Piloted Vehicle.
The Royal Belgian Air Force was supported with regard to airworthiness certification aspects of candidate Remotely Piloted Vehicles.

Integrated Self Protection
Phase 1, project definition, of the National Technology Project (NTP) for an integrated smart Self-Protection Electronic Warfare (SPEW) manager was completed. Phase 2, demonstration of the concept, was started. The SPEW manager should improve the performance of available countermeasure equipment such as jammers, radar warners and decoy dispensers while reducing the workload of the pilot. The project is carried out in co-operation with the TNO Physics and Electronics Laboratory (FEL).

Military Flight Support
Support has been provided to the RNLAF on the tactical and operational use of the F-16 aircraft and on the safety analysis of the air show programmes for the Lockheed Martin F-16 and the Pilatus PC-7 aircraft.
Performance models of aircraft that could act as opponent to the F-16 have been created. These models are subject to a continuous validation process in order to improve their reliability.
The software used for thè calculation of aircraft performance and trajectories has been updated.

V/SHORAD
NLR participated in the NATO feasibility study (Very)/SHOrt Range Air Defense Systems (V/SHORAD) as a subcontractor to Fokker Space. NLR contributed in the Command and Control and Target Sensor working groups. The project was completed.

ULT-JOIND
The ULT-JOIND (Unit Level Trainer Joined Operations Integrated Network Demonstrator) project was started. The purpose of this project is to investigate and demonstrate the applications of networked simulation for the RNLAF. It is carried out in a consortium with TNO Physics Electronics Laboratory (FEL) and Fokker Space, for the RNLAF. In the project, the Unit Level Trainers (ULTs), fixed-based F-16 MLU simulators of the RNLAF will be linked to a number of simulation facilities in the Netherlands in one complex Synthetic Environment. The simulation

facilities include air defence systems such as the Patriot and Hawk, Command & Control stations, a Forward Air Controller simulation and the National Simulation Facility (NSF) and ITEMS of NLR. Apart from providing the NSF and ITEMS, NLR also provides the expertise in RNLAF F-16 operations, needed to assess the potential use of networked simulation.

IFPC

The IFPC (Integrated Flight Propulsion Control) project was started. The purpose of this project was twofold. First, to develop an interfacing method to enable swift implementation of Matlab/Simulink-generated C-code into the simulation software of the NSF. Second, in order to be able to gain experience in the field of thrust vectoring, to apply the developed interface method to implement modified flight control law software and a thermodynamic model of the F100-PW220 engine with controllable nozzle angles in the F-16 simulation software. Additions to the standard F-16 MLU HUD format were made, to support high-angle-of-attack operations.

Distributed Simulation of F-16 Mock-up and NSF

Several F-16 MLU flight simulation facilities of NLR were linked together in an attempt to demonstrate the technical capabilities. These facilities were the NSF, the Generic Cockpit Mock-up, AVIATOR and ITEMS. AVIATOR is a desktop simulation, using simulation software that is identical to the software used in the other two facilities. As a consequence, three different levels of 'cockpit fidelity' could be demonstrated in the same synthetic environment.
The link between the local facilities was based on SCRAMNet. Other facilities can be connected through a standard DIS/HLA interface.

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'.

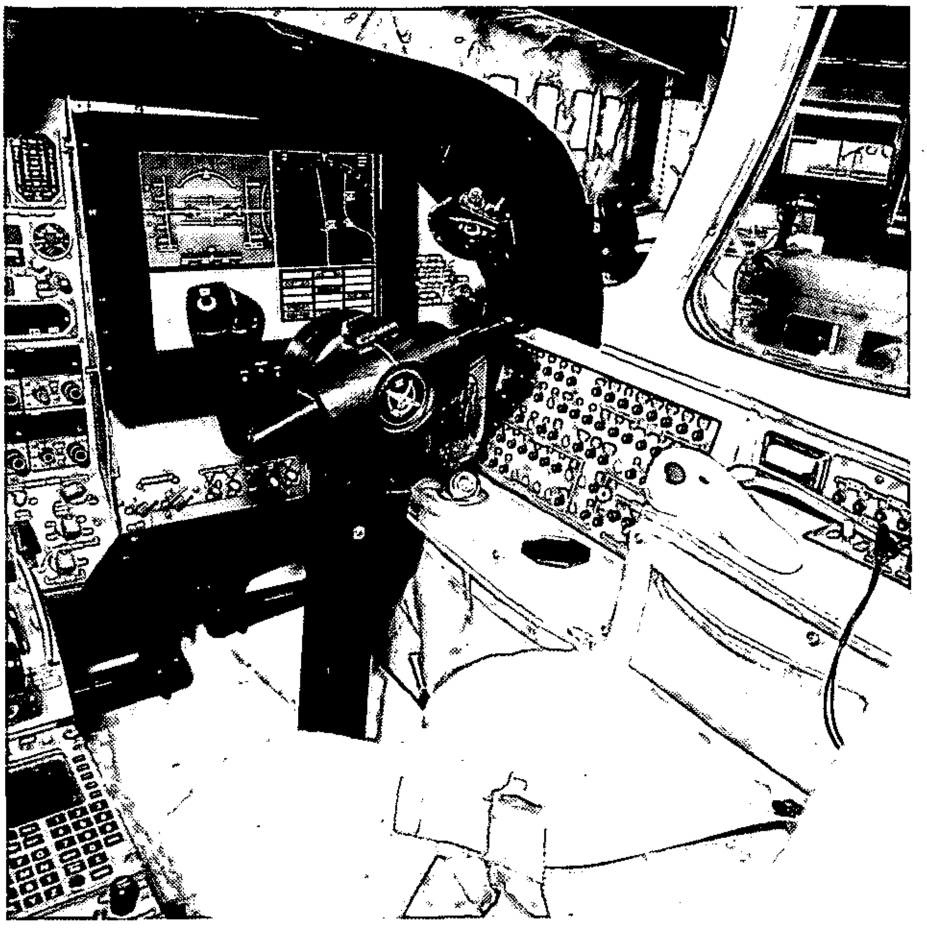
NLR participated in the EU Fourth Framework projects HELIFLOW (Improved Experimental and Theoretical Tools for Helicopter Aero-mechanic and Aeroacoustic Interactions), RESPECT (Rotorcraft Efficient and safe Procedures for Critical Trajectories), ROSAA (Rotorcraft Simulation with Advanced Aerodynamics) and EURICE (European Research on aircraft Ice CErtification).

In co-operation with Fokker Aerostructures and SP Aerospace and Vehicle Systems, NLR continued its participation in the Design and Development phase activities of the NH90 programme. One wind tunnel test campaigns was conducted in the DNW Low Speed wind Tunnel (DNW-LST). One employee was co-located at Eurocopter's flight test centre at Marignane as a member of the NH90 international flight-test team.

Support to the Royal Netherlands Air Force (RNLAF) was continued in the area of the CH47 D Chinook Avionics Control & Management System (ACMS) improvement. A familiarisation study has been conducted in applying the FlighLab computer code, capable of predicting and analysing helicopter flight performance and handling quality characteristics, among other things. Activities were started to apply the code to the helicopters operating in the Netherlands at present or in the near future.

Under contract to the Royal Netherlands Navy (RNLN), flight tests with Lynx helicopters were performed onboard the new Amphibious Transport Ship (LPD). Preliminary SHOLs (Ship Helicopter Operating Limits) were determined. In the framework of the Lynx helicopter life extension programme, the RNLN was supported with the installation and certification of an AIDA (Automatic In-flight Data Acquisition) system.

Helicopter take-off and landing operations are limited by the platform's surface friction, among other things. Under contract to the RLD, the characteristics of the Helicopter Friction Tester (HFT), which is currently in use to measure surface friction, were further evaluated, and additional experiments were executed.



Cockpit of the Citation II research aircraft used in PHARE Demonstration 3 flight tests

Aircraft Operations

Research Aircraft

Fairchild Metro II

Intensive use of the Metro II research aircraft continued for the flight inspection of the radio navigation and landing aids in the Netherlands, under contract to Air Traffic Control the Netherlands (LVNL). A total of 358 flight hours has been made.

Cessna Citation II

A number of flights have been made with the Phased Array Universal Synthetic Aperture Radar (PHARUS) for various purposes including town and country planning and testing technical improvements. In addition, flights have been made to demonstrate the capability to use interferometric techniques for repeated flight paths over the same ground positions. This application required the use of NLR's highly accurate Position Reference System.

In the framework of European programmes, tests have been performed with the Experimental Flight Management System (EFMS), in support of the PHARE Demonstration project PD/3, and with the Advanced Flight Management System (AFMS). In these projects VHF and satellite data links were successfully used to exchange ATM flight plans between the airborne equipment and NARSIM. Apart from testing the experimental flight management systems the airborne tests were also used to test human-machine interfaces.

For the measurement of drag caused by snow on the runway, tests have been performed on a specially prepared runway (partially covered with natural snow and partially cleared for acceleration and deceleration) at Skavsta airfield in Sweden. For this test the Citation has been equipped with accelerometers, wheel speed sensors, data registration and video equipment. The tests were part of an EU project aimed at improving the airworthiness requirements for aircraft operations on contaminated runways.

Transport and Environmental Studies

Noise abatement research

Advanced Continuous Descent Approaches

New, environmentally friendly procedures are becoming feasible with the introduction of new approach, navigation and flight management systems. Recent examples are the current Continuous Descent Approaches (CDAs) on runway 06 of Amsterdam Airport Schiphol. Although this procedure has very good noise abatement characteristics, its applicability is limited because it reduces the runway capacity considerably, as increased separation intervals of 4 minutes instead of 1.8 minutes are applied. The reason for increasing the separation is the fact that ATC has to release the aircraft already in a very early phase of the approach, which makes the predictability of its arrival time over the runway threshold very poor.

NLR is seeking improvements to the CDA procedure with the objective to reduce the separation interval to the usual value. The way to achieve this is to guide the aircraft along a fixed approach path that is both laterally and vertically defined and to monitor and control its estimated arrival time over waypoints. Because of the substantial energy bleed-off, required during an approach (from a high altitude/high speed condition to a low altitude/low speed condition) this can be achieved according to a decelerated approach with the engines running in an almost flight-idle condition. Only when at low altitude the final approach configuration is obtained, the throttles move forward to the normal final approach power settings.
Software was developed for an Advanced CDA (ACDA) mode in the RFMS. A demonstration of the successful operation of a first version of this mode was presented on the RFS.

Technical Operational Measures Schiphol

Research on three Technical Operational Measures at Schiphol (TOMS) was carried out under contract to the RLD. The three measures concerned reduced-flaps approach, 3.2° glide slope approach and 3000 ft final approach altitude. The data for the evaluations have been obtained from flight simulator measurements on training simulators of KLM (MD-11, Boeing 747-400 and Boeing 737-400). The results of the reduced-flaps approach and the 3000 ft final approach altitude show that modest noise benefits can be achieved by these measures [see for example figures X and Y]. The KLM fleet has already implemented the reduced-flaps approach. In consultation with LVNL and RLD, a supplementary study has been initiated into possible adverse effects of the 3000 ft approach altitude on airport capacity.
The 3.2° approach did not show a significant contribution to noise abatement, whereas on the other hand, as a result of deviating from the ICAO 3.0° standard glide slope value, political problems are foreseen if this measure were introduced.

Study of Optimisation Procedures for Decreasing the Impact of Noise around Airports

Within the Fourth Framework Programme, in December, the kick-off meeting was held for a project called SOURDINE (standard musical terminology for 'mute' – Study of Optimisation procedURes for Decreasing the Impact of NoisE around airports. This project aims at defining new flight procedures leading to the reduction of noise in the vicinity of airports and the requirements for supporting tools. The fulfilment of the SOURDINE objectives requires a large spectrum of expertise. The consortium involves ATC system providers, research centres, an airframe manufacturer, an airline, Civil Aviation Authorities (including the RLD) and Airport Authorities, with support of ATC agencies. NLR is a major contributor to this project and is leader of the work package concerning the establishment of noise abatement solutions in which both short term and medium term noise abatement solutions are considered. The effect of these procedures will be evaluated for airports Amsterdam Airport Schiphol, Napoli Capodichino and Madrid-Barajas. The project will have a follow-up in the Fifth Framework programme.

Policy Analysis

Under contract to the government, assessments of the future development of noise exposure in relation to potential improvements in aircraft technology and aircraft management were carried out.

Air Pollution
Under contract to the European Commission, the study AEROCERT (Aircraft EnviROnmental Impacts and CERtification Criteria) into options for possible improvement of the existing certification procedures for emission of noise and exhaust gases was continued. AEROCERT is carried out by several partners in Europe. NLR is project co-ordinator.

NLR contributed to the EU thematic network on Identification of Aircraft Emissions Relevant for Reduction Technologies (AERONET). AERONET's expert group on Operations and Forecast of Air Traffic Development is co-ordinated by NLR.
In co-operation with Resource Analysis of the Netherlands and MVA of the UK, NLR was involved in the further development of AERO, a computer model for 'Aviation emissions and Evaluation of Reduction Options'.
Under contract to the International Air Transport Association (IATA), NLR continued a study into operational measures to reduce aviation emissions.
Supported by the Netherlands government, NLR is involved in the realisation of a report on 'Aviation emissions and the global atmosphere' which is realised by the Intergovernmental Panel on Climate Change. NLR as Co-ordinating Lead Author is responsible for the chapter on Air Transport Operations and the Relation to Emissions.

Noise Exposure
Noise exposure was calculated for actual and future situations at several airfields in the Netherlands. Under contract to the government, the actual noise exposure around Amsterdam Airport Schiphol was analysed and checked against the permitted noise budget.

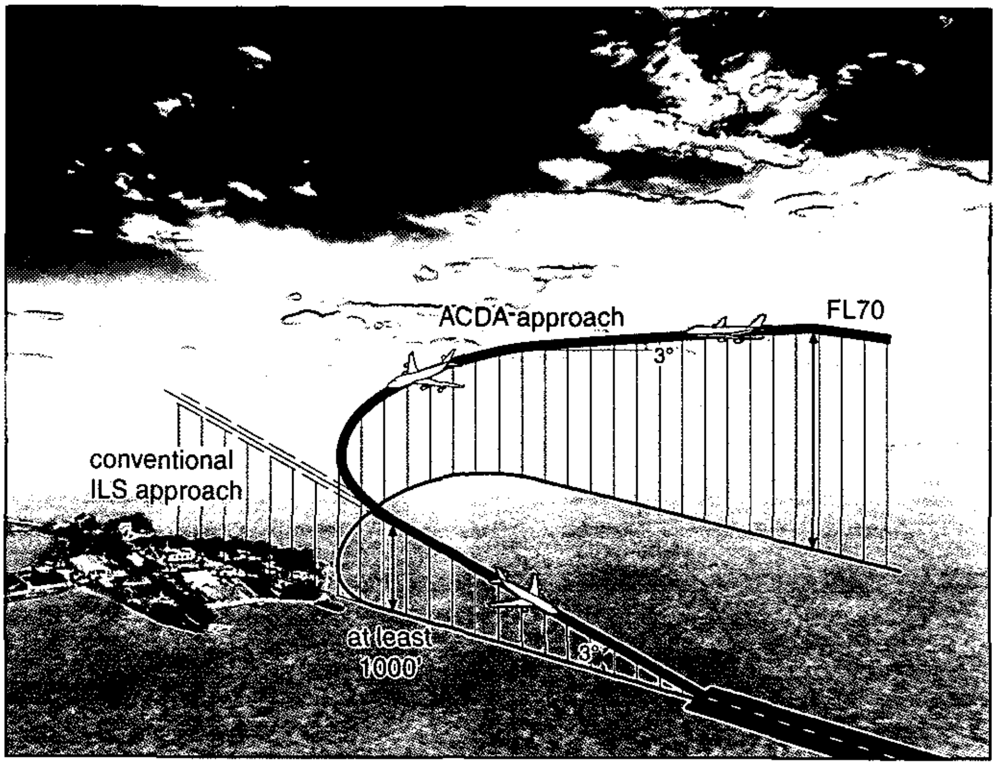
Studies into the environmental consequences of additional infrastructure were performed.
In addition, NLR performed research into the basic information required for noise exposure calculations, such as noise and performance characteristics of aircraft and dispersion in flight tracks.

Monitoring of Environmental Aspects
Under contract to the Netherlands Ministry of Housing, Physical Planning and the Environment, NLR analysed flight tracks and the related noise exposure for the surroundings of Brüggen and Geilenkirchen airbases. Under contract to the Netherlands Ministry of Transport, and under contract to the Air Traffic Control the Netherlands (LVNL), NLR worked on extensions of the functionality of FANOMOS (Flight track and Aircraft NOise MOnitoring System). The extended FANOMOS will perform the following functions: track and noise monitoring, calculation of noise exposure and matching of information on noise to recordings of flight tracks, complaints and flight plans.

Human Factors of Airport Hindrance
NLR participated in a study assessing the effects of excessive noise around secondary airfields in the Netherlands. This study concerned the potential physiological and emotional implications of such noise.

Accident Investigations
Support was given to the Netherlands Bureau for Accident and Incident Investigation concerning the incident with a B757 aircraft, which made a seemingly hard landing and veered off the runway at Amsterdam Airport Schiphol. Flight data was analysed, initially to see if windshear could be a factor in the incident. In addition some data was reconstructed using a flight-control model, where the hydraulics was modelled to simulate the transport delay of the pilot's cockpit control inputs to the relevant control surface deflections. Windshear could be ruled out as a factor of influence.

Third Party Risk Analysis for Airports
A considerable number of risk calculations was carried out for future traffic scenarios at a number of candidate future airport locations as part of the TNLI programme (TNLI: Future Netherlands Air Transport Infrastructure). Due to the fact that causal models for aviation safety are not yet available, considerable effort was spent on estimating future developments in aviation safety in order to arrive at adequate risk estimates.
A third party risk analysis was completed for the



Schematic of Advanced Continuous Descent Approach

airport of Rotterdam as input for the decision making process regarding the future development of the airport. Under a contract to the National Institute of Public Health and the Environment (RIVM), third party risk calculations were carried for Amsterdam Airport Schiphol. This work was part of the annual national review by the RIVM of the state and development of the environment. NLR supported a governmental working group tasked with the preparation of a government policy of third party risk around airports. This support included the conduct of trial third party risk calculations for a regional airport.
In the ongoing project on the development of third party risk calculation methods and models for military airbases under contract to the Ministry of Defence, some input data for model development were analysed.

An aircraft impact risk analysis was carried out for the Barsebäck nuclear power plant in Sweden. The analysis mainly concerned the calculation of impact probabilities related to air traffic of the nearby Kastrup airport (Denmark) and general aviation traffic in the Malmö FIR (Flight Information Region).

Facilities and Equipment

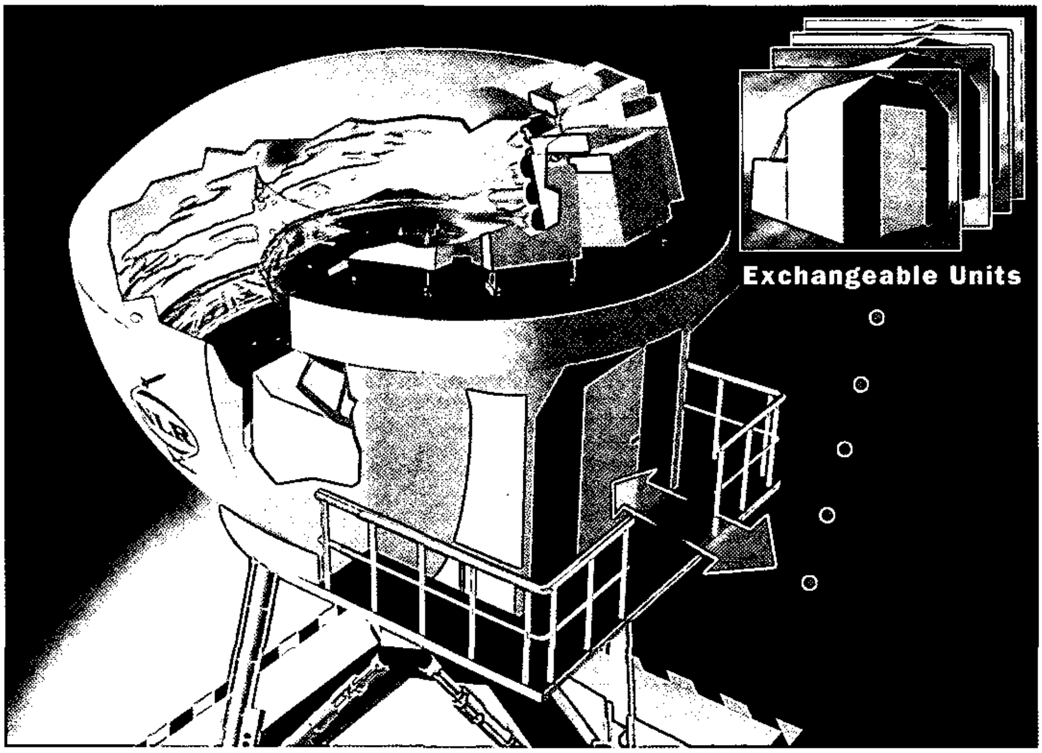
NLR Air Traffic Control Research Simulator
In order to run the PD/3 demonstrations, the NLR Air Traffic Control Research Simulator (NARSIM) was extended both in software and hardware. Most significant developments on the software side were the integration of the PHARE Advanced Tools (PATs) and the development and integration of an advanced Ground Human Machine Interface (GHMI). These developments were an important challenge for the NARSIM Client Server middleware that has been developed by NLR. The maximum number of servers was doubled twice for PD/3, giving a total capacity of 127 servers. The hardware of NARSIM was extended (temporarily) to cater for the large number of simulation positions. There were eight Sony 2k*2k displays, twenty-two computers, eighteen X-terminals and seven large workstation displays. In the final PD/3 simulations seventy-five servers were running simultaneously across all this hardware. Both the scalability and the flexibility of the NARSIM middleware proved their merit. In PD/3 a new integrated software version control and problem tracking system was applied, which has been used in many other projects as well.

NARSIM also participated in two projects, of which the results will be used to expand its capabilities. The EU project Platform for ATM Tools Integration up to pre-Operation (PATIO) has been successfully completed. It is an integration and experimental ATM simulation platform for the European community in order to provide support in their research, development and validation initiatives. The most important outcome of the project for NARSIM is GLASS, the Generic Library for Air traffic Simulation Services, a flexible and modular software package capable of simulating air traffic for a wide variety of exercises, in which the aircraft can fly completely autonomously or controlled by pseudo pilots.

Traffic Organization and Perturbation Analyzer
The Traffic Organization and Perturbation Analyzer (TOPAZ) facility continues to assist the safety assessment and model-based concept validation studies. In contrast to traditional ATM design approaches, TOPAZ emphasises an overall validation approach that views safety as the result of complex interactions between all ATM elements. The activities comprised the expansion of TOPAZ software modules with more advanced modelling capabilities, starting with the implementation of a future ATM scenario and the completion of a document containing the available TOPAZ software.
TOPAZ was used for an accident risk assessment with a human cognition model and served as a platform for new applications such as the development of models for human safety aspects and wake vortex induced risk.

Total Airspace and Airport Modeller
The Total Airspace and Airport Modeller (TAAM) is a workstation-based tool for the simulation of airspace and airport operations. It provides both fast-time and real-time evaluation capabilities in a gate-to-gate model simulating in detail: pushback, runway taxiing, en-route flight, approach and landing in one seamless application.
Work with TAAM was conducted to support policy decisions for the Future Netherlands Air Transport Infrastructure (TNLI) and to analyse the impact of accommodating near-future traffic amounts in the cases of an alternative to Amsterdam Airport Schiphol, reconfiguring Schiphol and moving all operations to a new site, in the North Sea. Airspace and route interference with other airports was researched as well as controller workload for the new traffic situation and the punctuality of operations at the airport considered.

Visualization of calculated risk contribution from air traffic around Amsterdam Airport Schiphol. White lines show runways, and blue dotted lines indicate the borders of water areas. Colours from bright yellow through red to black indicate the combination of accident probability and population density



Artist's impression of the RFS after the update

For the Spanish Air Traffic Control organization AENA, under contract to INECO, several studies were conducted to re-sector current ATC sectors because of new traffic routings. Also, several route alternatives were researched for the air shuttle between Madrid and Barcelona.
For Düsseldorf Airport some newly proposed layouts of future runway and taxiway systems were evaluated on capacity and bottlenecks.

Tower Research Simulator

The development of a Tower Research Simulator (TRS) was continued with the fixation of the User Requirements and the System Requirements. The TRS is a real-time man-in-the-loop simulation environment were the air traffic controller will be supplied with 'normal' tower and ground controller equipment and a high-fidelity out-the-window synthetic view of an airport.
An ergonomic tower controller working position console was designed and built. It provides numerous possibilities to install displays and input devices to optimise the controller working positions. Several high-performance computer systems were installed to form the computing infrastructure of the TRS.

Research Flight Simulator

Modifications were made to the Research Flight Simulator (RFS) for a multitude of simulation experiments and configurations.

In the next few years the RFS will undergo a major upgrade. The first milestone was reached by the procurement of the flight simulator cab, a generic transport aircraft cockpit. This cab will be developed, manufactured and installed by a consortium of Dutch industries headed by Siemens Nederland N.V. The generic simulator cab will become operational during the first quarter of the year 2000. Initially, it will be used while mounted on the existing six-degrees-of freedom motion system of the National Simulation Facility (NSF). The second phase of the RFS upgrade will comprise the procurement of a high-performance six-degrees-of-freedom motion system, a wide-angle field-of-view collimated projection display and a powerful image generator.

A study focused on the replacement of seven large graphical workstations providing the pilot displays in the RFS cockpit and the generic mock-up has been completed.

The model board visual system has been phased out. Until the procurement of a new advanced visual system, the Evans and Sutherland ESIG 3000 AT/GT image generator of the NSF will provide the outside visual in the RFS.

The modification of the simulation software structure of the RFS, to harmonise the NSF and RFS simulation software environments, has been finished. The Micro Five host computer has been phased out, and currently SGI Challenge host computers are used for both software development and real-time simulation.

National Simulation Facility

The F-16 cockpit of the National Simulation Facility (NSF) was equipped with an Electronic Warfare Management System (EWMS) for experiments within the MLU co-development projects. The manufacturer, TERMA, has changed the software of the EWMS to comply with the simulation requirements of the NSF.

Generic Mock-up

The computer systems and the out-of-the-window generation software of the generic mock-up have been replaced to enable the mock-up to fulfil the real-time and deterministic project requirements. Both a real-time database visualisation software package, VEGA, and a database generation software package have been procured, providing the capability to create, import, change and visualise almost any database needed for projects using the mock-up. The database generation software package comprises a database terrain modelling tool 'Terra Vista', a three-dimensional modeller tool 'Multigen II Creator Pro' and an OpenFlight file converter 'OKINO PolyTrans'. These tools will also provide support in the database generation of other flight simulation facilities at NLR, for example at the realization of the Tower Research Simulator.

Helicopter Mock-up

To enable pilot-in-the-loop evaluations of helicopter models to be performed, it has been decided to develop a helicopter mock-up. An electrical control loading system consisting of a cyclic, collective and rudder pedal assembly has been ordered from Fokker Control Systems.

Future Aircraft Systems Testbed

Major progress was made in the development of the Cessna Citation Future Aircraft Systems Testbed (FAST).
A central Flight Test Console was produced and installed in the aircraft. It includes new interface software for controlling and monitoring the experimental systems on board the aircraft.
The aircraft was prepared for participation in the PHARE PD/3 flight demonstration programme. This preparation included the development of 4D navigation functionality and the integration of the Eurocontrol Experimental Flight Management System (EFMS) with the FAST computer system architecture. Successful shakedown flights for the programme were carried out in January, and the final PD/3 flight demonstration took place in June. Although only a limited number of flights could be carried out, a successful demonstration of the future ATM concept, including datalink communication was given.

The preparations for the flight programme for the EU AATMS (Airborne Air Traffic Management System), aimed at the demonstration of the Euro-Telematik Advanced Flight Management System (AFMS), were also completed. Owing to the flexible set-up of the FAST architecture, many components could be re-used. A new development concerned the coupling of the AFMS, via the FAST flight control and display computer, to the autopilot of the Citation, such that 3D trajectories could be flown automatically. Shakedown flights with this configuration were carried out and the feasibility of automatic vertical and lateral navigation capability was demonstrated. The final AATMS flight demonstration programme was executed successfully.

A new and modern target computer system, including a sophisticated real-time operating system, was acquired for FAST. Further developments will focus on the implementation of (research) flight management functionality, in-flight human performance measurements, and extensions to the ground test and integration facility.

3.3 Structures and Materials

Introduction

Research and development activities in structures and materials were executed in the areas of loads, fatigue and structures technology, and in further improvement and extension of the laboratory facilities and measurement techniques.

Work was done under contract to, among others, the Netherlands Agency for Aerospace Programmes (NIVR), the Royal Netherlands Air Force (RNLAF), the Royal Netherlands Navy (RNLN), the Netherlands Department of Civil Aviation (RLD), the European Union, the Stork Aerospace Group and various other aerospace- and aeroengine-related industries.
In co-operation with industries, a significant effort was devoted to the definition of technology readiness projects, in the framework of Netherlands participation in the US Joint Strike Fighter (JSF) programme.
The total volume of contract research has increased by 25 per cent compared to 1997.

Loads and Fatigue

Aircraft Loads and Certification

The design criteria for continuous turbulence in current airworthiness requirements are not applicable to non-linear aircraft, equipped with active control systems. Under contract to the Netherlands Department of Civil Aviation (RLD), NLR has evaluated three simplified methods, so-called Deterministic Power Spectral Density (PSD) methods, and compared them with the Stochastic Simulation Method, whereby the design loads of the non-linear aircraft are obtained from response calculations in the time domain on turbulence patches with prescribed statistical properties. None of the deterministic PSD methods showed sufficiently reliable results. NLR has brought these results in into the RTO (formerly AGARD) Working Group 29 'Design loads for future aircraft'. The goal of this Working Group is to write an advisory report on this subject.
NLR has taken part in the Gust Specialist Meetings held twice a year under the aegis of the US Federal Aviation Administration (FAA) to discuss aspects of flight in turbulence and associated airworthiness rule making.

Under contract to the US Federal Aviation Administration (FAA), through RLD, NLR participates in the FAA's Flight Loads Programme. NLR participates in the analysis of flight loads data supplied by NASA, to determine required sampling rates for on-board aircraft loads/flight data recorders.

Under contract to the Netherlands Agency for Aerospace Programmes (NIVR), NLR evaluates various steady and unsteady aerodynamic methods to calculate lateral gust loads on aircraft. Of particular interest is the AESIM programme, which is also being developed by NLR under contract to NIVR. This study was finalized.

Load and Usage Monitoring

The Fatigue Load Monitoring programme of Lockheed Martin F-16 aircraft of the Royal Netherlands Air Force (RNLAF) has been continued. The RNLAF has procured new, advanced fatigue load monitoring equipment, called FACE, for the F-16s, based on specifications made by NLR. Load measurements will be carried out in each of the aircraft of the fleet. Quantities measured include strains in five different structural locations and a number of engine usage parameters. At the end of 1998, about 73 F-16s were provided with the FACE equipment. The Central Logistic Ground Station has been installed at NLR. This station was connected to four ground stations located at the squadrons, and monitoring was started. For storing and analysing the measured data, the relational data base program ORACLE was selected. Applications for the F-16 data base were written

Engine cycles are recorded on a sample of the fleet of Westland Helicopters Limited Lynx helicopters of the Royal Netherlands Navy. New instrumentation, named AIDA, to replace the equipment in use has been procured, based on specifications made by NLR. Work has been done for the development and certification of the hardware and software, in close co-operation with the manufacturer. The equipment will be installed fleetwide.

For the RNLAF, the preparation of a load measuring programme for the Lockheed Martin C-130 Hercules fleet was started.
For the Royal Netherlands Navy and the Portuguese and Spanish armed forces, load monitoring was being carried out on Lockheed P3 Orion aircraft.
On behalf of the Royal Netherlands Navy, NLR participates in the Service Life Assessment Programme (SLAP) and Service Life Extension Programme (SLEP) for the Orion aircraft. The SLAP/SLEP is a collaborative programme between the US Navy, the Canadian Forces, the Australian Forces en the Royal Netherlands Navy. As part of this programme a full-scale fatigue test on an Orion aircraft will the performed in the USA.

The Joint Strike Fighter (JSF) is being developed in the USA. To reduce maintenance costs, the JSF will be equipped with an advanced 'Prognostics and Health Management' (PHM) system. NLR takes part in a Dutch consortium that will develop parts of this PHM system. A programme has been defined and discussed with US manufacturers Boeing and Lockheed Martin, for the development of new PHM technologies. A main feature of this technology programme is that PHM technologies will be demonstrated in an F-16 environment using the advanced monitoring system FACE.

Gas Turbines

Methods to analyse the life of gas turbine components under service loading are being developed.

Under contract to the NIVR, a multidisciplinary project to determine the service life of gas turbine components by thermo-mechanical modelling was continued. The objective is to compute the service life of turbine blades by numerical analysis, and to establish the effects of various coatings on service life. The effect of the presence of cooling channels is also taken into account. The analysis tools to calculate the heat transfer, the temperature distribution and the thermal stresses in the engine components were developed. Models to calculate the life of the components have been reviewed.

In another NIVR programme, a method was developed and applied to determine the blade metal temperature experienced in service. This method is based on a non-destructive replication technique that reveals the microstructural degradation. It is applied to in-service exposed blades, originating from industrial gas turbines. The method and data obtained will be used to estimate residual lives.

Thermal Barrier Coatings (TBCs) applied by Electron Beam Physical Vapour Deposition (EB-PVD) are in service on internally cooled first-stage and second-stage turbine blades in the hot sections of gas turbines. NLR evaluated several coating systems for the Dutch Industry. Burner rig tests were performed to test the life of the coating system. The projects, funded by the Ministry of Economic Affairs' agency Senter, formed part of the cluster project EB-PVD Technology Development.

NLR participates in a national programme for investigating the necessity of coating internal cooling channels in turbine blades and vanes. This programme is conducted by the Dutch Gas Turbine Association (VGT). A review of requirements of internally applied coatings was made.

Failure Analysis

Several service failures related to the RNLAF F-16s were examined.
Although most service failures are related to fractures and/or cracks, other defects can also lead to malfunctioning. For example, some seat actuator bumpers malfunctioned because of severe deformation. The use of an alternative bumper material was proposed by the RNLAF. NLR carried out static and dynamic tests to compare the current and the alternative material. The alternative material performed better, and permanent deformation was not expected to occur under in-service loads.

During inspection a rudder trim bracket of a Pilatus PC-7 was found broken. Fractographic analysis showed that the bracket failed by fatigue. The bracket was prone to fatigue cracking because decarburization of the surface layer of the bracket led to a marked reduction in fatigue strength.

Several non-aerospace service failures were examined. A failure analysis was carried out on pre-loaded bolts that were installed in an air suspension system. The failures occurred after several days or after some weeks after installation. The broken bolts all came from the same batch. The examination led to the conclusion that the presence of hydrogen in conjunction with pre-existing cracks, which resulted from the forging process, led to crack growth by hydrogen embrittlement and final failure.

Fatigue and Damage Tolerance

Structural safety associated with the damage tolerance of lap joints in ageing aircraft is addressed in a programme under contract to the RLD, co-funded by the US Federal Aviation Administration (FAA). In particular the residual strength of a lap joint with multiple cracks is analysed.

The ageing aircraft issue is studied in the BRITE/EURAM (Basic Research of Industrial Technologies for Europe/European Research on Advanced Materials) programme SMAAC (Structural Maintenance of Ageing Aircraft). In the framework of this programme a computer program for the prediction of crack initiation and growth of multiple cracks in lap joints is being developed. A computer program for the prediction of the residual strength of stiffened panels with multiple cracks was made.

In the field of crack growth in metal structures, an existing collaborative programme with the Indonesian aircraft manufacturer IPTN was continued.

Statistical methods have been evaluated to review their applicabilities to risk assessment of cracked structures. The analysis methods, the number of necessary analyses and the required statistical information on the input parameters have been investigated.

A collaborative programme with the Portuguese Air Force, for the assessment of the severity of their aircraft usage using advanced load monitoring and damage tolerance analysis methods, was continued.

Structures Technology

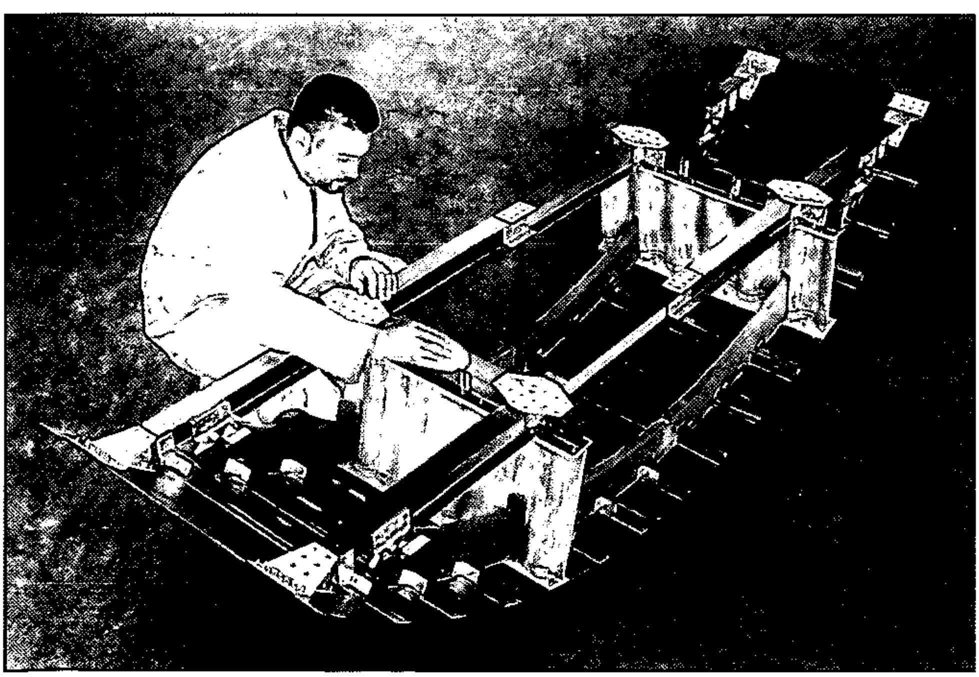
Design and Design Methods

Composite materials are increasingly being used in commercial and military aircraft. Compared to metal aircraft structures, the design methodology for structures made of composite materials is quite different. The anisotropic and heterogeneous nature of the materials results in different failure modes and mechanisms. Because design methods are often lacking, design is mostly based on the results of extensive test programmes. Whereas impact damage and the resulting loss of static strength are major design drivers for composite structures, fatigue loading is a major design driver for metal structures. With the introduction of new alloys and more efficient fabrication techniques, design methodology for metals must also be improved. The development of design methods is a major research activity of NLR, often carried out in international co-operation.

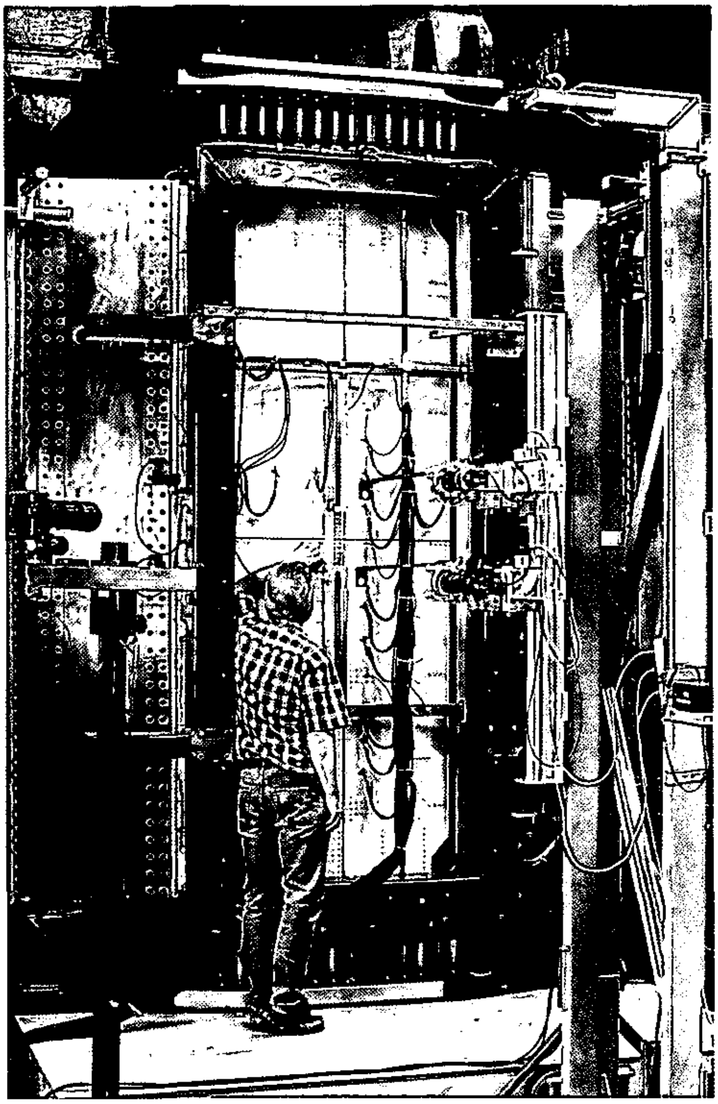
A project under contract to the NIVR to develop design methods for strength prediction of composite structures, both in undamaged and damaged condition, was completed. Part of this work was carried out in GARTEUR (SM) AG 22 (Design Methodology for Damage Tolerant Composite Wing Panels) under NLR leadership. The work is now being continued in the multinational programmes EDAVCOS (Efficient Design and Verification of Composite Structures) of BRITE/EURAM and DAMOCLES (Damage Management of Composite Structures for Cost Effective Life Extensive Service), a military programme carried out with DERA of the UK and FFA of Sweden. Expertise gained in the area of design and design optimization of composite structures was used in various programmes, such as the BRITE/EURAM programme CRASURV (Crash Survivability of Composite Aircraft Structures) for which a crashworthy sub-floor structure of a commuter aircraft was designed. Several stiffened panels were optimized using panel optimization code PANOPT, for an NIVR project focused on the development of fabrication technology for Resin Transfer Moulding (RTM). Within the framework of a national technology programme for SP Aerospace and Vehicle Systems, a set of torque links and a trailing arm,

of composite materials, were designed for application in helicopter landing gears. For landing gears the advantages compared to metals are not only lower weight, but also lower production costs and natural resistance to fatigue and corrosion.
On request, design capabilities developed for aerospace structures are also being used for non-aerospace customers. In this respect, several carbon-fibre masts and a boom were designed using the B2000 optimization code for yachts built by Royal Huisman Shipyard. The masts are very large structures, with lengths up to 57 metre and weights of up to 3 tonnes. Design optimization methodology has also been used for the design of a window section of a GLARE fuselage in BRITE/EURAM programme ADPRIMAS (Advanced Concepts for Primary Metallic Aircraft Structures). A composite leading edge structure was designed to resist bird impacts, on the basis of an innovative stretchable composite skin concept. This design will be evaluated within the framework of GARTEUR (SM) EG-22.

Structural Validation and Certification
The final evaluation of a structural design as well as of newly developed design methodology requires full-scale component testing. Fokker's design of a composite horizontal stabilizer as well as the underlying design methodology have been evaluated in a static and fatigue test programme on a major part of the load carrying structure. After saturation during a 9-month period in a hot/wet environment of 70 C and 85% humidity, a fatigue programme of 90,000 flights was carried out successfully, while the structure contained non-visible impact damages. These damages did not propagate during the fatigue programme, and afterwards the structure could even be loaded up to Design Ultimate Load without failure. A technology project for URENCO Aerospace to develop a composite helicopter drive shaft is being carried out. This project also requires the testing of full-scale components for a validation programme under environmental conditions. In BRITE/EURAM programme SMAAC (Structural Maintenance of Ageing Aircraft) large full-scale fuselage panels were tested for Airbus and Alenia aircraft to study the growth of multiple site damage in stiffened lap-joints of aluminium panels. In the programme ADPRIMAS (Advanced Concept for Primary Metallic Aircraft Structures) of the EU, similar tests are being prepared for fuselage panels with window cut-outs, made of GLARE by Shorts, to demonstrate the technological feasibility of GLARE fuselages. These panels are tested in a specially developed fuselage panel test set-up, in which panels are subjected to circumferential loads caused by in-plane pressure and axial loads, representative of cabin pressure and fuselage bending (due to taxiing and gust loading).



Crashworthy sub-floor structure designed and fabricated in the EU programme CRASURV (Crash Survivability of composite Aircraft Structures)



Fuselage panel of an ageing Airbus A300 tested in the EU programme SMAAC (Structural Maintenance of Ageing Aircraft)

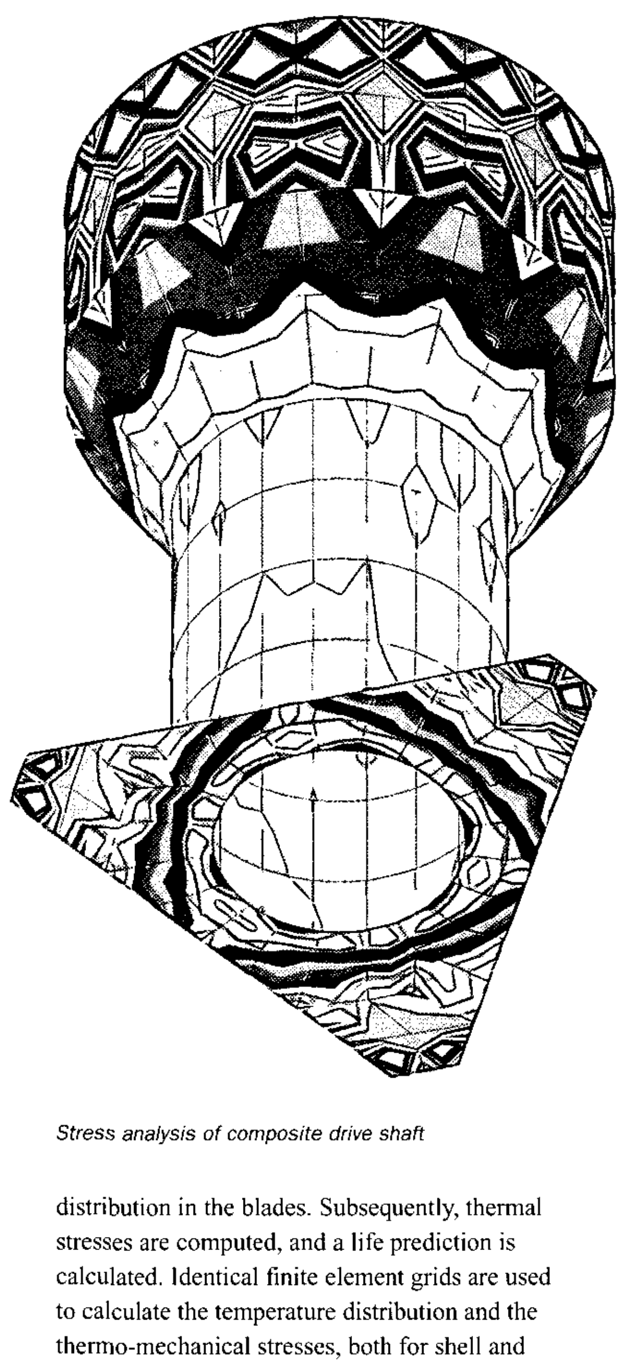
Computational Mechanics

Within the framework of the NIVR space programme NRT, a corrosion fatigue crack growth model was developed and implemented in NASGRO (a NASA/ESA crack growth programme), and successfully validated for simple configurations. Also, a special 'piezo' finite element has been developed to simulate active damping of vibrating structures, and to optimize the locations of the piezo-electric material. This topic is of interest to space applications and for equipment isolation in military aircraft and helicopters, and is addressed in co-operation with international partners in GARTEUR Action Group (SM) AG-23 (Active Equipment Isolation and Structural Damping). The interest of the Ministry of Defence in the subject has resulted in NLR's participating in the EUCLID programme VIBRANT (Vibration Reduction by Active Control Technology). The damping of vibrations and noise becomes increasingly important for the Royal Netherlands Air Force and Navy, with the introduction of a range of new helicopter types, including Chinook helicopters with improved vibration characteristics. NLR is monitoring the information on this issue provided by the manufacturer. For the USAF and DWA, manufacturers of Metal Matrix Composites (MMC), stress analyses are carried out of the F-16 engine access cover with ventral fins. The objective is to evaluate the influence of structural modifications, including the use of MMC, on the stress distribution.

The expertise of NLR in the area of fatigue and damage tolerance has been further developed and applied under various contracts. Residual strength and risk assessment were topics addressed in BRITE/EURAM programme SMAAC (structural maintenance of ageing aircraft).
Optimization of aircraft design was the subject of GARTEUR Action Group (SM) AG-21 (Multi Disciplinary Wing Optimization), which, under NLR leadership, focused on wing design with flutter constraints in co-operation with the Delft University of Technology. Structural optimization exercises have also been carried out with B2OPT, an optimization module of the B2000 finite element code developed by NLR. In particular, the ADPRIMAS GLARE fuselage/window structure, the landing gear torque links for SP and the carbon fibre masts for Royal Huisman Shipyard were all designed with the help of this optimization code.

Crash and impact are relatively new areas of interest that reflect NLR's aim of improving the safety of aircraft and operations. The major objective of BRITE/EURAM programmes CRASURV and HICAS (High Velocity Impacts of Composite Aircraft Structures) is to develop computer codes to model crash scenarios and bird impacts for composite aircraft structures. NLR has contributed to the design of a crashworthy sub-floor structure of a composite fuselage of an ATR-type commuter aircraft, and with the development of material models. For the RLD, a computer code is being developed to model the collision of an aircraft with approach light structures near runways. The code has been validated by comparison with test data obtained with wing sections hitting realistic approach light structures at 140 km/h.

A multidisciplinary project is being carried out under contract to the NIVR, to determine the service life of gas turbine components by thermo-mechanical modelling. The objective is to compute the service life of turbine blades by numerical analysis, and to establish the influence of various coatings on service life. The effect of the presence of cooling channels is also taken into account. The analysis starts out by determining the heat transmission to the blades by CFD analysis, followed by computing the temperature



Stress analysis of composite drive shaft

distribution in the blades. Subsequently, thermal stresses are computed, and a life prediction is calculated. Identical finite element grids are used to calculate the temperature distribution and the thermo-mechanical stresses, both for shell and solid elements. The PATRAN/B2000 interface for thermal elements was extended, and the thermal elements of B2000 were tested and modified. Steady-state analyses were carried out using B2000, while transient analyses were carried out with MARC.

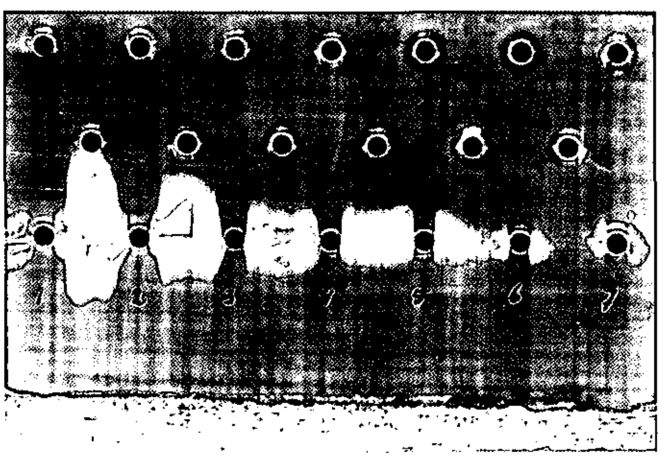
All new developments in the area of computational mechanics are being carried out within the B2000 finite element code. This highly modular code featuring an accessible database structure is very well suited to the needs of the typical researcher. New algorithms, finite elements, material models, or optimization strategies can be implemented very easily, which is demonstrated by the fact that the Delft University of Technology and Twente University both operate and contribute to the code. Aeronautical research establishments DLR of Germany and CIRA of Italy also use the code, which facilitates the exchange of software developments. NLR is pursuing a co-ordinating role in the development of B2000 and has contributed to the organization of the second users conference, held in Lugano.

Evaluation and Characterization of Materials and Processes

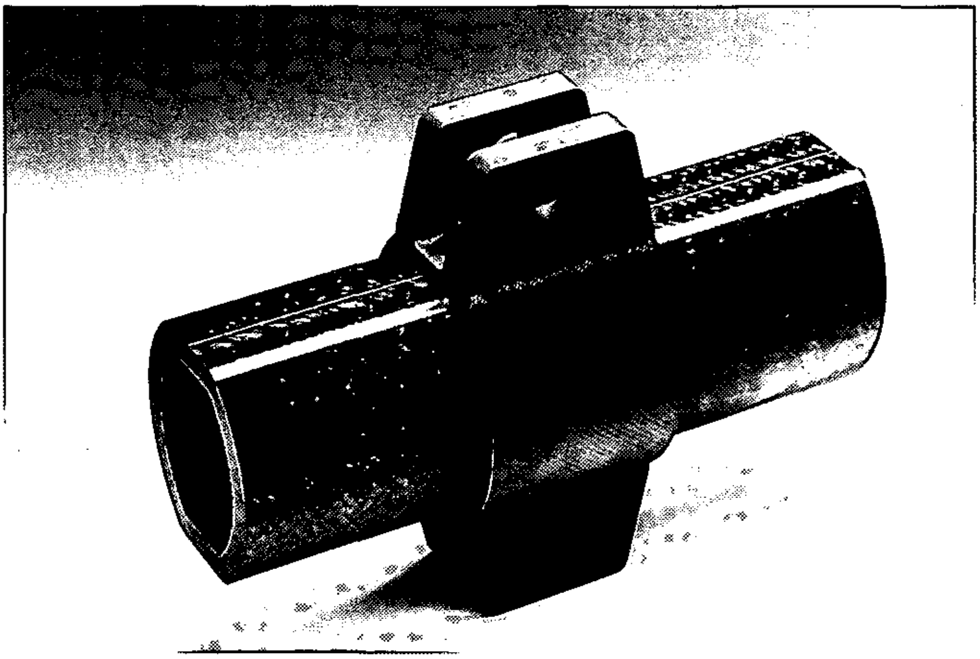
Materials and processes are being evaluated by NLR for their mechanical properties or the effect that certain processes may have on these properties. Under contract to the NIVR, the properties of new, high strength steel brands are being investigated, as well as the feasibility to use the environmentally friendly phosphor-sulpher anodising process to replace the traditional chromium-based anodising process. Under contract to the RNLAF, chromate-free paint systems are evaluated with respect to the more severe regulations that will be imposed in the future. The effect of the stretching of aluminium alloy 2024 on the fatigue properties has been studied. It was shown that this fabrication process is feasible, and may lead to reduced fabrication costs, because of the elimination of several heat treatment cycles. Under contract to the NIVR, several projects are being carried out for the GLARE Technology Programme in co-operation with Delft University of Technology and Structural Laminates Industries. These projects concern the determination of fatigue and residual strength properties, including environmental effects. The mechanical properties of riveted joints connecting GLARE fuselage parts were investigated in an APERT co-operation programme with Indonesia and in the EU project ADPRIMAS. Also, within ADPRIMAS, the corrosion properties of several weldable aluminium alloys were evaluated, while the effect of corrosion damage on the fatigue life of riveted joints was studied within The EU project SMAAC (Structural Maintenance of Ageing Aircraft). The effects of solvents used in cleaning agents and paint strippers on composite materials were investigated for the RLD. Fractographic techniques to establish failure modes in composite materials were developed in GARTEUR (SM) AG-20 (Fractographic Aspects of Fatigue Failure in Composite Materials). A qualification programme for filament-wound carbon/epoxy material was started. This material will be used for a composite drive shaft developed by Urenco Aerospace.

Fabrication Technology

The development of fabrication technology for structures made of composite materials was continued. Several techniques are used, including the traditional prepreg/autoclave technique, the double diaphragm technique for thermoplastics, the prepreg/oven technique, and the Resin



Delamination of a GLARE lap joint, studied in co-operation with Indonesia under the APERT programme



Component of a generic composite landing gear developed for SP Aerospace and Vehicle Systems

Transfer Moulding (RTM) technique. Especially RTM, which can be used for complex parts with concentrated load introductions, as well as for thin-walled shell structures, with the use of an autoclave, was applied in many projects. A large composite landing gear component was made for SP Aerospace and Vehicle Systems, using braided preforms made by Eurocarbon. Panels were made with preforms that were fabricated by stitching stacks of several layers of fabric. RTM was also used to fabricate a cargo door for the EU APRICOS (Advanced Primary Composite Structures) programme. The double diaphragm technique was used to fabricate components of a main undercarriage wheel door of carbon/PPS thermoplastic material developed by the company Ten Cate, for Fokker Special Projects. The door has been mounted on a Fokker 50 operated by KLM. The traditional prepreg/autoclave technique has been used in the EU project CRASURV (Commercial Aircraft Design for Crash Survivability) to build a crashworthy commuter subfloor structure. The prepreg/oven technique was used for the development of a suitable fabrication process for large carbon/epoxy masts with lengths of up to 57 m, made in one piece. The first mast, designed by NLR and manufactured by Royal Huisman Shipyard, has become operational in December 1998 and has performed according to expectations. The feasibility to use the same technique has been evaluated for Holland Rail Consult.
Friction Stir Welding (FSW) is an emerging technology. Preliminary experimental results indicate that it is possible to manufacture flawless butt-joint welds in 2024T3 and 7075T7 aluminium alloys (sheet materials in the range of 0.4 to 4.0 mm).

Certification Tests
Stork/Fokker Aerostructures has designed and manufactures the horizontal stabilizer, the elevator and the common rudder for Gulfstream Aircraft (GII-V).

In the past, certification tests have been carried out on the stabilizer (fatigue tests) and the elevator (static tests) by the NLR Test House at Schiphol-Oost. In 1998 certification tests (static tests) on the common rudder for the Gulfstream II to V have been carried out successfully, within a very tight time schedule. Also detailed tests and shaker tests on structure parts were done under this contract.

Certification tests on coupons and structural details of the J-nose of the A-340-500/600 were started under contract to Fokker Aerostructures.

For the Fokker 60, various certification tests have been carried out.

This work, under supervision of Fokker Services, consists of:

- Fatigue test on a large cargo door
- Fatigue test on a main wing spar
- fatigue tests on wing panels

Facilities and Equipment

NLR Test House Schiphol

The decision was made to continue the NLR Test House Schiphol operation at least until 2003 at the Schiphol-Oost location.

With the installation of a Windows NT network with new workstations and personal computers, this Schiphol operation will be fully integrated in the computer infrastructure of NLR.

Where needed the range of facilities to carry out structure and systems tests were modernised.

Structures Testing and Instrumentation Equipment

Data acquisition systems have been upgraded. Control systems for the fatigue test benches have been replaced. A new strain gauge instrumentation procedure was being developed.

A calibration system for linear displacement transducers has been designed, manufactured and certified.

Materials Research Equipment

A start has been made with the replacement of the ageing PSEM scanning electron microscope.

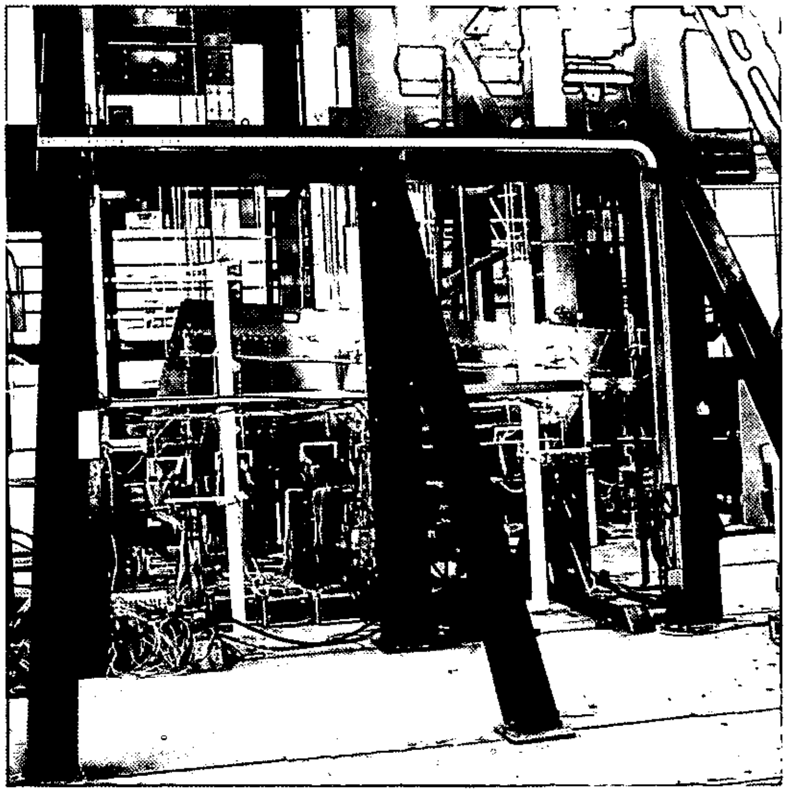
The new system will be specified so as to be capable of carrying out the work for the Joint Strike Fighter (JSF) research programmes.

An image analysis system for light microscopy has been introduced. This was the last step in digitising all the pictures made within metallography and accident investigation programmes.

For environmental tests on electronic and aviation systems a drip test was defined, and a contamination system has been developed.

Manufacturing of Fibre Reinforced Materials

New mould materials for Resin Transfer Moulding (RTM) were introduced and tests with hybrid production techniques combining prepreg with dry weavings were performed.



Rudder for Gulfstream GV

3.4 Space

Summary

The development of Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit) continued into the manufacturing phase. The construction of the experiment tank, a challenging task, was successfully concluded.

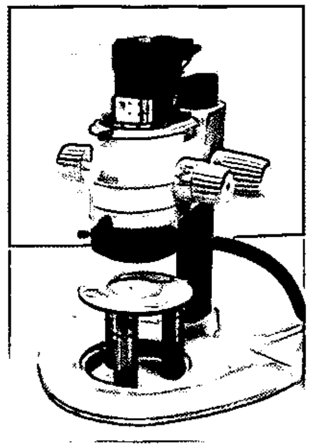
The development of the Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA) was restarted, with expanded requirements and enlarged design tasks.

Compact Biobench microscope models were delivered to the European Space Agency (ESA). Design and breadboard experiments with Miniature Microscopes were executed. These types of microscope are intended for use on the International Space Station (ISS).

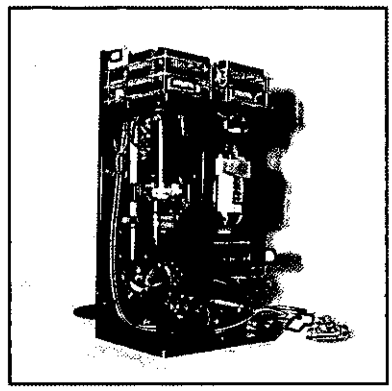
The technology for ISS utilisation and operations support has been further developed. This encompasses projects such as: LIPAS, a simulator of a Doppler Wind Lidar to be placed on the ISS; SPACT, a speech-controlled Advanced Crew Terminal for cosmonaut support on Mir, and Telescience, interactive support of in-orbit experiments from the ground. These activities were performed within the context of the Dutch Utilisation Centre (DUC) at NLR. Other DUC activities concerned the development of a European Drawer Rack Facility Responsible Centre and a Space station User Information Centre, both planned at the premises of ESA's European Space Research and Technology Centre (ESTEC) at Noordwijk.

A number of thermal-vacuum research projects were executed, including the Loop Heat Pipe Flight Experiment and the Two Phase flow Experiment II.
The AOCS test equipment for ESA's scientific spacecraft INTEGRAL (International Gamma-Ray Astrophysics Laboratory) was successfully tested and delivered.

A number of remote sensing projects have been executed. Among them were the PHARE/CORINE programme for geometric correction of Landsat images of Eastern Europe, the development of software for the analysis of time series of satellite images, investigations in lossless compression of remote sensing data, and simulations of radiative transmission models.
RAPIDS, a Personal Computer (PC)-based ground station for remote sensing satellite data, has been successfully operated in Indonesia and is planned to be demonstrated in Bangladesh.
ESA has approved the NLR RAPIDS ground station as a national station, enabling the NLR National Point of Contact to develop ERS near-real-time services for Netherlands value adding companies.
The National Earth Observation Network NEONET has entered the implementation phase.
An Internet Website COCONUDS (Co-ordinated Constellation of User Defined Satellites) has been developed through which people can participate in electronic discussions about user needs and requirements for low-cost earth observation satellite constellations.
A definition study for an airborne radar system for forest monitoring in Indonesia, named Siramhutan, has started.



BioBench Dissecting Microscope functional model



BioBench Research Microscope

A number of global navigation satellite projects for various customers have been initiated. These included the performance validation projects EGNOS-AIV, ECUREV and GNSS.

The remote-sensing data processing system RESEDA was upgraded to generate digital elevation models from stereo satellite imagery.

A Class 100,000 clean room was constructed.

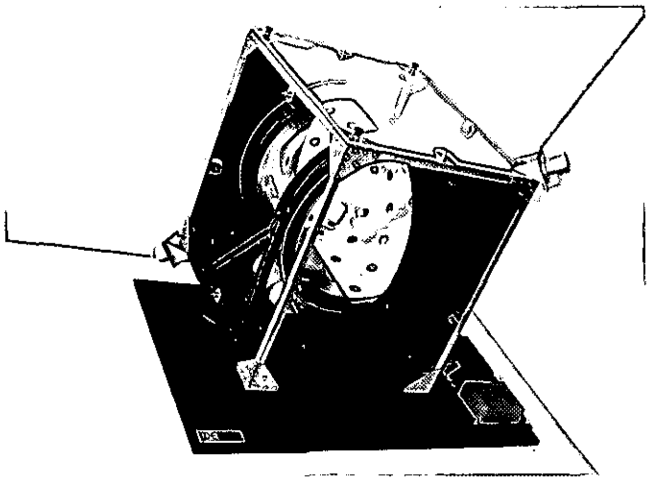
Sloshsat FLEVO

Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit) is a small satellite for fluid dynamics research, to be launched by a Space Shuttle. A team headed by NLR and including Fokker Space of the Netherlands, Verhaert and Newtec of Belgium and Rafael of Israel develops the satellite under contract to ESA and the Netherlands Agency for Aerospace Programmes (NIVR).

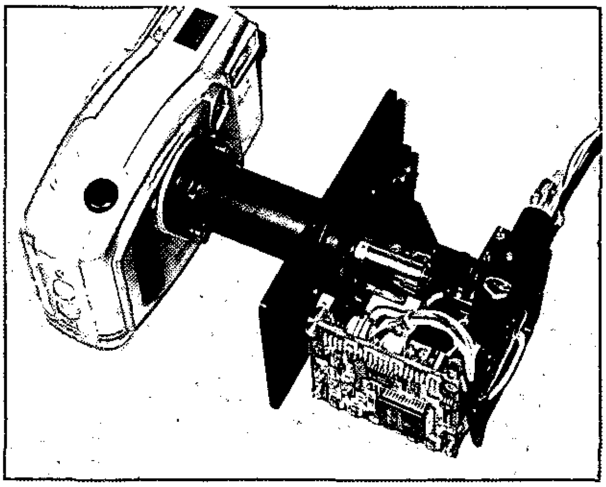
The work has focused on finishing Phase C, the design phase of the project, and starting Phase D, the realization of subsystems. Actions defined during the Critical Design Review close-out meeting have been dealt with, and a detailed planning for Phase D has been produced. The execution of Phase D of the project was started. The manufacturing of many subsystems including the on-board data handling system and the on-board software were completed, with only a few tests yet to be performed. The hardware for the system for measuring the satellite's accelerations and rotations has also been completed, except for some final tests.

The realization of the experiment tank has revealed some serious and unanticipated difficulties. Problems in the manufacturing process caused the loss of the first prototype, and incited a re-assessment of the production process. Using the help and expertise of small Dutch companies, adaptations in the production process were introduced. In this process, the tank was constructed around an aluminium core. This core was coated with polyethylene by a hot electrostatic spraying process. The coat was then covered with polyethylene fibre and Aramid reinforced epoxy that provides the structural strength. In the final step the aluminium core was very slowly dissolved in lye. This process yielded a successful second prototype. The good quality of this prototype led to the decision to use it as the flight tank, rather than making a third one. In doing so, extra delays in the schedule could be avoided. The experiment tank structure was completed. Parallel to manufacturing the experiment tank, work was done on the sensor system. Innovative measurement systems were developed both for the determination of flow velocity, using NTC resistors, and for the measurement of the water height at various locations in the tank, by determining the capacity between pairs of sensor rings in the tank wall. The integration of the sensor electronics with the tank structure was begun.

A successful Critical Design Review of the Reaction Control Subsystem (RCS), manufactured by subcontractor Rafael, was held. After the acceptance of the design, Rafael has started to produce a layout of the RCS-related piping that will run through the satellite. Also the manufacturing of the qualification and flight RCS components was started.



Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit)



Compact remotely controllable microscope, 100 mm long, for the International Space Station

The electronic system for the control of the RCS, the Valve Drive Electronics (VDE), which is manufactured by the European Space Research and Technology Centre (ESTEC), has also been completed.

The Sloshsat FLEVO project team participated in the organization of the 'Colloquium on Sloshsat and Liquid Dynamics in Spacecraft'. Members of the team have clarified aspects of the satellite in presentations, and the anticipated Sloshsat FLEVO experiments have been discussed.
A number of activities were performed in order to consolidate and expand the small-satellite experience in NLR. Furthermore, a database with information on commercially available small-sat launch vehicles was developed and has been maintained.

Space Robotics

The Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA) is being developed to provide Russia with means to prepare, train and support manipulator operations on the International Space Station (ISS). Preparation and mission support will take place at the Mission Control Centre and RSC-Energia near Moscow. Cosmonauts will be trained for both external and internal control of the arm at the Gagarin Cosmonaut Training Centre in Star City. ESA will use its version of MPTE for operator training and support tasks such as software maintenance.

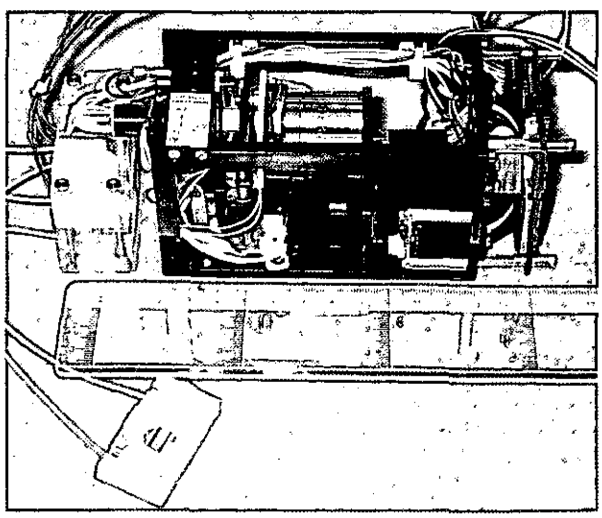
The project was restarted with an iteration and expansion of the user requirements in close co-operation with Fokker Space, the ERA prime contractor, and ESA. This led to an update of the design, culminating in a so-called delta System Requirements review and a delta Architectural Design review, respectively. The Detailed Design phase started. The MPTE team was expanded to cope with the strict schedule requirements imposed by ESA. The team was furthermore expanded with employees of Origin and ICT.

To enable activities for the MPTE to be continued in the future, work aimed at supporting the industry, mainly involving modelling and simulation, was done in the NIVR Space Technology programme. Furthermore, research has been conducted and presented in the area of tele-operations for robotics technology and training. Tele-operation technology test bed developments at NLR were posted at the ASTRA '98 workshop.

Microscopes for Research in the International Space Station

Compact BioBench Microscopes

The Final Presentation of two so-called BioBench microscopes for the European Space Agency (ESA) took place at the European Space Research and Technology Centre (ESTEC) at Noordwijk. The microscopes, a high-magnification research



Compact remotely controllable microscope, 160 mm long, for the International Space Station microscope and a stereoscopic dissecting microscope, are designed for use on the International Space Station. The functional models have been developed as part of the Laminar Flow Bench Technology Study, conducted for ESA by Fokker Space who awarded the contract for the BioBench microscopes to NLR.

Miniature Microscopes

NLR delivered conceptual designs, supported by breadboard experiments, to achieve realistic compact microscopes. This work concerns the so-called Miniature Microscopes, which are under development for ESA. The microscopes are planned to be used in cell biology research in micro-gravity during space flights in the International Space Station.
They are being developed for use in the standard containers of the Biolab and the Modular Cultivation System. The Dutch-Belgian industrial team consists of prime contractor Fokker Space, NLR, Delft Sensor Systems, and Logica.
The contribution of NLR consisted of the selection and testing of miniaturised compact microscope optics and the design and production of electronic controllers. The team has produced two compact remotely controllable microscopes named MiMi-100 and MiMi-160, where the numbers indicate the overall length of the microscopes in millimetres. The cross sections are close to 60x60 mm^2. The longest microscope is capable of switching between three fixed magnifications. Both microscopes can apply both bright field and phase contrast microscopy. All microscope functions, such as scanning, focusing, and magnification switching can be remotely controlled. Furthermore, a remote controlled fluid sample life support and observation system is incorporated.

Utilisation Technology

Under contract to ESA and NIVR, NLR continued to develop technology to facilitate efficient utilisation of the International Space Station (ISS). Four examples are given below.

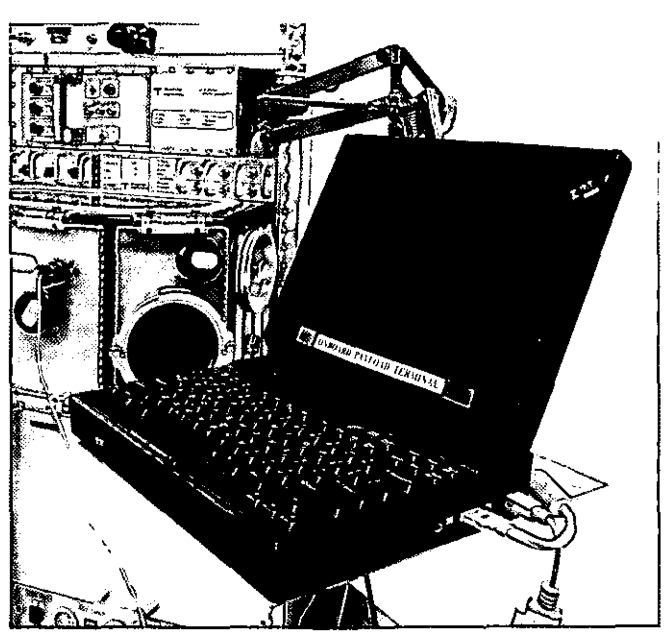
Advanced Crew Terminal

The Advanced Crew Terminal (ACT) supports the crew in space with a set of generic tools such as procedures, multi-media support and virtual control panels. The uniform configuration concept of the ACT assures a 'common look and feel' in handling multiple experiment payloads. The ACT was extended by Origin for use in a 'Web' environment. Subsequently, NLR has equipped the ACT with commercially available 'Web'-based speech recognition and synthesis packages, in the SPACT project (Speech I/O equipped ACT). The laptop computer that can host the ACT-software is the type commonly used in the Space Shuttle, and will be the standard in the ISS.

The Muscle Atrophy Research and Exercise System (MARES) was found available to use the ACT as its selected user interface. MARES will be part of NASA's Human Research Facility onboard the ISS. NLR and Origin started the development of the tools necessary to create the ACT for MARES.
Preparations were started to support the Sloshsat FLEVO project with the ACT user interface onboard the Space Shuttle from which FLEVO will be launched.

Telescience

Scientists from the Netherlands are expected to participate in the utilisation of the ISS. Interactive remote operation (telescience) of payloads will be an important utilisation method. The application of network technology (ATM/ISDN/Internet) and image compression have been further evaluated as



Advanced Crew Terminal (courtesy Origin) elements of the telescience chain. In particular, *communication link budgets and image viewing*, including stereo, have been explored. For this evaluation a telescience simulation set-up is available.

Lidar Performance Analysis Simulator

NLR, in co-operation with the Royal Netherlands Meteorological Institute (KNMI), has designed and developed most elements of the Lidar Performance Analysis Simulator (LIPAS). This work is performed under contract to ESA, with additional support from NIVR. LIPAS simulates the Doppler Wind Lidar ALADIN as specified in the Atmospheric Dynamics Mission (ADM), when accommodated on the ISS. The aim of the ADM Earth Explorer Mission is to demonstrate the possibility of providing three-dimensional wind fields in clear air, thereby helping to rectify a major deficiency in the current (meteorological) operational observing network. Such data could be assimilated into numerical weather prediction models and climate models.
LIPAS will be used to assess different instrument configurations, such as different transmitter (laser) wavelengths, detection techniques, and mission-related items such as communication.

Fungus On-Orbit Demonstration

Together with ATO-DLO of Wageningen and Stork Product Engineering (SPE), NLR started the preparation of a Fungus On-Orbit Demonstration (FOOD) experiment, in co-operation with the ESA Advanced Life Support working group MELISSA. The goal of this experiment is to demonstrate waste conversion by means of mushroom cultivation in the European Drawer Rack (EDR) onboard the ISS. Application of this method in space missions is of interest because re-use of waste can limit the expensive supply of food and contribute to a reduction of the amount of waste on board.

Dutch Utilisation Centre

European Drawer Rack Facility Responsible Centre

Activities in the framework of the Dutch Utilisation Centre (DUC) were focused on the Facility Responsible Centre for the European Drawer Rack (EDR-FRC), and carried out in co-operation with the Belgium User Support and Operations Centre (B-USOC). *The European Drawer Rack is* to become one of the micro-gravity facility racks in the European Columbus Orbital Facility module in the ISS. The Responsible Centre for this facility is proposed to be co-ordinated and supported by NLR-DUC and B-USOC. The EDR-FRC is planned to be accommodated in the Erasmus building at ESTEC.
The preliminary proposal by DUC/B-USOC for the EDR-FRC has been extended with proposals from Dutch industry (Fokker Space, Origin, Stork Product Engineering, and Bradford Engineering) covering the first hardware element, an EDR functional model for demonstration and training purposes.
The DUC participated in the *Utilisation Payload* and Operations Working Group, together with other European user support and operation centres (B-USOC, CADMOS, MARS, DLR-MUSC). Close co-operation and future joint projects have been discussed between NLR-DUC and DLR-MUSC.

Space Station User Information Centre

In the Erasmus building at ESTEC, a Space Station User Information Centre is being developed. NLR *contributed to this development* by providing consultative support to ESA and NIVR on potential Dutch industrial contributions. The integration of virtual reality, multimedia presentation, multimedia library technology, Internet access, satellite networking and digital television were investigated as part of this support.

Thermal-Vacuum Research

In the framework of the NIVR project 'Development of components for heat transport', contributions were made to a number of studies concerning new components for flow measuring (Flow Metering Assembly spatialisation, Ultrasonic Flow Meter, Vapour Quality Sensor) in TPX II, and for heat transport (two-phase loop components) for a Phased Array Radar Module. These contributions consisted of additional reporting and analysis, adaptation of aerospace technology to terrestrial conditions and recalibration and testing of the Vapour Quality Sensor in TPX II.
For Signaal, a feasibility study of a two-phase cooling system for a mobile Phased Array Radar (PAR) instrument was carried out. It provided an

overview of modern two-phase cooling techniques and of the possibilities and limitations to incorporating two-phase cooling techniques in a PAR. A basic set-up was described and issues such as availability, maintainability, safety and constructive properties were addressed.

Activities in a Computational Fluid Dynamics (CFD) analysis project were aimed at both maintaining practical skills in CFD and supporting technical projects in which CFD calculations might be helpful in design or measurement and testing matters. As an example of the first aim, several two-phase modelling techniques were tested. Considerable support was given to flow calculations of the measuring section of an ultrasonic flow meter.

Loop Heat Pipe Flight eXperiment

A preliminary assessment of the flight data from the Loop Heat Pipe Flight eXperiment (LHPFX) was made, and Dynatherm was supported in the preparation of the contribution 'Loop Heat Pipe Flight eXperiment', to the 28th International Conference on Environmental Systems in Danvers, USA.

The major part of the modelling and analysis was performed. Because of the close thermal contact, detailed analysis on component level was rather complex. Further two-phase flow modelling will be combined with the results of TPX.

TPX II

The activities for TPX II (Two Phase flow eXperiment) led to the Final Acceptance by ESA. The TPX II flight hardware was delivered to ESTEC, and shipped to NASA for the Space Shuttle STS-95 flight of 19 October 1998. After the flight the experiment was retrieved at Kennedy Space Center and returned to NLR.

Integral AOCS Test Equipment

Two sets of the Attitude and Orbit Control System (AOCS) Test Equipment for ESA's gamma-ray astronomy satellite INTEGRAL (International Gamma-Ray Astrophysics Laboratory) were delivered, one to Matra Marconi Space of Bristol and one to Alenia Spazio of Turin. The hardware design of the equipment was based on the AOCS Test Equipment previously developed for the X-ray Multi-mirror Mission (XMM). The hardware included the VME Master Crate, the Remote Terminal Unit, the Stimuli and Monitoring Electronics and the Power Distribution Unit simulator. The test software running in the host computer was largely based on the XMM AOCS Test Equipment, but was adapted to comply with the telemetry and telecommand definition of the INTEGRAL satellite.

The AOCS Electrical Ground Support Equipment (EGSE) system was delivered and installed at MMS Bristol. It was used for the testing of the INTEGRAL AOCS Electrical Model at subsystem level and will be used for the testing of the AOCS Flight Model.

INTEGRAL AOCS Special Checkout Equipment (SCOE) was delivered and installed at Alenia Spazio, Turin. For this system the hardware of one of the XMM AOCS EGSE, which was no longer needed in the XMM project, was re-used. The test software was upgraded to INTEGRAL standards. This system is being used for AOCS testing at spacecraft level.

For NLR the two deliveries mark the start of a maintenance period for the two systems, which will last until launch of the INTEGRAL satellite, planned in 2001.

Remote Sensing Applications

The value and the handling of remote sensing information for Dutch military applications were studied in a number of projects.

For the fifth successive year NLR has carried out image processing work under contract to the European Union in the framework of the PHARE programme for reconstructing the economies in countries in Middle and Eastern Europe. The work comprises the geometric correction of Landsat Thematic Mapper satellite images for, until now, twelve East-European countries: Poland, Czech Republic, Slovak Republic, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovenia, Albania, the Former Yugoslav Republic of Macedonia and Bosnia-Herzegovina. Tailored satellite maps were made, based on the map projection systems of the countryies concerned and in country-specific layout. Recently more sophisticated, so-called ortho-correction methods were introduced for correcting the satellite images for height distortion, especially for the mountain-

NLR has developed a COCONUDS (Co-ordinated Constellation of User Defined Satellites) Website, through which interested persons can participate in an electronic forum discussion on user needs and user requirements for such constellations and missions.

Map Sheets

NLR, together with TNO Physics Electronics Laboratory, ICT and the Delft University of Technology are investigating the suitability of commercial software packages that geo code radar satellite imagery.

For the Gasunie N.V. NLR participated in a study to evaluate the possibilities of spaceborne and airborne remote sensing techniques for the monitoring of the gas transport net.

SIRAMHUTAN

SIRAMHUTAN (System Informasi Radar untuk Manajemem Hutan), a definition study for an airborne radar system for monitoring tropical forests in Indonesia, was started. This study, by a consortium of Fokker Space, NLR, TNO, ITC and LUW, under contract to the Ministry of Economic Affairs and the BCRS, aims at delivering an end-to-end system based on the PHARUS technology.

Global Navigation Satellite System

Various simulation methods were being studied for use in the EGNOS project (European Geostationary Navigation Overlay Service) and subsequently harmonised with the GNSS (Global Navigation Satellite System) Performance Validation project for Eurocontrol.
NLR contributed to a proposal to ESA by GMV of Spain for the development of the so-called Required Navigation Performance Prediction Set, part of the Application Specific Qualification Facility, an element of the EGNOS Support Segment.
In addition, NLR has proposed to ESA, via Airsys ATM of Germany, to perform the EGNOS dynamic measurement trials (with NLR's Metro II *research aircraft) and to set-up* EGNOS Independent Monitoring Stations for static measurements. Fugro (*Adviesbureau voor FUnderingstechnieken en GROndmechanica*) is expected to participate in this EGNOS-AIV project.

NLR started negotiations via GMV of Spain with the European Commission to investigate the need and benefits of accurate satellite navigation beyond European borders (in particular in Africa) and to participate in the development of a demonstration tool embedded in the overall EGNOS system test bed. Fugro is expected to participate also in this project.

Miscellaneous Activities

A contribution has been made to the reference mission DaimlerChrysler Aerospace (DASA) is defining in the framework of the programme Autonomous Guidance, Navigation and Control for Small Atmospheric Return Capsules. The work is to result in a design toolbox.

Facilities

The Remote Sensing Data processing system (RESEDA) was substantially upgraded by implementing specialist photogrammetric software by which it is possible to generate Digital Elevation Models (DEM) from stereo satellite imagery or stereo aerial photography. With this software and improvements to the hardware, the RESEDA system is now capable of providing actual terrain data to be used in simulation facilities such as the National Simulation Facility.

The laboratory test facilities have been extended with a clean-room facility that satisfies the international standard of Class 100,000 (particles per cubic foot).

3.5 Informatics

Summary

Activities in the area of informatics, or information and communication technology, included the development, production and life cycle support of information systems for a variety of application areas. Major areas were: air traffic management; consultation, command and control in military environments; process and product improvement; simulation and virtual environments.

In the field of decision support systems for airport applications, NLR supported operators, regulatory authorities and policy makers. Models for helping to reduce the impact of air transport on the atmosphere and software for assisting in the allocation of runways were implemented in operational systems. The development of decision support tools for surface traffic on airports and air traffic management was continued.

In the field of planning for air traffic flow management, NLR introduced a system architecture based on the Common Object Request Broker Architecture (CORBA) in a new tool for the support of co-operative planning by controllers.

In the area of surveillance, NLR continued the development of radar data processing systems for civil and military use. NLR supported sites that implemented NLR radar trackers and studied the feasibility of algorithms that integrate aircraft-derived data with radar data.

In the area of consultation, command and control, NLR has continued to support several national and international customers. Existing information systems were upgraded and modernised, and technology development under the auspices of the Western European Union was continued. NLR participated in a group of Dutch companies that entered into a Basic Ordering Agreement with a NATO agency for engineering services, software and hardware.

In the modernization of the Operational Management Information System, in use at Volkel Airbase since 1983, the software development was concluded. Under a EUCLID programme, NLR has continued work in the area of decision support, planning and tasking.

Under a programme of the Western European Armament Organization, NLR has continued work on multisensor data fusion.

In the area of reliability, availability, maintainability, safety and certifiability, the support to designers and operators of aircraft and space systems and to aviation authorities was continued.

For the Netherlands Department of Civil Aviation (RLD), a study on the collision risk associated with a potential second runway at Lelystad Business Airport was conducted.

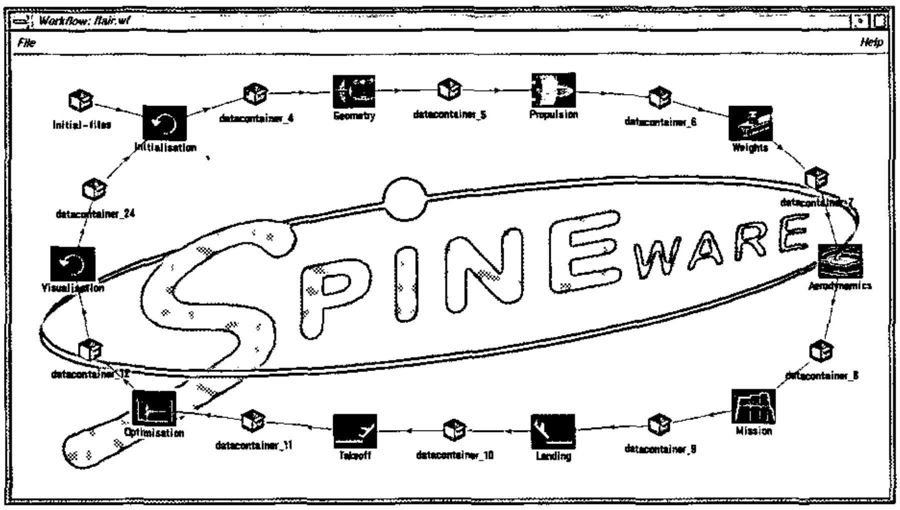
A project using NLR's safety critical software development process has been completed. The first version of the resulting avionics product comprising software classified at DO-178B level A (safety critical) was certified.

Activities for supporting process and product improvement concerned the further development and application of working environments for the conservation, accumulation and re-use of know-how in enterprises and between co-operating enterprises.

Under contract to supercomputer manufacturer NEC, NLR has continued the development of the software package SPINEware, a tool for the development of working environments in virtual enterprises that provide users with one single virtual computer giving transparent access to the resources of a computer network. SPINEware was made compliant with the Common Object Request Broker Architecture (CORBA) and was configured such that both Windows NT-based and UNIX-based computers can be integrated into a seamless virtual environment

NLR's facility based on SPINEware for Computer-Aided Control Engineering, ISMuS, its facility for software development, ISEnS, and the working environment for Statistical and Risk Analysis, ISTaR were applied in various projects.

A study on Continuous Acquisition and Life Cycle Support (CALS) of systems of the Netherlands armed forces was concluded by providing recommendations.



SPINEware supports composition of workflows, e.g. for this typical aerodynamics optimization cycle

NLR contributed in the preparation of the ENHANCE project for aeronautical concurrent engineering, for which the extended enterprise is the major concept.

NLR continued providing support to the development of simulation models for Automatic Debiting Systems proposed for automatic road tolling stations.

Concerning robotics simulation and control, NLR continued the participation in the development of the European Robot Arm (ERA) conducted by Fokker Space.

The use of NLR's computing facilities with the powerful supercomputer, an NEC SX-4 with sixteen processors of 2 GFLOPs, showed considerable growth for both computing and information management. NLR's computing centre is one of four HPCN (High Performance Computing and Networking) centres in the Netherlands that are members of an association that provides the Netherlands scientific and industrial community with access to top level high performance hardware and software. The replacement of the SX-4 supercomputer by an SX-5 supercomputer was prepared. This will increase the computing power at NLR by 100 per cent.

NLR participated in the AEREA Working Group on Supercomputing and Networking, making preparations for a virtual AEREA Common Computing Centre (ACCC).

Decision Support Systems for Airport Applications

NLR continued its ICT and mathematics support to operators, regulatory authorities and policy makers on airport environmental monitoring and decision support.

Monitoring

To reduce noise pollution, Amsterdam Airport Schiphol uses so-called preferential runway allocation. As far as weather conditions and numbers of aircraft are within the restrictions of the runway use, aircraft will depart from or arrive at the runways that cause the least noise problems. NLR has developed two systems concerning this preferential runway allocation. The Runway Allocation Assistant System (BGAS) provides advice to the Executive Air Traffic Controller in the allocation of runways to aircraft, based on the preferential system, runway availability and weather conditions. The system is installed at Schiphol Approach and Schiphol Tower. The Runway Use Inspection System (BGCS), used by Air Traffic Control the Netherlands (LVNL), provides information on the actual allocation of runways in comparison to preferential runway use.

Planning on and Around Airports

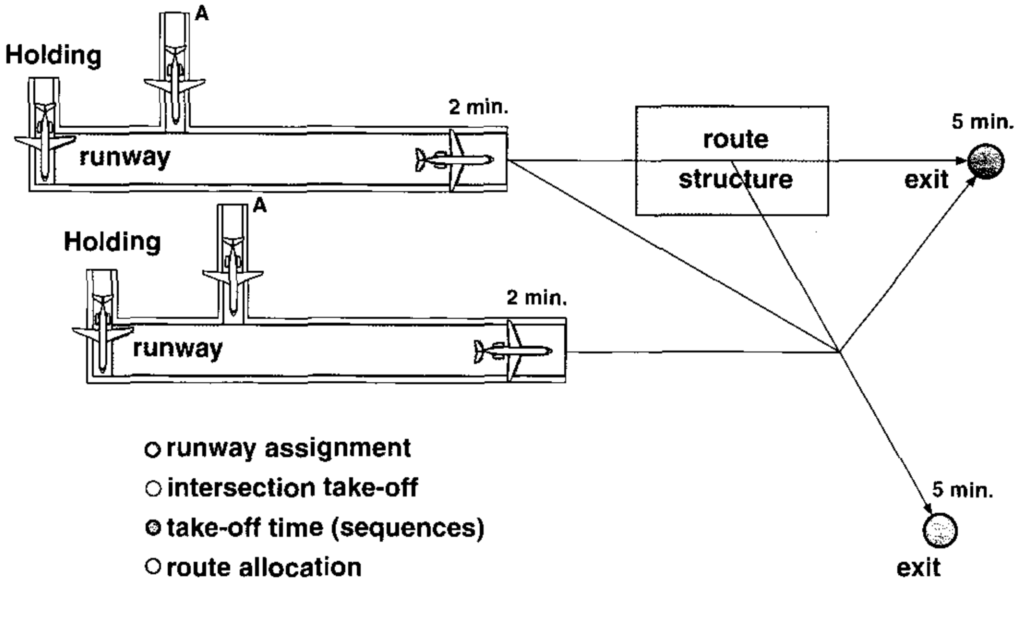
Within the EU MANTEA (Management of surface Traffic in European Airports) project, NLR provides the MANTEA Departure Sequencing (MADS) tool, which proposes optimal runway usage and Standard Instrument Departure (SID) allocations under nominal and bad weather situations. The MADS distributed open architecture, based on the Common Object Request Broker Architecture (CORBA), was designed and implemented to facilitate a novel way of co-operative planning by controllers. NLR also provided assistance to the demonstration of tools to controllers at the MANTEA validation site of Rome Fiumicino. Presentations and a demonstration of MADS were given at international conferences.

NLR continued being involved in the EU project DAVINCI (Departure and arrival Integrated management system for Co-operative Improvement of airport traffic flow). NLR has contributed to a survey of planning and co-ordination techniques and to the establishment of the client-server architecture, in which a central view of planning and plan management is maintained in a real-time database.

Planning for Air Traffic Flow Management

To aid planning for Air Traffic Flow Management, research on mathematical models and methods for supporting slot allocation has continued. Slot allocation is concerned with the assignment of departure slots to all flights departing from airports in a given area, such that overload in en-route control sectors and on runways is avoided. For Western Europe, the Central Flow Management Unit of Eurocontrol performs slot allocation. It has been shown that the current approach can be significantly improved by exact optimisation. In collaboration with DLR, NLR has developed a new solution method for a basic version of the European slot allocation problem. The method is based on an integer linear programming model. Computational results for real-world problems are encouraging, because they indicate both possibilities for real-time applications and very good, almost optimal solutions.

Research on models and methods for scheduling aircraft landings has been continued, to support planning for airport harmonisation and integration with air traffic management. Scheduling aircraft landings is the assigning of a runway and a landing time to aircraft inbound to an airport, whilst maintaining safety standards. These safety standards depend on the airport-specific runway configuration and weather conditions, for example on whether the runways are used dependently or for combined landings and takeoffs, or face different wind conditions. The objective is to determine a schedule that minimises some measure of inconvenience for aircraft, airlines and/or passengers such as delay and fuel costs, and noise pollution. NLR has developed an algorithm for this problem. This algorithm will enable the air traffic controller to react quickly to changes in the operational environment, so that aircraft landings can be scheduled dynamically and flexibly.



MADS assigns a runway, a take-off time, and a route

Interdisciplinary Co-ordination

Several NLR departments are involved in a wide variety of aspects of Air Traffic Management, planning at airport, and command and control. A special interest group Planning has been installed in order to achieve a co-ordinated approach in the area of planning, to exchange expertise and intensify collaboration. The group focuses on modelling and on the application of methods and techniques from mathematical optimisation and artificial intelligence in planning and replanning.

NLR has become a member of EvoNet: the ESPRIT Network of Excellence on Evolutionary Computing. Within this network NLR has the lead of the Aerospace Working Group.

Surveillance

NLR continued the development and installation of radar data processing systems for Eurocontrol, for national aviation authorities, and for military applications.

ARTAS (ATM Surveillance Tracker and Server)

The formal qualification test by NLR of the ATM Surveillance Tracker and Server (ARTAS) was completed successfully. The test was approved by the customer, Thomson AIRSYS-ATM, and the user organization Eurocontrol. The first ARTAS system has become fully operational at Amsterdam Airport Schiphol. Additional evaluation systems were installed in Lisbon, Brétigny and Gatwick. NLR provided support in evaluation and tuning to Eurocontrol and to the evaluation sites. Meanwhile, several minor tracker upgrades were requested by Eurocontrol and implemented under contract to Thomson AIRSYS. Further enhancements to ARTAS trackers were proposed to Eurocontrol.

NLR provided support to Air Traffic Control the Netherlands (LVNL) in the tuning and evaluation of the ARTAS tracker in operation at LVNL. The support effort resulted in improved height tracking performance and track accuracy performance in the Schiphol terminal manoeuvring area (TMA). In addition, the effect of the introduction of new radars on the overall tracking quality was investigated

ARTAS2 Feasibility Study and Prototype Implementation

ARTAS2 is an enhancement of the existing ARTAS system, such that the system can handle aircraft-derived data, delivered by means of Mode-S and Automatic Dependent Surveillance (ADS). The feasibility study, intended to investigate algorithms that properly integrate this additional information in aircraft tracking, was continued by means of simulations demonstrating the potential performance of the new algorithms, and by prototyping these algorithms, based on the existing ARTAS tracker. The simulations showed that significant performance improvements can be expected. The prototype implementation was completed and testing has started, mainly using simulated data. Some live data was also processed successfully.

Quality Assessment Facility for Multi-Radar Tracking

NLR has continued the work on the Track Accuracy Analysis (TAA) prototype, under contract to the Eurocontrol Experimental Centre. NLR used the TAA prototype successfully for tuning and evaluation of the accuracy performance of the ARTAS tracker at LVNL. The operational experience gained in this activity was used to improve the TAA prototype further. The matured TAA prototype was demonstrated to a group of intended users.

Aeronautical Telecommunication Network

For the Aeronautical Telecommunication Network (ATN), the Network Management Centre (NMC) project was concluded with the delivery of a set of network management tools for the ATN Trial Infrastructure (ATIF). The tools are used at Eurocontrol Bretigny, France, to support ATN trials and experiments. NLR provided support in the operation of the NMC.

A technology transfer contract on ATN was signed between the Institute of Information Industry (III) of Taiwan and NLR. NLR developed a comprehensive technology transfer programme. This programme included a five-day in-depth technical workshop on the system and software development. The workshop was followed by five months of training in developing applications. The training case concerned the development of software for the Flights Information Service (FIS) application tailored for the national environment of Taiwan.

Consultation, Command and Control

NLR has continued its support to the Royal Netherlands Air Force (RNLAF) and other national and international armed forces. Support of existing information systems included upgrading and modernization activities. Applied research and technology development under the auspices of the Western European Union was continued, with the aim of incorporating results into systems of customers.

Basic Ordering Agreement with NATO

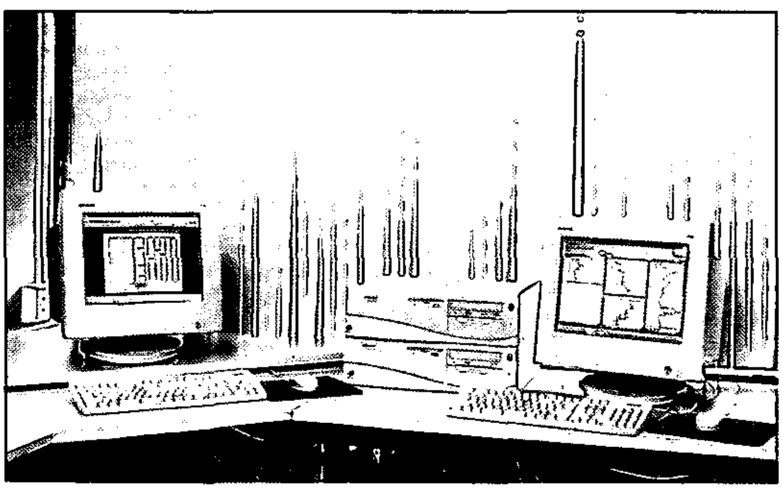
NLR has entered into an agreement with a group of Dutch companies for co-operation in projects in the area of Command, Control and Communication Information systems. The group operates under the name DUCOM: 'Dutch Combination for (Multi-) national operations'. Participating companies are: Getronics Software bv, Holland Institute of Traffic Technology bv, Klein Poelhuis-Voltman bv, NLR, Quality Center Nederland bv and Plenter Consultants bv.
DUCOM has entered into a Basic Ordering Agreement (BOA) with NATO Consultation, Command and Control Agency (NC3A) for engineering services, software and hardware.

Operations Management Information System

Under contract to the Royal Netherlands Air Force (RNLAF), NLR has concluded the modernization of the software for the Operations Management Information System (OMIS) which has been in use at Volkel Air Force Base since 1983. OMIS supports the RNLAF in the preparation of aircraft for missions to be flown by assisting in the communication of information between control centres and units. The software was redesigned and implemented using 4GL COTS (Commercial-Off-The-Shelf) software development tools from Oracle. The target hardware platform is a network of PCs running Microsoft Windows NT.
The system has a completely new Windows NT-like user interface, and functions according to the client-server concept as opposed to the original OMIS, which performed centralized computing. Application of multiple replicating Oracle database servers provides failsafe operation of the system. The new software, OMIS-2, successfully passed the Factory Acceptance Test.

Mission Support Systems

Work on mission support systems in a programme funded by the Ministry of Defence for the Hellenic Air Force (HAF) was continued. This work was aimed at upgrading the output capability of the Mission Support System/ Pandora's (MSS/P) Combat Mission Folder (CMF) to a level suitable for semi-operational or



OMIS2 client (left) and development station (right) operational use. The major goal of this project is knowledge transfer regarding the use and design of automated mission preparation systems.

Navigation

For the Royal Netherlands Air Force (RNLAF) NLR investigated what ellipsoid is the best alternative to the WGS84 ellipsoid for navigation, taking into account the possible operational areas and their sizes. The Apache AH-64A helicopters of the RNLAF cannot use the WGS84 ellipsoid. These helicopters can only use the Australian National, Bessel 1841, Clarke 1866, Clarke 1880, Everest, and International ellipsoids.

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 eighteen 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 (C3I) systems.

NLR research has focused on artificial intelligence techniques for time-critical planning and replanning. The results have been implemented in a demonstration system for the allocation of sorties and artillery to prioritized targets in a military peace enforcement scenario. The system has been demonstrated successfully to a large audience of representatives of the contributing Ministries of Defence.

Multisensor Data Fusion

Under the military research and development programme of the Western European Armament Organization, NLR has continued its co-operation with Signaal, TNO-FEL, Thomson-CSF and Systèmes et Informations to produce a near real time demonstrator for multisensor data fusion. A system, based on an architecture that enables components to be rapidly integrated, was developed, integrated, tested and evaluated. The fusion process was applied in a number of military scenarios. From a helicopter and a drone with simulated sensors and from ground-based positions, visual, radar, infrared and moving target indicator sensor data are obtained. Data are first numerically fused at low level. Subsequently, from observations, tracks are grouped, and recognition and where possible identification of objects and units takes place. Finally, situation assessment takes place. Using artificial intelligence, information is inferred about military units and intentions. If more information is needed, this is conveyed to the sensor management node, which decides what sensors can best be allocated to the task.

NLR's contributions were in several areas, including the following:

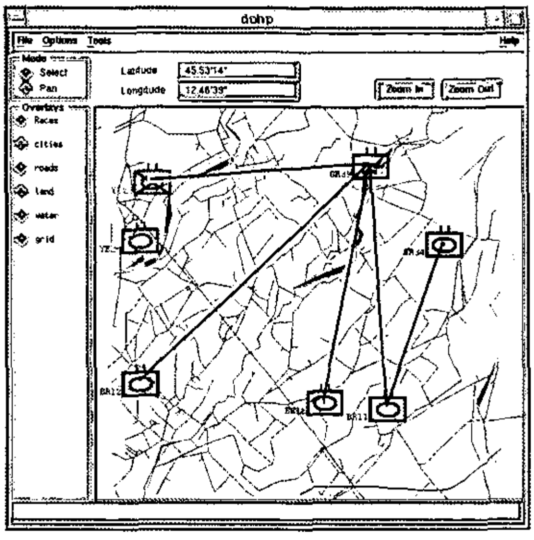
- heliborne data fusion of moving target indicator and electronic support measures data
- global ground-based and heliborne data fusion, which combines heliborne data fusion information with Signaal's ground-based fusion
- situation assessment, in which five knowledge sources reason both separately and co-operatively about content and intentions of military units
- integration and evaluation.

The demonstration model was shown to the customer and delivered to all consortium partners.

NLR took part in a feasibility study into Advanced Vision Systems (AVS). Such systems provide an electronic image of the outside world in order to extend the operational envelope and to improve flight safety. For instance, they enable military aircraft to operate better under low visibility and/or night conditions, which today limit operations. AVS are classified as Enhanced Vision Systems (EVS) or Synthetic Vision Systems (SVS). An EVS presents an image of the environment by merging imagery obtained from imagery sensors, and therefore requires techniques for image fusion. An SVS presents an image from a geographic database using accurate information on the current aircraft position and attitude by fusing data from navigation sensors. Thus, an SVS requires techniques for data fusion. NLR has made an inventory of state-of-the-art techniques for fusing images, for EVS, and for fusing data from navigation sensors, for SVS.

There are hierarchical and non-hierarchical image fusion algorithms. Hierarchical algorithms first decompose each source image into a set of pattern selective elements (such a set is called a pyramid), then assemble a pyramid for the composite image by selecting salient patterns from the source image pyramids, and finally construct the composite image from its pyramid. Examples are Gossip, Laplacian, and wavelet pyramids. Unlike the class of hierarchical algorithms, non-hierarchical algorithms are diverse. Pixel-by-pixel and neural networks are examples of such algorithms.

Data fusion techniques are divided into cascaded and non-cascaded approaches. In both approaches, Kalman filters are applied.



Resource Allocation in Offensive Air Support and Fire Support

Reliability, Availability, Maintainability, Safety and Certifiability

NLR continued providing support to civil and military designers and operators of aircraft and space systems and to aviation authorities in the field of reliability, availability, maintainability, safety and certifiability.

Safety

As in previous years, NLR contributed to the Mathematicians Drafting Group (MDG) of Eurocontrol in the Reduced Vertical Separation Minimum (RVSM) programme. Several discussion papers dealing with statistical aspects of monitoring the height-keeping performance of RVSM-approved aircraft were drafted. A major issue addressed concerned the sample sizes needed. NLR acted as a liaison between the MDG and a Mathematicians Implementation Group (MIG) carrying out quantitative safety assessments for the North Atlantic Region. NLR also acted as a mathematical advisor to the Eurocontrol member of the ICAO Review of the General Concept of Separation (RGCSP) Panel.

For the RLD a study was conducted of the collision risk associated with a potential second, parallel, runway at Lelystad Business Airport. Radar data on general aviation visual approaches were collected and modelled by appropriate probability distributions. These distributions were then used in an existing collision risk model to estimate the possible collision risk. As this model does not take into account the risk-reducing effect of the 'See-and-Avoid' principle underlying visual approaches, a literature study was carried out to investigate the feasibility of modelling this effect.

Wake vortices are an important factor in determining separation minima between aircraft during approach/landing and take-off. A predesign was made of a probabilistic model for the accident risk due to wake vortices. The predesign proposes to base the model on three submodels, for the evolution of a wake vortex, for the evolution of an aircraft trajectory, and for the accident probability given the relative position at which an aircraft encounters a wake vortex.

NLR has been developing a fast-time simulation model to compute the accident, incident, and crash-into-terrain risks due to wake vortices for aircraft landing on parallel runways.

Automatic In-flight Data Acquisition

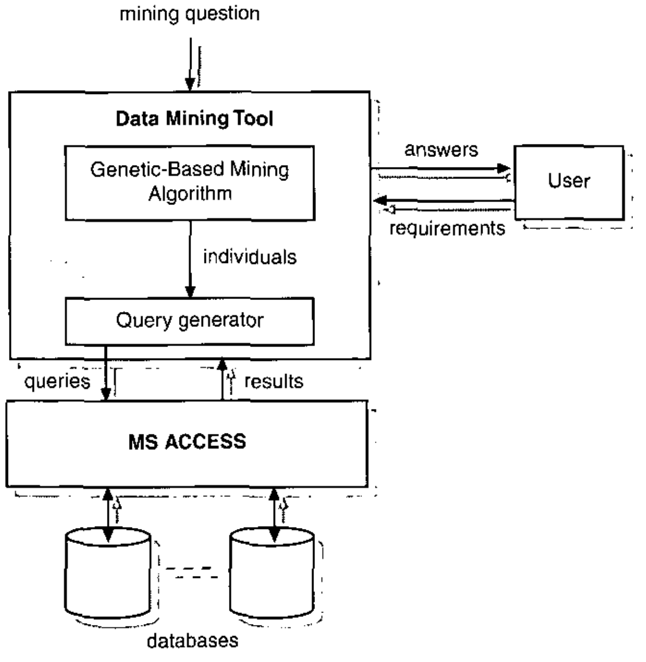
The Royal Netherlands Navy has awarded NLR a contract to produce the software for the AIDA (Automatic In-flight Data Acquisition) Host Station. The AIDA system measures various safety-critical and damage-sensitive items onboard Lynx helicopters. The Host Station software provides the user with facilities to store and manage measured data, to display them graphically, and to compute condensed usage data. The software was designed and partly implemented.

Avionics software

The development of the software for the Flight Control Display Module (FCDM) of a Flight Display Subsystem was completed (see also Capita Selecta). The FCDM acts as a data concentrator, and generates commands that cause the flight control and navigation data to be displayed on the Primary Flight Displays and the Navigation Displays. The safety-critical FCDM comprises Built-In Test, Input/Output, boot, kernel, scheduler and application-specific components. The development process complied with the DOD-STD-2167A software development standard, with a number of adaptations and enhancements in order to satisfy the prescribed EUROCAE/RTCA ED-12B/DO-178B avionics software certification standard. Because the software includes parts classified at different RTCA-DO-178B safety levels, a propriety software-partitioning scheme has been applied.

Process and Product Improvement

NLR supports customers in process and product improvement, and pays attention to process and product improvement within NLR. The use of ICT plays an increasingly important role in these improvements. Computer based working environments are created that support conservation, accumulation and re-use of know-how and products.



Schematic of data mining process

Continuous Acquisition and Life-cycle Support

Fokker Services and NLR, under contract to the RNLAF, completed a feasibility project on the implementation of Continuous Acquisition and Life-cycle (CALS) applications for the Integral Weapon System Management of the Patriot guided missile weapon system. Recommendations were made for life-cycle support and for improvements of the maintenance engineering process and the configuration management process for the RNLAF. The RNLAF took delivery of a demonstration CD-ROM containing national technical manual data merged into extant electronic technical manual data using the Standard Generalized Markup Language and hyperlinks.

NLR's participation in the Netherlands Interservice CALS Working groups on Life Cycle Costing and on Electronic Technical Manuals was continued.

Data Mining

An area of research that has seen a recent surge in commercial development is data mining, the nontrivial extraction of implicit, previously unknown, and potentially useful information from large data sets. NLR applies data mining techniques to achieve insight in events related to aerospace, such as aircraft incidents, atypical flights, etc. Relevant data warehouses are set up and are mined using a prototype tool, called Sharvind, under development at NLR. Sharvind is a re-targetable and extensible data mining tool, which means that it is capable of being coupled to different databases/warehouses, and that new mining algorithms can be easily plugged in. The tool is equipped with a genetic-based mining algorithm.

Middleware for Generation of Working Environments and Virtual Enterprises

Several advanced industries are developing integrated networks of commercial software to mesh modelling and simulation tools into a seamless, virtual manufacturing environment to reduce the life-cycle cost of their products. Examples are Boeing and Lockheed Martin, in the preparation for the Joint Strike Fighter development. One of the additional goals of such networks is the generation of virtual companies: temporary consortia of independent member companies, which come together to exploit market opportunities quickly. The companies have to be assembled without regard for organization size, geographic location, computing environments, technologies deployed, or processes implemented. A so-called middleware computing layer on top of the network of connected computers is used to integrate the heterogeneous computing environments of the companies in the virtual enterprise. The most promising standard for the middleware is the Common Object Request Broker (CORBA) standard. In the past few years NLR has developed the middleware product SPINEware for the supplier of NLR's supercomputer NEC. SPINEware was adapted to the CORBA standard and configured to be capable of being used to integrate computers with Windows and Windows NT as well as UNIX operating systems.

Working Environment for Control Engineering

To enhance the re-use of models, the ISMuS working environment, based on SPINEware, for simulation and control engineering has been extended with a model library part. Each model contains at least an executable version, source code, and on-line documentation to support both the users and the developers of the model. Existing models such as for the simulation of constrained controlled robotic manipulators and some models for the education of trainees and new employees have been integrated in the model part. The tool TraCE, for the simulation of robotic manipulators that on purpose are in contact or come into contact with their environment, has been modified and extended. The alphanumeric user interface has been replaced by a dedicated graphical user interface, and sensor models and control laws for the simulation of a controlled robotic manipulator with flexible joints have been added. An accompanying educational simulation program has been developed to introduce the field of simulation of controlled objects that on purpose are in contact or come into contact with their environment.

Tool for the Development of Simulators

NLR contributed to the development of the EuroSim facility, a computer based tool to generate engineering simulators. The tool is being built by a Dutch consortium led by Fokker Space. To obtain further access to the international simulation market with the Eurosim facility, a consortium is being created by Fokker Space, Origin and NLR.

International Working Environment Based on a Wide Area Network

NLR has contributed in the GARTEUR Flight Mechanics, Systems and Integration Exploratory Group (FM) EG-17 on the creation of an Action Group. The Information Technology part of the proposed contribution of NLR focuses on the development of a model library for the Action Group and co-operating Action Groups, on the establishment of a Wide Area Network (WAN) that includes the model library, and on a demonstration of the capabilities of SPINEware to integrate the WAN into the working environments of the Action Group members.

Working Environment for Statistical and Risk Analysis

The SPINEware-based working environment for Statistical and Risk Analysis ISTaR has been applied in modelling activities of accident locations around Amsterdam Airport Schiphol and around regional airfields. Models have been developed and integrated for reuse in the environment.

Enhanced Aeronautical Concurrent Engineering

Global competition in all segments of the civil aircraft business continues to intensify. To cope with this, the major European players in the aeronautics industry decided that use should be made of the experience that concurrent engineering can be now combined with state of the art Information and Communication Technology to build the capability required for enhanced design, fabrication and support processes, throughout the whole aeronautic industry. This led to the definition of the EU ENHANCE project (Enhanced aeronautical Concurrent Engineering) by a consortium of 13 contractors, including the co-ordinator. These contractors are: Aerospatiale (co-ordinator), British Aerospace, Dassault Aviation, Eurocopter, Liebherr aerospace, Messier Dowty, NLR, Rolls Royce, Sextant Avionique, MTU and SNECMA. The project will be executed by the contractors and 41 associated contractors representing airlines, SME's, Information Technology vendors and research institutes. NLR is leader of two of the nine work packages, Information Technology and Support. The project will be funded by the EU under ESPRIT (European Strategic Programme for Research and Development in Information Technology) and BRITE/EURAM.

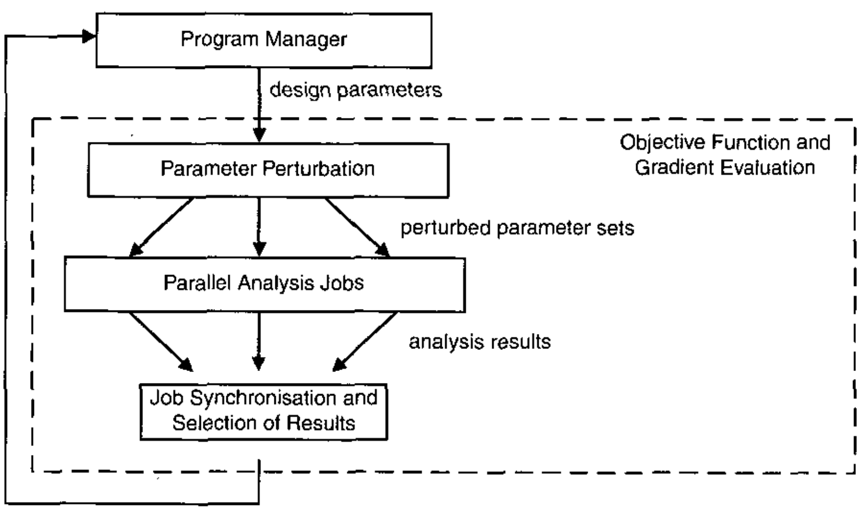
Simulation

NLR maintained its proficiency in the computationally intensive areas of the simulation and visualization of existing or future situations.

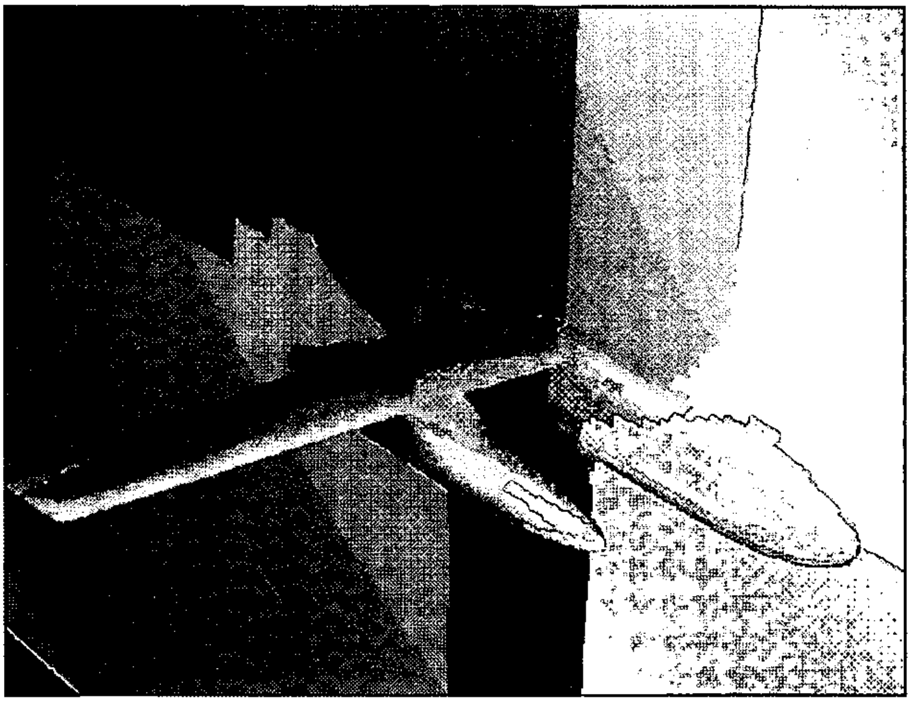
Flow Simulation

Work was done on improving the flow solver ENSOLV, which is part of the ENFLOW system for the simulation based on the Reynolds-averaged Navier-Stokes equations of viscous flows around complex aerodynamic configurations. The numerical accuracy, convergence speed, and robustness of the implementation of the k-omega turbulence model were improved. Furthermore, a modification of the k-omega turbulence model was introduced to make it more suitable for vortex-dominated flows; this modification was tested for the flow around a delta wing.

In the framework of NICE (Netherlands Initiative for CFD Engineering with HPCN), partially funded by the foundation HPCN and co-ordinated by NLR, the development of parallel and distrib-



Parallel analysis jobs in the design optimization tool



Domain decomposition of the mesh around a generic aircraft as applied in the flow solver Hexadap

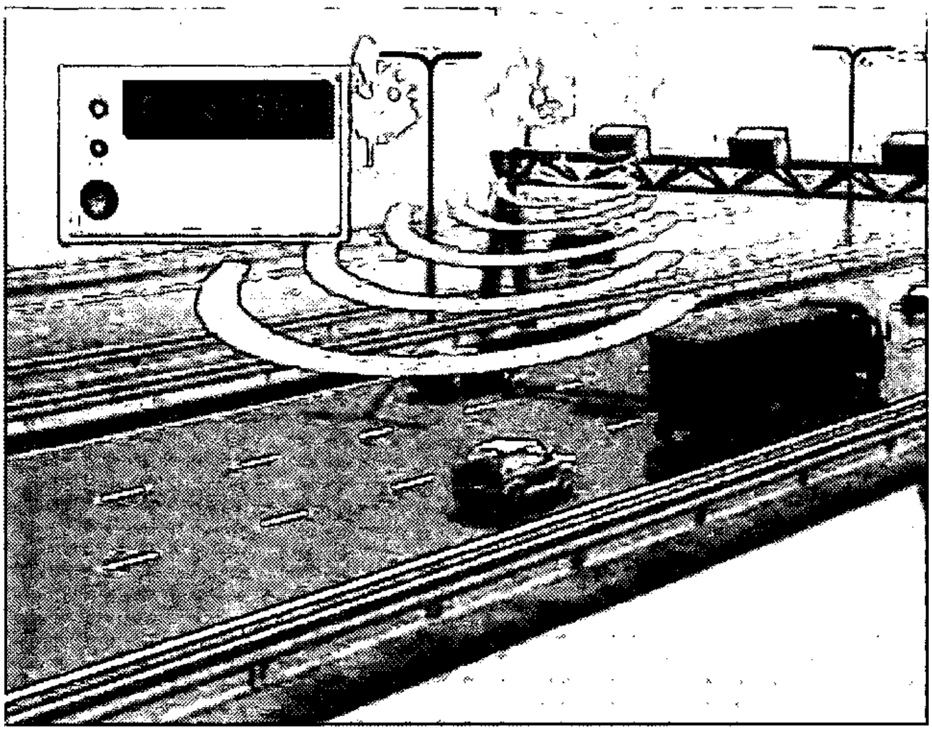
uted CFD applications was continued. The SPINEware-based digital working environment HCS (HPCN Centre for flow Simulation), was used for CFD design problems by several third parties supported by the NICE partners.

The parallelization using grid partitioning of the unstructured flow solver Hexadap for time-accurate flow simulation on the NEC SX-4 has been extended to the integration part of the solver, resulting in a speed-up of 11.8 on 14 processors with respect to one processor. The performance on 14 processors is 8.5 GFLOPs. With this result, a contract for the execution of complex time-accurate simulations could be obtained from Boeing. At present, the emphasis of the further development of Hexadap is on enhancing the performance on machines based on the virtual shared-memory concept, where software shields the software developer from the physically distributed memory. Explicit implementation of communication between processors is not necessary, but the communication overhead still has to be minimized. To this end, the data structures have been altered by mapping them on the parts of the mesh, and separate data structures have been defined for the cells on which the flow is calculated and the cells on which the grid is adapted.

The generic software tool for design optimisation has been enhanced with respect to the accuracy and applicability of the optimisation, the portability of the tool and the accessibility in networked heterogeneous digital working environments. The optimisation tool has been used successfully in several design optimisation problems that involved highly different CFD simulations. Applications included designs of an airfoil in transonic flow, a hot air curtain device, and parameter identification in a model describing the spray generated by aircraft tyres running through standing water.

Vehicle Simulation

Simultaan is an R&D programme initiated by the Netherlands foundation SIMNED, partly funded by the foundation HPCN, and executed by the SIMNED partners NLR, TNO Physics Electronics Laboratory, Siemens Nederland, Fokker Space, Hydraudyne Systems & Engineering, and the Delft University of Technology. In Simultaan, existing knowledge and products are combined with tools to be developed, to arrive at a permanent infrastructure in the Netherlands for real-time simulation that involves complex high performance computing and networking.



Artist's view of road pricing system (illustration courtesy Ministry of Transport)

NLR participates in almost all activities of Simultaan, but its responsibilities and major contributions are in the area of mathematics and ICT. They concern the design and implementation of generic and complex behaviour models and the design and implementation of a generic scenario management tool. In addition, NLR works with Fokker Space on the design and implementation of a repository.

An instantiation of a behaviour model will be made for a specific class of vehicles, such as planetary rovers, trucks, cars, tractors and caterpillar-tracked vehicles. Using a multibody dynamics package, a vehicle model has been made. A specially designed wrapper enables source code exported by the multibody package of EuroSim to be incorporated. The model contains the sub-models necessary to simulate contact transition of all the wheels, independently.

The generic scenario management tool SMARTFED (Scenario Manager for Real-Time Federation Directing) can be used for real-time monitoring and control of networked simulations. SMARTFED also offers functionalities for the definition and execution of scenarios.

Simulation of Automatic Debiting Systems

The Ministry of Transport is planning to introduce automatic tolling systems on the main roads leading to major cities for road pricing (rekeningrijden). A number of international consortia have offered proposals for an Automatic Debiting System (ADS). The evaluation of these proposals was performed using a detailed simulation of the behaviour of the proposed ADS systems using the ADSSIM program package developed by the University of Amsterdam and CMG under the auspices of the ministry. NLR has supported the consortia in the development of simulation models in this evaluation phase. NLR in co-operation with the University of Amsterdam has conducted a strategic study for the ministry concerning the feasibility of alternative chipcards in the ADS systems.

After the conclusion of the evaluation, four consortia have been selected to submit a design proposal and also to demonstrate the operation of their systems in a pilot test on the A12 near Woerden. Following evaluation of the design and of the test results, two of these four consortia will be commissioned to develop their systems further. NLR has provided the ministry with support in both the pilot test and the design evaluation.

Robotics Simulation and Control

Attention has been paid to robotics simulation and control mainly for space applications.

Simulation of Mechanical Systems With Multiple Colliding Elements

NLR participates in the INTAS project 'Mechanical Systems with Multiple Colliding Elements'. In co-operation with Fokker Space, a project definition has been initiated to investigate dextrous manipulators, where NLR will be responsible for the contact dynamics.

Robotics Simulation

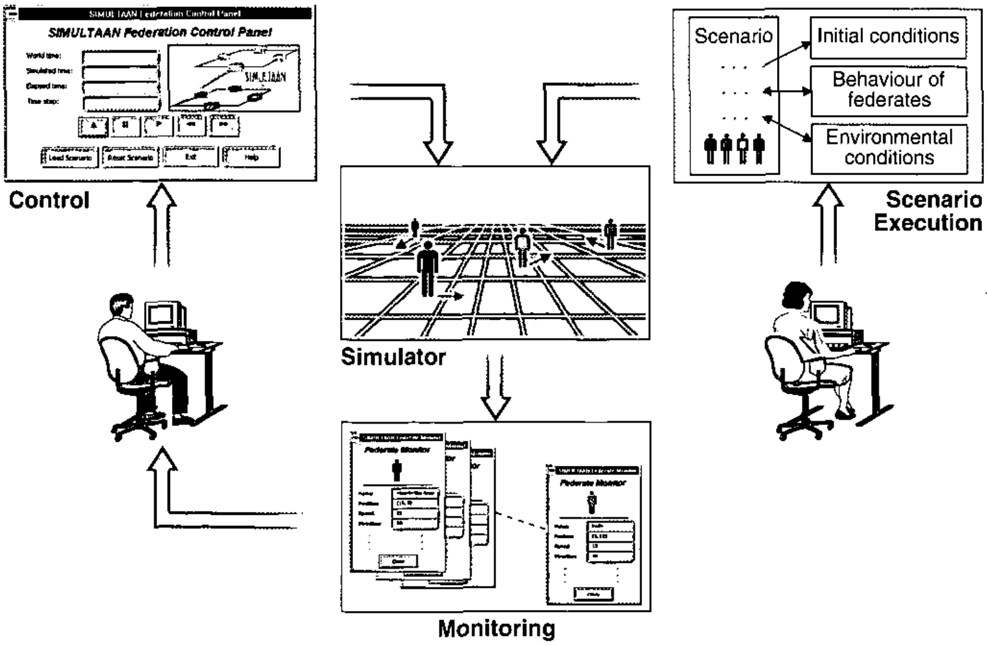
NLR continued participating in the development of the European Robot Arm (ERA) at Fokker Space. The participation concerned the ERA Simulation Facility (ESF) and the ERA Exception Handling system.

Robotics Operations

The specification of the Exception Handling, or Failure Detection Isolation and Recovery (FDIR) system, was modified due to changes in the ERA design and due to additional restrictions imposed by the ERA subsystems. Threshold values were determined for a number of motion-related checks. Simulations were performed with the ESF to show that the resulting stopping distances are within the safety objectives. Test requirement specifications were written to verify the system requirements related to FDIR. To support operations, FDIR-related sections were written for the Flight Operations Manual, the set-up of Electrical and Mechanical checkouts was defined and the Operational Requirements Verification Plan was written.

In the framework of the ERA Evolution programme, research was started towards the use of signal analysis techniques for a predictive maintenance facility. A predictive maintenance facility will aid in the determination of what maintenance both on hardware and on software should be performed, and when. A study on observer-based and identification-based FDIR schemes for a robotic joint was completed. This study, funded by the Netherlands Agency for Aerospace Programmes (NIVR), was carried out in co-operation with the Delft University of Technology.

ERA will fly on the International Space Station as part of the Russian segment. To prepare missions, to train operations with ERA and to validate missions, Mission Preparation and Training Equipment (MPTE) is being designed by NLR. An advanced software development



Schematic of real-time monitoring and control of networked simulations environment has been set up for high-quality distributed software development, testing and configuration management, using a variety of software provided by ESA/Fokker, Commercial Off The Shelf (COTS) and public domain software.

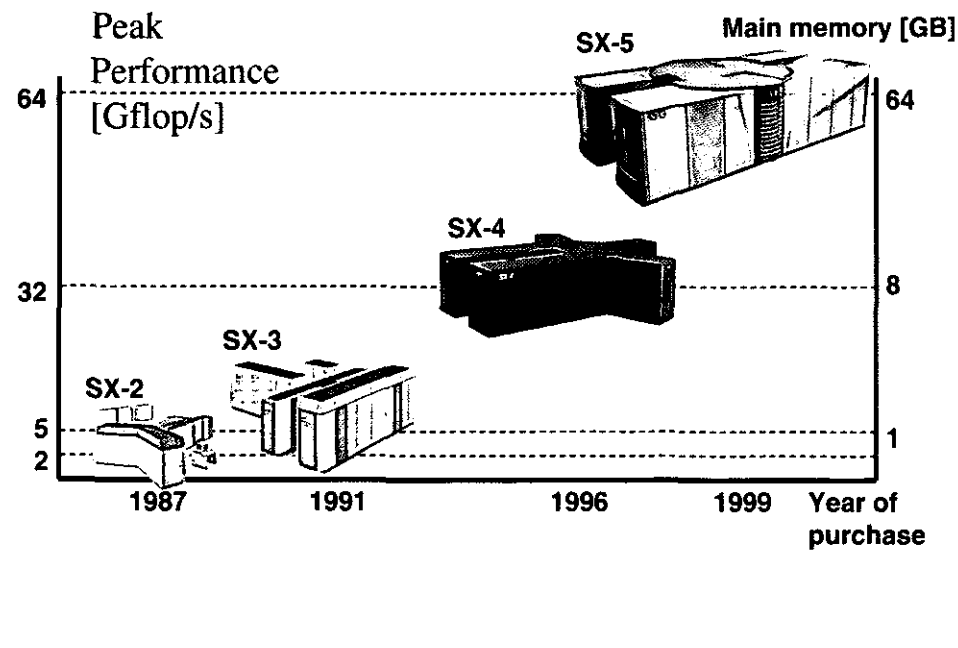
A GARTEUR Exploratory Group (EG-19) on Fault Tolerant/Reconfigurable Control was established, tasked to write the Terms of Reference (project plan) for an Action Group on Fault Tolerant Control. An initial limitation of the scope was achieved, requirements and evaluation criteria were written, and a Work Breakdown Structure was produced.

Information and Communication Infrastructure

The NLR Information and Communication Infrastructure (ICI) can be considered as the central nerve system of NLR Amsterdam and NLR Noordoostpolder combined. Both internal and external users can be provided access to computing facilities for data processing, simulation and experiments in NLR's facilities. The basic infrastructure, the computer network, consists of a high-speed communication network and several facilities. Among the facilities are a 32-GFLOP UNIX-based supercomputer (an NEC SX-4), several other UNIX-based servers, a non-UNIX mainframe and several PC servers. The communication network connects the facilities to workstations, X-terminals, PCs and terminal equipment for experimental facilities such as wind tunnels, flight simulators, ATC simulators and space simulators. The number of stations increased from 1533 to 1813.

A 34-Mbps ATM (Asynchronous Transfer Mode) link connects the computer networks of the two sites of NLR. In both sites, segmented networks provide the users with high-speed communication performance. The networks of three of the largest buildings were upgraded from Ethernet to a 155-Mbps ATM connection to the backbone and FTP (File Transfer Protocol) cabling to the workplace. The FTP cabling allows 100-Mbps Ethernet and 155-Mbps ATM connections at the workplace to be implemented easily. The standard for desktop connectivity is switched high-speed Ethernet via LAN switches.

Work at NLR is becoming more and more dependent on the availability of the computer facilities. Measures have therefore been taken to improve the availability of the facilities, resulting for the average worker in an availability value close to 99%. This value concerns the simultaneous availability of all relevant elements of the ICI.



Growth of supercomputer power at NLR

To make state-of-the-art supercomputer power available to NLR and its customers, during 1998, a letter of intent has been signed for the replacement of the NEC SX-4 supercomputer by an SX-5 supercomputer. This SX-5 is a shared-memory supercomputer (64 GB main memory) with eight vector processors. Each vector processor has a processing speed of 8 GFLOPs.

The gateway between NLR and the outside world is becoming more and more important, as both the traffic from NLR to the outside world and the use of NLR facilities from the outside world is increasing rapidly. The computer facilities provided the base for 34-Mbps European pilot experiments. To maintain security, a start was made with an upgrade of the network security measures. This will include ISDN, high-speed dial-back and the implementation of a better firewall on the 34 Mbps Internet interface.

The use of the computer facilities showed considerable growth, not only for computing but also for information storage and retrieval. The file server facility provides to all systems a file system that can be accessed from all locations at NLR. The total size of this file system increased from 240 GB to 390 GB. It includes more than two million files. The introduction of the SAMBA protocol on the file server makes the central file system also available from desktop PCs. During nights and weekends, the fileserver facility is used for backups. Backups can be made of all UNIX systems and all PC servers at NLR automatically. In weekends a full dump is made. The total size of all full dumps during a weekend increased from 240 GB to 450 GB, and the number of files dumped increased from seven million to ten million.

To support the use of PCs, central PC servers are available. A start has been made with an upgrade of the PC server structure to a single domain of Windows NT servers.

The NLR computing centre is one of the four High Performance Computing Centres (HPCN) in the Netherlands combined in ANKHER (Associatie van Nederlandse HPCN Kernen), which provides the Dutch scientific and industrial community with access to high performance hardware and software.

NLR participated in the Working Group on Supercomputing and Networking of AEREA. In this working group all seven European Aeronautics Research Establishments participated. Attention was paid to standardization and to the set-up of the computational infrastructure for an AEREA Extended Enterprise, the so-called AEREA Common Computing Centre ACCC.

3.6 Electronics and Instrumentation

Summary

In the area of avionics, on behalf of the Netherlands Department of Civil Aviation (RLD), NLR participated in several Working Groups of the European Organization for Civil Aviation Equipment and the Radio Technical Commission for Aeronautics.

Under the Fourth Framework Programme of the European Union (EU), NLR continued to participate in the project Generic Avionics Scalable Computer Architecture, aimed at the demonstration of an incremental certifiable avionics computer resource.

Under the European Co-operation for the Long Term in Defence (EUCLID), the project RTP 4.2 on the development of an 'Avionics Architectures Evaluation Tool' was started.

Supported by the Netherlands Agency for Aerospace Programmes (NIVR), a study on Future Operation Concepts for Utility Systems has been started, in co-operation with Fokker Elmo. NLR performed the simulation of a utility system architecture.

Under contract to Fokker Elmo, NLR completed the development of the Flight Control Display Module for next-generation civil helicopters and fixed-wing aircraft.

NLR continued participating in the development of software for the NATO Frigate Helicopter (NFH) Mission System of the NH90, for track-to-track associations of tracks from surface and subsurface vessels.

NLR provided support to the Royal Netherlands Air Force (RNLAF) in several projects, including studies concerning tactical data links.

Under contract to the Netherlands Ministry of Defence, NLR started a research project into smart skin array technology, concentrating on the electromagnetic interaction of conformal antennas with the aircraft structure.

Work continued on the Phased Array Universal Synthetic Aperture Radar (PHARUS), a fully polarimetric airborne SAR. NLR also contributed to the study of a spaceborne SAR, mainly dedicated to the global monitoring of land surfaces and ice, as well as participating in the EUCLID programme Advanced Space Synthetic Aperture Radar (SAR) Sensor Technology.

NLR in co-operation with Signaal Special Products developed a non-volatile Mass Storage Device for the International Space Station under contract to the European Space Research and Technology Centre (ESTEC) and NIVR. In addition, a research programme was started to investigate the feasibility of the use of solid-state memories.

In the field of electronics, NLR continued the design, manufacturing and realisation of a number of Data Collection Units for the Large Solar Simulator of ESTEC.

Under contract to BFGoodrich AERCOR, NLR continued the development of the Remote Frequency Indicator and Fuel Panels for the NH90 helicopter.

Under contract to Eurocontrol, NLR continued the development of units of the Airborne Data Link Processor, for communication with a Mode S transponder.

Under contract to ESA/LABEN, NLR continued the development and installation of the Safety System Sub-Assembly for the Automation System of the Italian Aerodynamic Plasma Wind Tunnel.

In the area of instrumentation, NLR supported flight testing with a Fokker 100 by Fokker Aviation.

The European Research on Aircraft Ice Certification project was concluded by additional flight tests with the Metro II research aircraft.

NLR participated in a number of projects related to the Global Navigation Satellite System (GNSS). In the EU Fourth Framework project

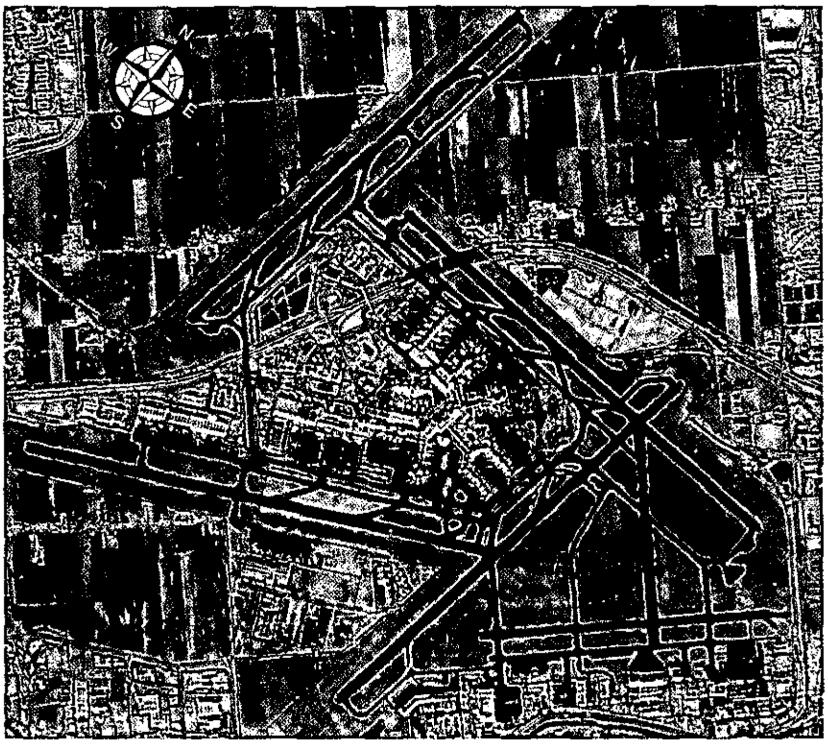


Image of Amsterdam Airport Schiphol by PHARUS, airborne Phased Array Universal Synthetic Aperture Radar

Multimodal Approach for GNSS-1 in European Transport (MAGNET B), tests were carried out with GPS-based positioning systems developed by partners in the project. Preparations were made for a trial involving service cars of Amsterdam Airport Schiphol (AAS) and NLR's Metro II research aircraft to demonstrate Surface Movement and Control System (SMGCS) applications. In the GNSS Performance Validation (GPV) project of Eurocontrol, recommendations were made for validation procedures for integrated GNSS/IRS receivers.

Within the PD/3 demonstrations of the Programme for Harmonised Air Traffic Management Research in Eurocontrol (PHARE), the Experimental Flight Management System (EFMS) on board the Cessna Citation II research aircraft was integrated with the NLR Air Traffic Research Simulator (NARSIM) through a PATN (PHARE Aeronautical Telecommunications Network) data link, and used to demonstrate ATM concepts in flight.

In the Airborne Air Traffic Management System (AATMS) project of the EU Fourth Framework Programme, a large scale integration effort was performed for flight trials with NLR research aircraft concerning experiments with an advanced FMS, intended for near term replacement of current FMSs. A trials set up was realised with the aircraft connected through a PATN ATN data link to NARSIM. A number of flights were carried out in the presence of representatives from the EU and Eurocontrol. Air Traffic Controllers and pilots from outside NLR participated in the trials.

Under contract to the Royal Netherlands Air Force (RNLAF), a flight test instrumentation system for the F-16 MLU was designed. Cockpit control panels for the new system were developed and acquired data acquisition units were tested. Other military flight test support included the installation of helicopter flight test instrumentation for helicopter/ship qualification tests for the Royal Netherlands Navy (RNN) and the use of a tracking telemetry system for F-16 Helmet Mounted Cueing System tests of the RNLAF together with other EPAF countries.

Under contract to the Ministry of Defence, an interface demonstrator was developed to adapt the new 'generic reconnaissance interface' of the F-16 MLU to the existing Orpheus reconnaissance system of the RNLAF.

In the field of facilities and equipment an outdoor Antenna Test Range (ATR) was installed. The ATR will be used as a research facility for determining the characteristics of new antenna types, including conformal array antennas. The EMC laboratory successfully passed its yearly quality audit, and was appointed Competent Body for the European EMC Directive by the Netherlands Radiocommunications Agency (RDR).

The realization of an Avionics Systems Integration Rig (ASIR) has been started. ASIR is planned to become an important, generic simulation environment for civil and military avionics systems in the next few years,

The software of the NLR Infrastructure for Computer-based Electronics Systems development Tools was updated, and a pilot project was started for the implementation of Product Data Management tools.

SATCOM data 3 and VHF digital data links mode 2 and 4 were installed in NLR's research aircraft to provide the means to carry out Air Traffic Management research and demonstration projects.

The Position Reference System (PRS) was adapted to provide ILS-like steering signals to the autopilot of NLR's Cessna Citation II research aircraft to enable flights to be repeated with under 10 metres of difference between tracks.

For flight test instrumentation purposes, fibre optic gyros were studied and new data acquisition equipment and signal conditioning units were evaluated.

The Data Acquisition Equipment Calibration Laboratory and the Calibration Laboratory for Electromagnetic Quantities successfully passed the yearly audits by the Dutch Council for Accreditation.

Avionics

Support to the Netherlands Department of Civil Aviation

Under contract to the Netherlands Department of Civil Aviation (RLD), NLR participated in working groups of the European Organization for Civil Aviation Equipment (EUROCAE) and the Radio Technical Commission for Aeronautics (RTCA). NLR attended the EUROCAE Working Group 48 and RTCA Special Committee 182 meetings concerning the definition of Minimal Operational Performance Standards for an Avionics Computer Resource (ACR). The purpose of this ACR is to integrate several aircraft applications on a single hardware platform, providing the possibility of incremental certification. By segregating the applications (software), the certification effort will be limited to new or modified applications. The guidelines for a standard Application Programming Interface provide portability and re-use of application software.
Related to this subject, NLR started an analysis for the incremental certification process and the reusability of application software. Incremental certification is new with respect to current software certification practices. The objective of the research is to assist the RLD in judging the ACR concept.

Advanced Avionics Systems

Under the Fourth Framework programme of the European Union, NLR participates in the project Generic Avionics Scalable Computing Architecture (GASCA), executed by several European partners led by Dassault Electronique of France. The objective of this project is to define, build, demonstrate and validate an advanced avionics architecture to integrate several aircraft applications onto one computer platform. GASCA provides an architecture that is compliant with the Minimal Operational Performance Standards that are currently being defined for the Avionics Computer Resource within EUROCAE Working Group 48/RTCA Special Committee 182. Based on the GASCA architecture defined in the earlier phases of the project, the definition of the hardware/software demonstrator was started. NLR was specifically involved in the definition of the demonstrator applications and of the test platform. The demonstrator applications will perform basic aircraft functions including flight control and flight management. The test platform communicates with the demonstrator (where the applications run), provides the data required for the applications and monitors the data produced by the demonstrator. At the end of 1998, NLR started the implementation of the test set-up.

The EUCLID RTP 4.2 project started with Italy, Spain and the Netherlands participating. NLR is National Main Contractor, having three sub-contractors within the Netherlands. The objective of this project is to define and develop an Avionics Architectures Evaluation Tool (A2ET). With this tool, avionics architectures can be modelled and their performance can be analysed. The core concept of the tool is based on 'blue-prints', which describe the architecture of the system. Application blueprints describe the application requirements (what is needed in terms of resources), resource blueprints describe the system resource (what is available) and the system blueprint describes the mapping between applications and resources (which application runs on which resource). Each architectural element is associated with a performance model, to be able to measure, for example, network utilisation, transaction delays, timing conflicts, etc. The identification of the requirements for the tool was started. NLR was specifically involved in the requirements for architecture description (blueprints) and the requirements for the structure of the tool itself.

Future Operation Concepts for Utility Systems

Supported by NIVR, NLR in co-operation with Fokker Elmo studies Future Operation Concepts for Utility Systems (FOCUS). The goal of the project is to develop and to validate innovative technologies that can be applied in control concepts for utility systems in aircraft. In the project, a number of fundamental choices in the area of Man-Machine Interfacing will be studied. To enable concepts for interaction between pilot and utility system controls in the cockpit to be evaluated, simulation of part of the utility systems is needed. This requires knowledge of the operation of several utility functions. At the start of the project, the aircraft type and specific utility system controls to be studied have been decided upon. The architecture of the Electrical Power Control and the Anti-Icing Control have been simulated.

Flight Control and Display Module (FCDM)

Under contract to Fokker Elmo, NLR has successfully completed the development of the software for the Flight Control Display Module (FCDM), which is a safety-critical part of the Flight Control Display System (FCDS). The FCDS is a subsystem of Sextant Avionique's new generation of helicopter avionics systems. It provides the pilot with essential guidance and navigation functions. NLR has developed the FCDM software using the guidelines in the RTCA DO-178B document, the application of which is mandated by the certifying authorities. Part of the software conforms to the highest software level, whereas other parts could be classified at lower levels. Partitioning software has been developed to guarantee that software classified at different levels do not interfere under any circumstances, and to reduce the total verification effort. The software architecture is based on configuration tables that drive the functional operation. The FCDM software has been written in the C programming language and was verified among other things with the aid of a commercially available software verification tool that also provides detailed structural code coverage information. The completion of the FCDM software development took place on-site at Sextant Avionique in Bordeaux. Here, the FCDM was also integrated in the FCDS integration rig, and the complete subsystem was validated. More details on the FCDM are given in the Capita Selecta.

NH90 Mission System Development

NLR participates in the design and development of the Nato Frigate Helicopter (NFH) Mission System of the NH90 helicopter. NLR develops a software module that performs track-to-track associations of tracks generated from surface and subsurface vessels, using information from sensors such as radar, Forward Looking Infra-Red (FLIR), Electronic Support Measures and sonar. The main goal of this module is to reduce operator workload. Currently, track associations of this kind are performed manually. Using the new software module, the operator confirms or rejects suggestions, and is relieved from the task of comparing tracks in detail. Functional evaluations and simulations have been carried out to specify the behaviour of the module in more detail and to validate the design goals. Several prototype algorithms have been identified, with techniques ranging from straightforward mathematical approaches to fuzzy logic and artificial intelligence. Performance and robustness criteria have been defined, and the algorithms have been evaluated against these criteria.

Support to the Royal Netherlands Air Force (RNLAF)

NLR provided support to the Royal Netherlands Air Force (RNLAF) in several projects, including the modelling of avionics architectures and tactical data links. In the area of avionics architecture modelling, a functional model of an instrumentation system has been developed. The model was verified by comparison with the behaviour of real hardware. In the area of tactical data links, interoperability between platforms was investigated. This specifically related to different data link protocols that are applied on the various data link subsystems. In addition, operational aspects of applying data links in a tactical scenario, Close Air Support, were investigated.

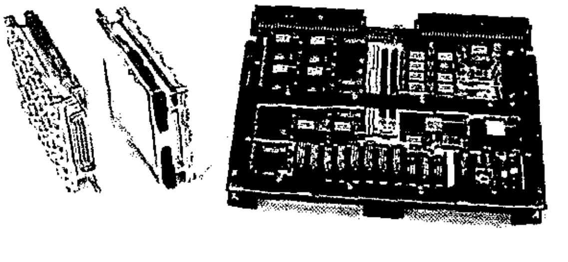
Smart Skin Array Technology

Under contract to the Netherlands Ministry of Defence, NLR started a research project into Smart Skin Array Technology. Smart Skin arrays are active phased array antennas of the conformal type that are constructed in the form of thin flat layers and use transmit/receive modules. Smart Skins are especially suited for applications on aircraft or ground-based platforms, where they are flush-mounted to the exterior of the vehicle. The Smart Skin technology is aimed at the improvement of aircraft performance and avionics system capability by integrating sensors, signal processors, signal and power distribution networks and associated control functions with a composite load-bearing skin structure to form an active interface with the flight environment. NLR's activities concern the electromagnetic interaction of conformal antennas with the aircraft structure. NLR has developed a hybrid method for the calculation of this interaction between the aircraft fuselage and a conformal array antenna mounted on the aircraft. This method combines both high-frequency methods and boundary integral equation methods. Antenna radiation pattern measurements have been performed on single patch antennas in NLR's EMC facility.

Synthetic Aperture Radar Technology

NLR continued work on the Phased Array Universal Synthetic Aperture Radar (PHARUS), a fully polarimetric airborne SAR, a co-operation of the TNO Physics and Electronics Laboratory (FEL-TNO), the Delft University of Technology and NLR. Several flights were conducted with PHARUS on the Citation II research aircraft to collect data for Remote Sensing users. Special emphasis was given to some experimental settings of the beam steering and guidance of the aircraft along a straight trajectory. In addition, in co-operation with Fokker Space, FEL-TNO, the Wageningen Agricultural University and the International Institute for Aerospace Survey and Earth Sciences (ITC), a market study was carried out concerning the commercial exploitation of PHARUS in Indonesia.

The EUCLID programme (CEPA 9, RTP 9.3) 'Advanced Space SAR Sensor Technology' was continued. NLR participates in the areas of Electronic Counter Counter Measures (ECCM), Digital Control, and Thermal Analysis and Control. The goal of the programme is to define



Space–qualified Mass Storage Device

and develop new technologies to be used in military spaceborne SARs.
For the ECCM work package, jamming due to non-intelligent sources (so-called brute force jamming) was studied. It was determined what measures, at least theoretically, can be taken onboard spacecraft to counter such jamming. For the digital control work package, a PC-based demonstrator system has been defined for proving the control concept, defined before. This demonstrator will interface with transmit/receive hardware modules developed by a partner in the project. Thermal analyses of the three concepts of a spaceborne SAR (S-band, X-band and combined S/X-band) were made. Thermal models were conceived and calculations of heat transfer were made. Possible solutions for thermal control were discussed.

Mass Storage Device

NLR, in co-operation with Signaal Special Products, developed a space-qualified non-volatile Mass Storage Device (MSD) for the International Space Station under contract to ESA and NIVR. Each MSD unit contains two hermetically sealed and vibration-isolated state-of-the-art Commercial Off The Shelf (COTS) hard disk drives. The drives are electronically protected against radiation effects and can be operated in mirror mode for increased data reliability. The devices will be accommodated in various VME-based data management computers in the Russian Service Module and in the Columbus Orbital Facility, the ESA laboratory module.

After the delivery of one qualification and three flight models for the Service Module in the course of 1997, the MSD programme continued in 1998 with the start of the deliveries for Columbus. A second qualification model was built. Because of different vibration and shock requirements, a design change of the cartridge interior was realised. The acceptance and delta-qualification tests were performed successfully.

A research programme to investigate the feasibility of the use of solid-state memories instead of hard disk drives, under contract to the NIVR, was continued. This work included a number of radiation tests. NLR performed proton tests at the Paul Scherrer Institute in Switzerland. Solid-state memories are capable of operating under more extreme environmental conditions. Moreover, the absence of any moving parts contributes to a higher reliability and guarantees that they do not generate microgravity environment perturbations.

Electronics

Satellite Electronics and Ground Support Equipment.

As a subcontractor of Fokker Space B.V., NLR continued its involvement in the ESA project Cosmic Dust Aggregation (CODAG). This is an experiment to simulate the early phase of dust aggregation in proto-planetary disks. NLR has developed, built and delivered a major part of the on-board electronics and ground support equipment for CODAG

Temperature Data Acquisition System

Under contract to ESTEC, NLR continued the design and development of a prototype Data Collection Unit (DCU) for the Temperature Data Acquisition System (TEMPDAS). The system will be mounted on a motion system inside the Large Space Simulator (LSS) of ESTEC, which provides simulation of in-orbit conditions. Two partners of ESTEC, IABG of Germany and Intespace of France are also involved in the project. The purpose of TEMPDAS is to enlarge the number of thermocouple channels that can be measured, reduce the number of slip rings used for information transmission, and reduce the possibility of data corruption. A prototype DCU with three thermocouple multiplexer boards, power supplies, special housing and driver software has been designed and built.

Wind Tunnel Instrumentation and Signal Conditioning

The instrumentation for a rotating instrumented model propeller was produced, tested and delivered. This propeller was used in the EU Fourth Framework project Advanced Propulsion Integration Aerodynamics and Noise (APIAN).

Wind Tunnel Safety Systems

Under contract to LABEN of Italy, NLR completed the development and installation of the Safety System Subassembly of the Automation

System of the Italian Aerodynamic Plasma Wind Tunnel. The system is based on redundant Programmable Logic Controllers (PLCs) and PCs with a Windows NT operating system.

Miniaturisation of Satellite Test Equipment

Supported by NIVR, NLR in co-operation with the Dutch industry HYMEC, finalised the miniaturisation of a current/voltage source, by further development of existing and proven circuitry. For evaluation purposes, two types of miniature electronic circuits were built, one based on the use of Surface Mounted Devices and one based on thick-film hybrid techniques with naked chips.

NH90 Remote Frequency Indicator

NLR continued its support to Dutch industries in the design and development of avionics equipment for the NH90 helicopter. Under contract to BF Goodrich AERCOR of Zevenaar, the programmatic and technical co-ordination of the development activities and the execution of analyses required for the delivery of the Remote Frequency Indicator (RFI) were continued. The RFI is a five-field LED-based indicator. The displays are both Night Vision Goggle compatible and sunlight readable. Each NH90 helicopter will be equipped with two RFIs.

NH90 Fuel Panels

Under contract to BF Goodrich AERCOR, activities were continued to support Fuel Panels design and development. Extensive environmental tests were carried out, such as temperature, salt spray, humidity, EMC/EMI, and shock and vibration, mostly at facilities operated by NLR.

Airborne Data Link Processor Unit

Under contract to Eurocontrol, NLR continued the development of Airborne Data Link Processor units (ADLP). The ADLP provides intercommunication functions necessary to interface data link communication systems with a mode S transponder onboard aircraft. It acts as a data collector for ARINC 429 avionics buses. After collection and preprocessing, the data is transmitted to the ground via the mode S-transponder.

Instrumentation

Flight Testing and Flight Test Instrumentation

Flight Testing at Fokker Aviation

NLR supported the flight test activities at Fokker Aviation. An NLR Production Flight Test system, installed in a Fokker 100 series aircraft, was used in thrust reverser tests. Several ground and flight tests were executed. Calibrated data sets were delivered for further analysis.

Measurement and Analysis Techniques for In-Flight Research

Position Reference System

In co-operation with the Delft University of Technology, the so-called LAMBDA-algorithm for the solution of phase ambiguities of GPS-signals was tested using GPS phase data acquired during earlier test flights with Fokker aircraft. A computer program, installed in NLR's Flight Test Data Processing Station, provided position accuracies in the 0.1-m class (3-D) and gave good indications of the reliability of the ambiguity solution.

Flight Guidance for Repeat Pass Interferometry

The Position Reference System (PRS) was adapted to provide ILS-like steering signals for the autopilot of the NLR Cessna Citation research aircraft, to enable the aircraft to fly the same tracks repeatedly, with a reproducibility better than 10 m. This was a prerequisite for interferometric measurements by the PHARUS synthetic aperture radar installed in the aircraft. This objective was met during four successfully flown tracks.

Engine Exhaust Measurements

The research programme for the in-flight validation of engine exhaust emissions models was concluded with the final reporting of the results of ground tests of spectroscopic detection techniques that could be used in flight. The Fourier Transform Infrared spectroscope yielded good results for CO and NO in the light emission measurement mode, but performed less well for NO_2.The results were presented at the 'Gas Turbine Engine Combustion, Emission and Alternative Fuels' symposium of the NATO Research and Technology Organization in Lisbon.

Support to the European Union

Aircraft Ice Certification

The European Research on Aircraft Ice Certification (EURICE) project, which is part of the Fourth Framework programme of the European Commission, was completed. It has been carried out by a consortium led by CIRA of Italy. The results of the project, which was aimed at aspects of aircraft flying under icing conditions, ranging from meteorological data to incident/accident data bases and certification regulations, was presented to representatives of the European Commission and the JAA, and at a conference of the European Geophysical Society. The main result from the flight tests, carried out with NLR's Metro II research aircraft equipped with a pod carrying special sensors, was that, under icing conditions, quite a number of atmospheric situations were outside the scope of current certification regulations of JAR 25. This result was confirmed by measurements by other partners.

Prototype Aeronautical Telecommunication Network

The Prototype Aeronautical Telecommunication Network (ProATN) project entered its second phase under approval by the European Commission and Eurocontrol. The Boundary Intermediate System (BIS) was integrated with all partners, and work started to shift from development to preparation for the integration, deployment and validation. ProATN is intended to provide the communication network for the EU EOLIA (European Pre-Operational Data Link Applications) project to implement its applications. Co-ordination between the two projects proved to be a challenging task. The basic document of ProATN, the 'Technical Annex' was thoroughly updated to provide a clear goal for phase 2 and a coherent approach of the partner's tasks and responsibilities. In advance of the installation in NLR's Cessna Citation of the Air Traffic Services Unit (ATSU) developed by Aerospatiale, an Integration Plan was developed.

Airborne Air Traffic Management System

After three years of preparations, the EU Fourth Framework project Airborne Air Traffic Management System (AATMS) reached the status of demonstrations and flight tests. A newly developed Advanced Flight Management System (AFMS) was installed in the Cessna Citation II research aircraft. This AFMS was designed as a near term replacement of current FMSs. It featured ADS (Automatic Dependent Surveillance), CPDLC (Controller-Pilot Data Link Communication) and AOC (Airline Operations Centre) functionality defined in the CNS/ATM-1 specification. During the flights the aircraft communicated via digital data link with the NLR Air Traffic Control Research Simulator (NARSIM). Communication was based on the use of the PATN (PHARE Aeronautical Telecommunications Network) data link infrastructure, which was adapted to provide the ADS, CPDLC and AOC functionality. Two data link subnetworks were available: SATCOM and VHF Data Link (VDL) Mode 2. These two subnetworks have complementary characteristics. The former is expensive, has a low data rate performance but provides nearly global coverage, whereas the latter is cheaper, provides higher data rates, but has coverage limited to the line of sight. In operational applications, VDL could be used until its unavailability requires switching to SATCOM. In the integration of the ground, airborne and data link part of the system, a team of OGMA from Portugal, National Avionics from Ireland, ETG from Germany and ARINC from the US was working closely together at NLR. The system performed well, and was demonstrated in a number of flights to representatives of the European Commission and of Eurocontrol. The higher data rates of VDL with respect to SATCOM were confirmed. Commercial pilots flew and evaluated the system, while two professional air traffic controllers attended NARSIM.

Multi-modal Approach for GNSS-1

The Global Navigation Satellite System (GNSS) project 'Multi-modal Approach for GNSS-1 in European Transport (MAGNET-B)' is being carried out by a consortium led by Dassault Electronique. NLR contributes in the field of pseudo-operational experiments with a number of GPS-based positioning systems that were developed by other partners in the project.
In co-operation with Amsterdam Airport Schiphol (AAS), preparations were made for Automatic Dependent Surveillance (ADS) and Surface Movement and Ground Control System (SMGCS)

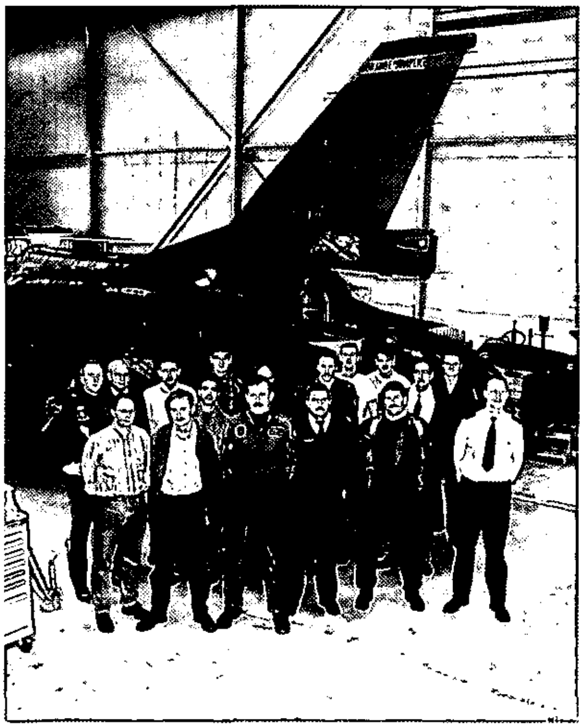
tests involving NLR's Metro research aircraft and a number of service cars of the airport. Bi-directional VHF data links of the Self-organizing Time Division Multiple Access (STDMA) type will be used, both for position reporting and for improving the GPS position with differential corrections from a local ground station. Integration tests in the laboratory, involving the experimental ground station and the combined VDL/GPS-receiver/transmitters, were successful.

In another experiment, a GNSS-receiver, using differential corrections from EGNOS test signals, was flown. Results were compared with an independent reference system.

Support to Eurocontrol

GNSS Performance Validation

NLR was nominated prime contractor for the project GNSS Performance Validation by Eurocontrol. The goal of this project was to propose suitable validation procedures with respect to GNSS (Global Navigation Satellite System) which comprises GPS, GLONASS and EGNOS. Work in the area of instrumentation focused on the validation of integrated GNSS/IRS-receivers. Several types of integrated receivers and their behaviours were described.



Klu/NLR team who install flight test instrumentation in an F-16 MLU

Recommendations were given with respect to the validation of the integrated receiver. Fault-tree analyses of stand-alone and integrated receivers have been performed, and recommendations with respect to the integration of a GNSS receiver with other sensors were given.

Experimental Flight Management System

In the Eurocontrol Programme for Harmonised Air Traffic Management Research in Eurocontrol (PHARE), NLR takes part in the development, evaluation and demonstration of an Experimental Flight Management System (EFMS). As a part of the final PHARE Demonstration programme PD/3, the EFMS with a new software version was integrated with the Airborne Human Machine Interface (AHMI) and the NLR ATC Research Simulator (NARSIM) through a SATCOM ATN sub-network. EFMS/AHMI was implemented in NLR's Cessna Citation II and connected to the Primary Flight Displays and navigation displays at the positions of the flying and the non-flying pilots who conducted the flight tests. The pilot flying could switch one of the displays between a conventional Primary Flight Display with additional augmentations for 4-D guidance and an advanced 'tunnel in the sky' concept. The feasibility of the PHARE 4-D flight plan negotiation concept could be demonstrated in a number of flights, but it was found that the current SATCOM sub-network was causing delays that had a serious impact on its operational application. The tunnel-in-the-sky presentation was judged by the pilots to be a valuable tool for flying 4-D trajectories.

Military Flight Test Support

Helicopter/Ship Qualification Instrumentation

For the qualification tests of the Westland Lynx helicopters on board the new Amphibious Transport Ship 'Rotterdam' of the Royal Netherlands Navy, a data acquisition system was installed in the Lynx. Data were transmitted to the data processing system on board the ship by means of a telemetry link.

F-16 MLU Flight Test Instrumentation

The work for the contract awarded by the RNLAF for the development and installation of a flight test measurement system in an F-16 MLU progressed well. Modification descriptions were made, and the electrical and mechanical architecture and design were completed. The system will use remotely located data acquisition units, controlled by a central system and interconnected by means of a serial bus. A cockpit control panel for controlling the basic system functions by the pilot was developed. Flight test data will be displayed in the aft cockpit on a PC-compatible computer with an LCD display for which a special console was developed. A video interface to present flight test data as well on the Multi Function Display of the forward cockpit was designed. The system will be able to record all Mil Std 1553 Mux buses in a format compatible with existing RNLAF/NLR replay systems and with the configuration used at Edwards AFB for F-16 MLU development testing. The larger part of the data acquisition units was acquired and functionally tested.

F-16 MLU/ORPHEUS Interface

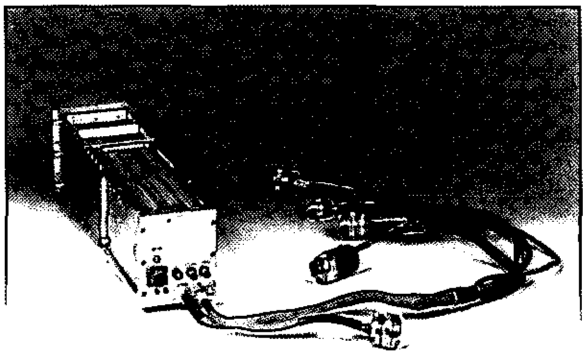
In preparation for the transition of the ORPHEUS reconnaissance system of the RNLAF from the F-16 OCU to the F-16 MLU, an ORPHEUS MLU Interface Demonstrator (OMID) was developed. This unit was designed to fit into the F-16 pylon in order to prevent the necessity of modifying the ORPHEUS system itself. OMID converts the commands on the F-16 'Generic Recce Interface' into signals compatible with the current ORPHEUS. It was functionally tested and entered an environmental qualification programme in preparation of the flight test phase.

Telemetry for F-16 MLU Tests

A new transmitter and receiver with tracking antenna capable of handling telemetry data of rates of up to 6 Mbps was used for an F-16 MLU flight trials programme of the EPAF countries to test a Helmet Mounted Cueing System.

Missile Warning System Tests

Under contract to the RNLAF, NLR has participated in a project to evaluate a Missile Warning System for use with the F-16 aircraft. In order to operate the Missile Warning System and to



F-16 MLU/Orpheus Interface

transfer data to the various systems, the RNLAF F-16B Orange Jumper flight test aircraft was equipped with an additional Mil Std 1553 Mux bus and an Electronic Warfare Management System. NLR was responsible for the installation of this equipment and the reconfiguration of the standard Orange Jumper instrumentation systems to record and process the data from the Missile Warning System.

Facilities and Equipment

Facilities for Environmental Testing

Both the Electromagnetic Compatibility (EMC) and the Vibration and Shock Test (VST) laboratory carried out numerous measurements under contract to customers from the aerospace and non-aerospace industry. The EMC measurements were mainly carried out in NLR's anechoic room. An Open Area Test Site (OATS), annexed with a heliport, enables the EMC Laboratory to carry out measurements both on small test samples (e.g. emission measurements according to the European EMC directive) and on larger test items such as helicopters (e.g. radiated immunity tests). The OATS was also used for the calibration of antennas. Apart from the usual EMC measurements according to aerospace, defence and civil standards, measurements were carried out concerning the shielding effectiveness of cables and materials. An outdoor Antenna Test Range (ATR) was installed. The ATR will be used as a research facility for the determination of the characteristics of new antennas types, including conformal array antennas.

The EMC Laboratory is accredited by STERLAB. In addition, the EMC laboratory was appointed Competent Body for the European EMC Directive by the Netherlands Radiocommunications Agency (RDR). As Competent Body for the EMC Directive, NLR is authorised to review and certify Technical Construction Files (TCFs) for a wide range of products. TCFs need to be written for the cases where the manufacturer has not applied harmonised standards. The function of the Competent Body is to assess the TCF and to generate a report or certificate.

NLR increased its capabilities to execute complete packages of environmental testing for customers. Test programmes involved the facilities for Vibration and Shock, Electromagnetic Compatibility, Temperature, Pressure and Humidity, Thermal Vacuum, Thermal Cycling, Salt Spray, Fungus, Fluid Contamination and Rain. Wherever NLR did not posses the required facilities, part of the testing was subcontracted to test facilities elsewhere (e.g., for fungus testing).

Avionics Systems Integration Rig

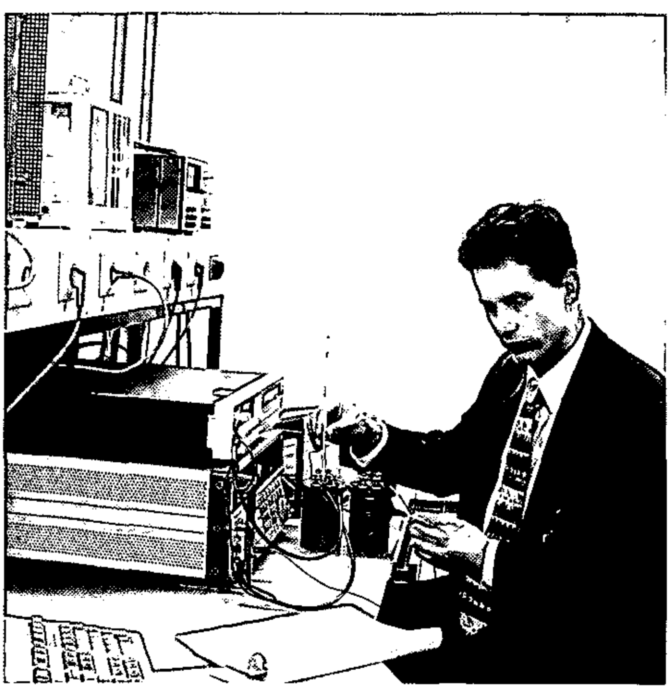
NLR is developing an Avionics Systems Integration Rig (ASIR), which will serve as an integration platform for modern avionics systems. This rig, a simulation environment, will enable NLR to perform tests and evaluations of the performance of avionics equipment in general and of various military and civil aircraft installations in particular. ASIR will be used in assessments of operational issues, modification evaluations, accident investigations and fault analyses, and serve as a development and test platform for avionics. A start has been made with the development of the ASIR core system, including the definition of the necessary hardware and software.

Computer Aided Engineering of Electronics

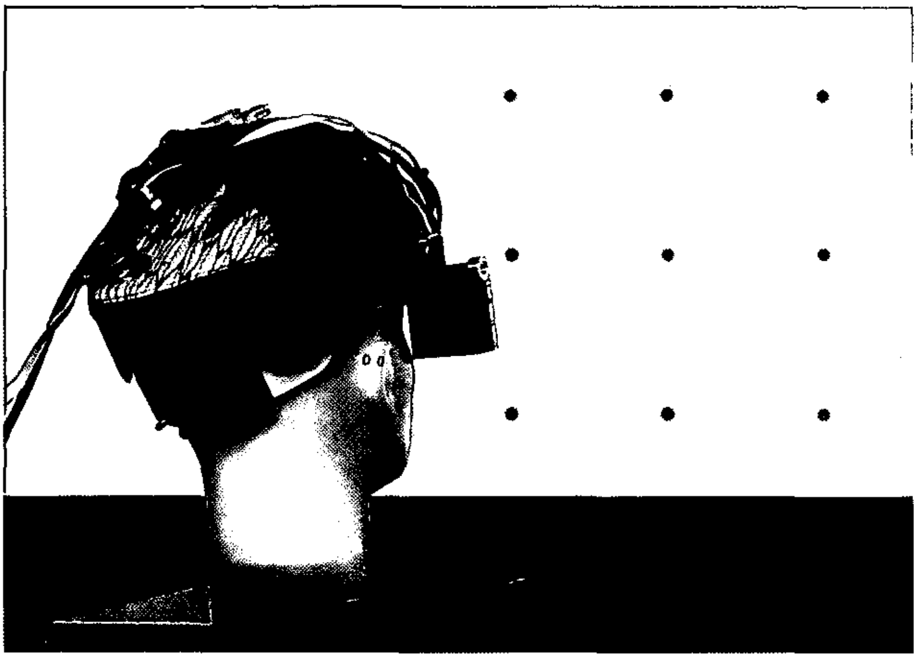
The NLR Infrastructure for Computer-based Electronics Systems development Tools was updated with new software for programming the currently used Logic Cell Arrays. Projects for design and development of electronic equipment have become increasingly complex. For securing the integrity of product design data, so called Product Data Management is needed. A pilot project was started for the introduction of Product Data Management tools. Existing workstations were replaced by more powerful ones, in order to host the CAE tools.

Calibration Laboratory for Electro-magnetic Quantities

The calibration laboratory for Electro-magnetic quantities has successfully applied for the continuation of its long-standing accreditation based on EN45001 and ISO 9001 by the Dutch Council of Accreditation (RvA). The laboratory has carried out numerous calibrations on electrical test equipment, used by NLR and industry. Working standards and equipment were updated.



Calibration engineer in the laboratory for Electromagnetic quantities



Laser calibrator for the gaze-tracker

Prototype Production Facilities
Facilities for the production of prototypes, such as clean rooms and general workshops were extended with special mounting equipment for Surface Mounted Components.

Instrumentation for Research Aircraft
Work on the instrumentation of research aircraft largely concerned the integration of the equipment under test in Air Traffic Management research and demonstration projects with aircraft systems, airborne computers, data links and displays at the two experiment positions for pilots.
The implementation of SATCOM Data 3, VHF Data Link (VDL) Mode 2 and VDL Mode 4 data links providing communication based on the PATN protocols proved to be a very valuable tool for ATM experimental research with NLR research aircraft.

Facilities for the Acquisition and Processing of Measurement Data
The specifications of fibre optic gyros were studied for use in flight tests as was the application of laser anemometers. New data acquisition units, the Micro Miniature Signal Conditioner (MMSC) and the Programmable Master Unit (PMU) were evaluated for applications with remotely located MMSCs under control of a single PMU by means of a serial command/data bus. This PMU is capable of providing selected data to a Cockpit Control Unit (CCU) that was also acquired.

The Mil Std 1553 Multiplexing data bus has become widespread in military aircraft. The integration of older aircraft with modern avionics systems or vice versa requires interface electronics. To meet this requirement, the development of a generic 1553 interface adapter based on Commercial-off-the-Shelf (COTS) VME computer modules was started. It will be used in projects of the RNLAF and of a foreign customer.

To support the measurements for human factors research, a third head/eye-tracking system was put into operational use. Improvements concerning the calibrating procedure and the comfort of the person under test were achieved.

The Data Acquisition Equipment Calibration Laboratory, accredited for pressure calibrations successfully passed its yearly audit by the Dutch Council for Accreditation. Calibrations for several customers were carried out.

3.7 Engineering and Technical Services

Summary

Contract work and capacity were reasonably well balanced in the year. Although in the first six months the workload was rather high, after that the projected high workload did not materialize due to a number of cancelled and delayed contracts for wind tunnel models. This made room for some more own research, especially in the field of rotating balances, remote control and stereo-lithography. Also, non-aerospace work was acquired from mechanical engineering companies to fill the available capacity.
A decision to keep and further exploit the Huron EXC milling centre was taken, despite some limitations to this high-speed 5-axis machine.

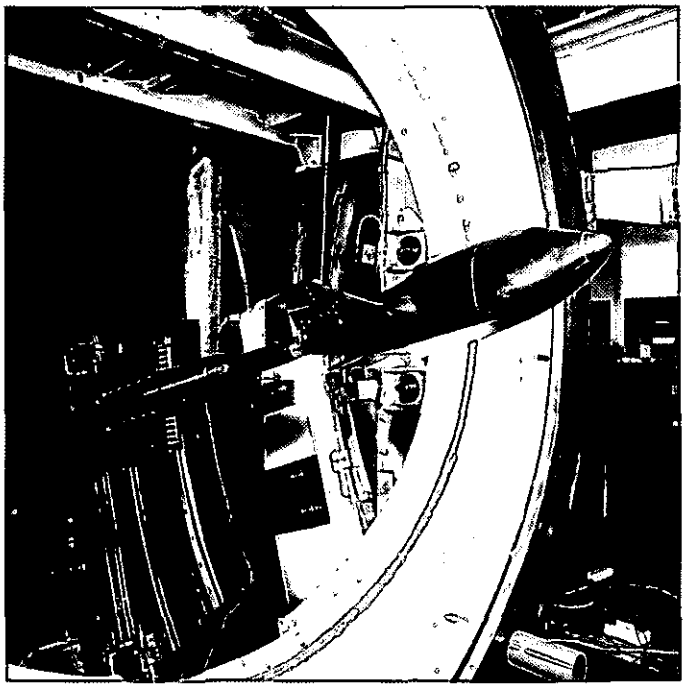
Wind Tunnel Models

A number of wind tunnel models and installations were developed. An important project was the development of the components for the BRITE / EURAM propeller research programme APIAN (Advanced Propulsion Aerodynamics and Noise): the propeller units with carbon composite propeller blades, the rotating balances and the propeller test stand for the DNW-HST.
For another BRITE/EURAM programme, EUROSUP (Reduction of Wave and Lift-Dependent Drag for Supersonic Aircraft), a fuselage model and three wings with different leading and trailing edge deflections were made for supersonic, transonic and subsonic speeds.

For Cessna, an outer wing panel was extensively modified for tests in the DNW-HST.
For CIRA, a launcher model was built for tests in the DNW-HST and DNW-SST. For ESA two space re-entry vehicle models for the X38 programme were built, one for tests in the DNW-HST and DNW-SST, the other for tests in wind tunnels S4/F4 of ONERA.
In addition, various models of external customers were adapted for measurements in the DNW-HST.
Design work was started on an all-new outer wing panel for Cessna, and for a heavily instrumented wing for a full-span model for AerMacchi. These models were expected to be tested in the DNW-HST.

In general, quite some effort was spent in the operational support of the Dutch wind tunnels. In particular, tests in the DNW-HST required a lot of support.

Apart from complete models, also model components were developed, under subcontracts for customers. Examples are the carbon composite propeller blades for various European programmes such as APIAN (Advanced Propulsion Integration Aerodynamics and Noise) and FLA (Future Large Aircraft).



Scale 1:16 wind tunnel model of X-38 re-entry vehicle in the DNW-SST supersonic tunnel at NLR Amsterdam

For non-aerospace research, various models were made: models of ships, bridges, oilrigs, trains and buildings. These models, to be tested in the DNW-LST, were largely made of wood and composites.

Wind Tunnel Equipment

The largest wind tunnel equipment job was the propeller test stand for the DNW-HST, part of the APIAN research programme. Before the DNW-HST tests, the propeller installation itself was evaluated and cleared for correct behaviour in the Small Anechoic Tunnel (KAT) of NLR.
Also, various modifications to existing wind tunnel equipment were made in support of wind tunnel programmes in the DNW-HST, -SST, -LST and -LLF.
A study on a new type of low-reaction air supply system for the DNW-LLF was concluded by the construction of a prototype.

For non-aerospace research, a narrow but long model of a train tunnel was built to study the characteristics of shock waves in the tunnel due to passage of high-speed trains.
For tunnel ventilation research, a small wind tunnel was built as an extension to the KAT facility.

Strain Gauge Balances and Model Instrumentation

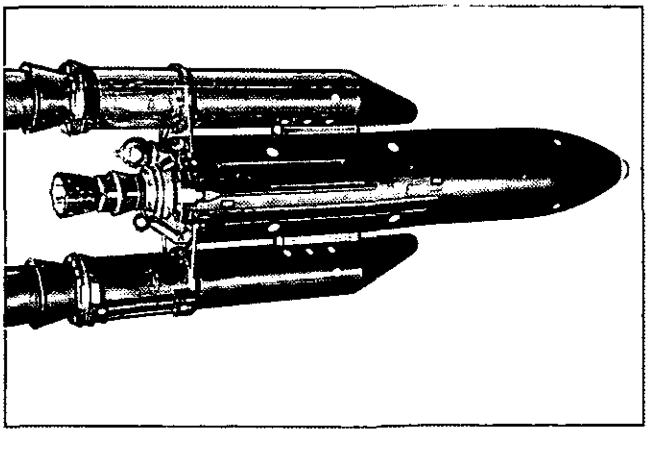
Fundamental research on strain gauge balances was continued. A Finite Element study was made to predict second-order interactions on high-load balances. The influence of cone connections on the adjacent measuring sections was studied. Also, it was investigated how the predictability of the output of control surface balances could be improved.
Furthermore, the usability of small strain gauges and compensation techniques were studied.

The development of the very slender specially-built six-component sting balance for the EUROSUP models was completed. The balance was used in the DNW-HST test programme, and performed to full satisfaction.
Development and construction of a high accuracy six-component sting balance for the DNW-HST was completed. This balance was developed as a replacement of an existing balance.
Also, the development was started of a heavy-load six-component sting balance for fighter type aircraft models, to be used in the AerMacchi test programme.
Rotating balances developed for the APIAN propeller test programme were tested in the DNW-LST and DNW-HST, and improvements were studied.
To support operations with the DNW-LLF, repairs were made to a sting balance, and various other instrumentation jobs were performed, both in the workshops of NLR and on site.

For the Netherlands Maritime Research Institute (MARIN), various sets of purpose-designed one-component strain gauge balances were instrumented.
A specialist of NLR instrumented model components of Aerospatiale on site in Toulouse.
For Fokker Space the design and construction was done of test equipment parts, instrumented with strain gauges, for robotics research.

Various Structures

Besides models and wind tunnel equipment several structures of very different nature were designed and/or manufactured.
Adaptations of NLR's existing airframe panel test rig were designed for tests under contract to three different customers.
Also, a test stand was designed for structural tests on the Urenco NH90 tail rotor drive shaft.
A full set of flight test equipment (brackets, racks, etc.) was made for the F-16 MLU programme.



Scale 1:76.5 model of Ariane 5 launcher for plume simulation tests

Many small components, including print plates and racks, for electronic equipment were made.

A cabin seat for NLR's Fairchild Metro II research aircraft was modified, and instrumentation racks were modified. Maintenance of the Research Flight Simulator and National Simulation Facility was supported.

Non-aerospace Activities

The attempts to offer capabilities and facilities of NLR to the Dutch precision engineering market were continued. 'NLR Precision Engineering' presented itself as such with a stand on the exhibition VAT98. The reactions of the industry so far have been positive, but actual results remained modest. However, work was acquired also from this market: a work of art was milled, an industrial designers model was measured and digitized, various instrumentation jobs were done, and a number of accurate milling jobs were carried out.

Development of New Techniques

To ensure the capability of designing and manufacturing highly complex products, in particular wind tunnel models, the development of new techniques and methods has been given continued attention.

Important effort was spent for resolving problems encountered with the APIAN rotating balances, to understand these problems and to improve the balances within the existing constraints. This effort has been partially successful.

Special attention has been given to the challenge to reduce both lead-time and costs of the development of wind tunnel models. Pressure on the reduction of lead-time has always existed, but has been increased by the industry in the past few years.

For this reason, new manufacturing techniques in the field of rapid prototyping were studied and practised, notably high-speed milling, stereolithography and other layered manufacturing techniques.
decided to proceed with the operation of this machine, but to improve its characteristics first. In the meantime, the machine was taken in full production as a three-axis milling machine. In 1999 a start will be made with high-speed milling, and later with five-axis simultaneous milling.

The CATIA CAD/CAM system was further extended and improved, software upgrades were installed, and three new, more powerful workstations were acquired.

A feasibility study was made for an aileron remote control system for a DNW-HST-size semi-span model or a DNW-LST-size full-span model. Due to the limited space available, and relatively high loads, the complications were such that a prototype was required to demonstrate the proper functioning of the remote control system. After a few modifications the demonstration was completed successfully.

To improve the process of making cost estimates for wind tunnel models, a strong need was felt for a model cost database, to be fed with the experience from the past. The structure of such a database was discussed and specified.

4 Internal and External Relations

Many visitors showed interest in activities of NLR. NLR participated in several airshows and exhibitions and organized various events. Some are mentioned below.

Visitors from the Netherlands

- Lgen. B.A.C. Droste, who paid a visit during JSF (Joint Strike Fighter) wind tunnel tests
- Lt.Col. B. Hop of the Royal Netherlands Air Force
- Cdre. P.N. van der Struis of the Royal Netherlands Navy
- Mr. J. Voigt, Director of the Netherlands Aerospace Group (NAG)
- Mr. J.H. Tankink and Mr. M.L.A. Durville of the Ministry of Economic Affairs
- Mr. S.Th.M.J. Bronsgeest, Corporate Manager Defence Participation and Offset of Philips Industries
- Mr. J. Fledderus, Dir.-Gen. Materiel of the Royal Netherlands Air Force
- Mr. E.R.M. Balemans, Member of the VVD fraction in the Parliament
- Drs. J.P. Pronk, Minister of Housing, Spatial Planning and the Environment
- Mr. Crince le Roy, of the Netherlands Department of Civil Aviation

Foreign visitors

- Mr. J. Leloup, Scientific Attaché at the French Embassy
- Prof. Volker von Tein and Dr. Herbert Diehl of the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR)
- Mr. Gordon R. Walsh, President and CEO of Interturbine
- Representatives of Northrop Grumman Corporation
- Mr. D. Estournet, Mr. P. Cunin and Mr. J. Arnold, of the French Ministry of Defence
- Representatives of Raytheon
- Employees of the International Institute for Aerospace Survey and Earth Science
- Mr. H. Ulrich, Mr. J.R. Carlsen, Mr.G.F. Bell, and Mr. R.M. Kylie of Lockheed Martin, showing interest in Air Traffic Management activities
- Mr. C. Dunker, Director, and Mr. G. Dealemans, Deputy Director, NASA GSFC-SSPP
- Brig.Gen.Eng. Terence Toth, Col.Eng. Tamadas Rath Ph.D. and Col. Györky Kapusy, of the Hungarian Ministry of Defence

Excursions

- Members of the Aeronautical Study Society 'Sipke Wynia' of the Haarlem College
- Junior members of KIvI (the Netherlands Royal Institute of Engineering)
- Members of the Study Society 'Isaac Newton' of Twente University
- Indonesian students, in the Netherlands for the Master Science Program at Twente University
- Cardiologists united in Vitratron Netherlands
- Students of the Pedagogics and Technical College of Zwolle
- Students of Ergonomics of the University of Rouen, France

Demonstration at the NLR stand at the ATC '98 Exhibition at Maastricht

- Students of an Aerosystems course of the Warfare Centre in the U.K.
- Students of the University of Maastricht, Faculty of Psychology
- Representatives of political parties in the *Staten* of Flevoland
- Air Sub Group of the Western European Logistics Group
- Teachers of the Netherlands Aerospace College (NLC)

Exhibitions

- In the field of materials, NLR participated in the *Journées Europeènnes des Composites* (JEC), Paris.
- The International Training Equipment Conference (ITEC) was held at Lausanne. In the stand of the Netherlands Industrial Simulator Platform (NISP), NLR showed its flight simulation capabilities.
- At the Open Days of the Royal Netherlands Air Force at Leeuwarden Air Base, visited by 75,000, NLR was present with a stand.
- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) at the Farnborough Airshow.
- At the exhibition VAT, the European Subcontracting Trade Fair in the Exhibition and Congress Centre of Utrecht, NLR focused on Precision Engineering, within the NVRT, the Dutch Society for Precision Technology
- NLR contributed to the Space Day Programme held at the Noordwijk Space Expo.
- The Netherlands Defence Manufacturers Association (NIID) organized a Symposium 'Investment in Peace' in The Hague. During this event NLR showed activities by means of pictures, video and a demonstration of prototyping avionics.
- NLR contributed to the exhibition at the IAF Congress Space '98 in Melbourne.
- During the exposition '*Het Instrument*' held at Utrecht many visitors contacted the NLR staff at their stand.
- Senter–EG Liaison organized a symposium and exhibition on 'Technology of Tomorrow' in the RAI Congress and Exhibition Centre, Amsterdam. NLR showed its activities in European projects by means of pictures.
- NLR participated in the National Mathematics Days at Noordwijkerhout.
- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) at the Asian Aerospace Exhibition in Singapore.
- At the Maastricht Exhibition and Congress Centre MECC, NLR participated with a stand during the ATC–'98 Conference. Especially NLR's capabilities in the area of Air Traffic Management were shown and demonstrated in the NLR stand.
- During the '*Bedrijvendag*' organized by the Delft University of Technology, NLR showed its activities by means of pictures.
- In the Aviodome, an exhibition was organized to show the public the history of Fokker. NLR showed its activities for Fokker, from past to present.
- The European Association of Remote Sensing (EARSEL) and the Netherlands Society for Earth Observation and Geo–Informatics (NSEOG) organized the symposium 'Operational Remote Sensing for Sustainable Development' at ITC, Enschede. NLR participated in the workshop and exhibition.

Events

- Well–attended New Year Receptions for NLR staff were held in both Amsterdam and the Noordoostpolder.
- Partners of the NLR Board members visited the site of the Floriade 2002 and the Cruquius Museum, in the Haarlemmermeer.
- At NLR Amsterdam and NLR Noordoostpolder introductory meetings were held for new employees.
- At NLR Noordoostpolder a Symposium 'Wind Effects of Traffic' was held under the aegis of the 'Steering Committee Wind Technology'.
- The DNW (German–Dutch Wind Tunnel) organized a Symposium in the Noordoostpolder on the PIV technique.
- Within the Programme for Harmonized ATM Research in Eurocontrol (PHARE), the PHARE Demonstration 3 was held at NLR Amsterdam.
- The National Simulation Facility (NSF) made a promotional flight for the winner of an F-22 fighter simulation game.

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 in 1997 under the Programme for basic research and development of facilities of NLR;
  - the preliminary Work Plan for 1999;
  - the Programme for basic research and development of facilities for 2000;
  - the Strategy Plan NLR;
- To the Boards of Directors of NLR and NIVR, on:
  - the results of the work carried out by NLR in 1997 under the 'Aeronautics Research Programme' of NIVR;
  - the reports NLR submitted to the Committee to be considered for suitability as scientific publications;
  - proposals for new research in the framework of the NIVR Basic Research Programme;
  - two proposals from the NIVR board concerning the NIVR Basic Research Programme.

Membership of the Scientific Committee

There were two vacancies in the Scientific Committee. Prof.ir. C.J. Hoogendoorn has continued functioning as a member *ad interim*. The vacancy caused by the resignation of Ir. F. Holwerda, appointed by NIVR, remained open, in connection with uncertainty about the future administration of NIVR.

At the end of 1998 the Scientific Committee was composed as follows:

Prof.dr.ir. P.J. Zandbergen, *chairman*
Dr. R.J. van Duinen
Prof.ir. C.J. Hoogendoorn *a.i.*
Prof.dr. T. de Jong
Ir. G.J. Voerman, *secretary*

Membership of the Subcommittees

In the course of 1998, for various reasons the following members of the subcommittees resigned: Ir. J.A.C. van Kaam (Subcommittee for Electronics and Instrumentation); Dr. B. Baud and Prof.dr. W. de Graaff (Subcommittee for Space Technology).

Although Prof.ir. H. Wittenberg had resigned from the chairmanship of the Subcommittee for Space Technology as of end 1997, suddenly changing circumstances prevented him from turning over the chair to the intended successor. Prof. Wittenberg has continued acting as chairman ad interim, and is expected to do so in 1999.

Two new members were appointed in the Subcommittee for Aerodynamics; three new members in the Subcommittee for Space Technology and one new member in the Subcommittee for Applied Mathematics and Information Technology.

In May 1998 notice was received of the decease of Lkol Vl. A.P. Okkerman, member of the Subcommittee for Flying Qualities and Flight Operations from 1972 to April 1998.

In May 1998 as well, notice was received of the decease of Prof.dr.ir. J.A. Steketee, until 1994 a member of the Scientific Committee and chairman of the Subcommittee for Aerodynamics.

The Committee is obliged to both LKol Okkerman and Prof. Steketee for the services they have rendered.

At the end of 1998 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
Ing. J. van Hengst
Prof.dr. ir. H.W.M. Hoeijmakers
Maj. ir. Th.W.G. de Laat
Prof.dr. ir. F.T.M. Nieuwstadt
Prof. ir. E. Obert
Prof.ir. E. Torenbeek
Prof.dr. ir. P. Wesseling
Prof. dr. ir. L. van Wijngaarden
Ir. E.J. Bos, *secretary*

Subcommittee for Space Technology

Prof.ir. H. Wittenberg, *chairman a.i.*
Prof.dr. ir. J.A.M. Bleeker
Ir. P.Ph. van den Broek
Dr. ir. N.J.J. Bunnik
Ir. P.L. van Leeuwen
Prof. dr. ir. L.P. Ligthart
Prof. ir. N.J. Mulder
Dr. A.M. Selig
Prof.Dipl.Ing. H. Stoewer
Prof. dr. ir. P.T.L.M. van Woerkom
Prof. ir. K.F. Wakker
Ir. D. de Hoop, *secretary*

Subcommittee for Structures and Materials

Prof. dr. ir. H. Tijdeman, *chairman*
Prof.dr. Joh. Arbocz
Ir. N. Fraterman
Prof.dr. ir. Th. de Jong
Ir. J.B. de Jonge
Lt Kol Ir. J.W.E.N. Kaelen
Ir. A.J.A. Mom
Ir. A.R.Offringa
Prof. dr. A. Rothwell
Ir. C.W. van Santen
Ir. L.H. van Veggel
Prof ir. J.J. Wijker
Prof.dr. ir. S. van der Zwaag
Ir. F.J.M. Beuskens, *secretary*

Subcommittee for Applied Mathematics and Information Technology

Prof. dr. ir. P. Wesseling, *chairman*
Drs P.J.W. ten Hagen
Prof. dr. J. Olsder
Prof. dr. ir. J. Schalkwijk
Prof. dr. ir. C.R. Traas
Prof.dr. A.E.P. Veldman
Ir. H.M.P. Förster, *secretary*

Subcommittee for Flying Qualities and Flight Operations

Prof. J.H.D. Blom, *chairman*
KTZSD b.d. 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
Prof. ir. E. Obert
Ir. H. Tigchelaar
Ir. L.V.J. Boumans, *secretary*

Subcommittee for Electronics and Instrumentation

Prof.ir. D. Bosman, *chairman*
Ir. W. Brouwer
Ing. H. de Groot
Lt Kol Ing. H. Horlings
Kol ir. E.B.H. Oling
Ir. L.R. Opbroek
Prof. ir. G.L. Reijns
Dr. R.P. Slegtenhorst
Ir. A.P. Hoeke, *secretary*

Concluding Remarks of the Committee

The changes occurring in and around the aerospace cluster, especially with the institutes the Scientific Committee NLR/NIVR advises, result not only from the reorientation after the demise of Fokker Aircraft and the subsequent initiatives taken by the Netherlands government, but from numerous developments, both internal developments on the basis of strategic/tactical considerations and external developments that occur independently but are of great importance to the functioning of the institutes in future.

For NLR a shift in emphasis has clearly occurred, in line with the strategy plan. The fact that the radical reorganization has taken place relatively quietly is a proof of the success of the operation that should not be undervalued.

In the area of aeronautics the Committee is of the opinion that the preservation and keeping up-to-date of system knowledge is essential; for that sufficient capacity must be applied in the various major disciplines, although this may mean stressing main lines in these disciplines. The research areas will also have to be included in capacity considerations in such a manner that the relations with customers can be offered sufficient perspective. Establishing priorities does not, however, beforehand lead to the right choices for the research to be carried out in the somewhat further future. For that, the analysis of scientific and/or social developments is the method to be preferred.

The basic assumption is that in society permanent technological renewal is required, the cost of which cannot be passed on to market parties; a government task permanently remains. In the Commission's view, the matter of efficiency obviously has to be considered, as well as the question whether the capacity for basic research might not be sub-marginal. Is it worth the effort? The Committee is of the opinion that that this question so far could be answered positively in general. In this respect it should be noted that keeping system knowledge up to date is strongly advanced if NLR can apply its system knowledge in the carrying out of actual technological/scientific projects. These projects may be taken up nationally, but in future will probably be increasingly international. It is therefore necessary for NLR to join European, transatlantic and worldwide co-operation projects and bilateral or multilateral management of infrastructures. Concerning the last-mentioned item, the first successes with the wind tunnels have already been obtained. These co-operations across borders within disciplines provide considerably more perspective than the sometimes advocated joining of national research establishments, from which in fact little spin-of or synergy is to be expected. The Committee again points out that taking part in Framework projects of the European Union requires very considerable efforts of NLR, largely at the expense of the basic research and equipment development. Although it is a matter of NLR choosing to apply – the expected yield is considered to be greater than the effort – because of the tendering system, it is impossible to determine the extent of this work in advance. Moreover, because of the international co-operation, the planning can only be affected to a small extent. Although this work is only funded for 50 per cent, it requires 100 per cent commitment. This aspect reduces NLR's flexibility in its basic research and facilities development, and with respect to other customers.

The Committee therefore advocates again the institution of a national co-funding arrangement for the European work, which has a variable volume. The budget of the Ministry of Transport for basic research and facility development, which was stabilized, highly appreciated by the Committee, after the demise of Fokker Aircraft, is coming under increased pressure. The Committee advocates to keep looking into the future also in this respect.

The Committee after discussions agreed with the Work Plan NLR submitted for 1999 and with the Programme for 2000. The Committee has observed that the wind tunnel capacity is taken up for a larger part than expected; this is a satisfying development. Furthermore, NLR occupies a good position concerning software development programmes in the European Framework programme. The Committee has further observed that the pressure on the basic research is strongest with NLR's Structures and Materials Division. Attention to this is desirable, given the importance of the relation with the manufacturing industry in the Netherlands. The Committee observes that the amount of reports produced by NLR remained at the same level, despite the increased international co-operation, which leads to different publication modes, whereas the quality is good to very good.

The reorientation studies for NIVR have not been concluded yet. The Committee has not been able to react to the results of the studies begun by Felix & Co. It has been made clear, however, that greater importance will be attached to advising by the Scientific Committee in the new management structure. As a foretaste, the Committee was asked to assess proposals of NIVR: a Proposal for an NIVR long-range basic research programme from 1999 and a Proposal for a basic research programme 1999. The Committee has welcomed the long-range programme with great approval and supports the programme 1999 as well. Clearly, discussions with NLR have taken place, so that overlaps are prevented from occurring. The programme also appears balanced, given the expected technological requirements of the industry. This is supported by the positive judgement by the Subcommittee for Structures and Materials of four detailed proposals for research by the corresponding Division. The Committee judges positive the wish of NIVR to contribute to the conservation of system knowledge in the Netherlands, although the capacity of the programme for this is apparently limited. The Committee notes also that, as a Scientific Committee, it has no opinion on the extent to which the proposed work will be employed in possible future projects such as the A3XX. The assessment as to how certain project definitions will lead to desired technology developments is rather the domain of NIVR in concert with industry in connection with the pursuance of participation.

In the area of space technology the Committee agrees with the view of NIVR and NLR that ESA will be following an ever more commercial approach in the granting of research and development assignments. Offering a good price/performance ratio will be of prime importance, whereas having at one's disposal the most modern technology may be decisive. It will no longer be possible to charge the technology development for strengthening the competitiveness largely to ESA; national budgets will have to be charged instead. This leads to the somewhat paradoxical situation that ESA will be able to claim that its projects are affordable, whereas in the individual countries industries will be able to build up competitive positions nationally, so that duplication of work is by no means ruled out.

In the area of scientific research in space and from space, the Committee observes that the limited budgets for scientific research of the Ministry of Education, Culture and Science will put pressure on the developers of scientific instruments and experiments such as SRON and NLR. The limited budget of the Ministry of Economic Affairs puts pressure on the microgravity research, because of the heavy commitment to the ERA robot arm. The Scientific Committee obviously advocates assigning sufficient weight to budgets for scientific research, exactly in order to bring about the required renewal of knowledge for future industrial projects.

6 International Co-operation

6.1 NATO Research and Technology Organization (RTO)

Introduction

On 26 July 1996, the NATO Council established the NATO Research and Technology Organization (RTO). The RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the alliance, to maintain a technological lead and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in Research and Technology (R&T) activities.

The total spectrum of R&T activities is covered by six Panels, dealing with:

– Studies, Analysis and Simulation	SAS
– Systems Concepts and Integration	SCI
– Sensors and Electronics Technology	SET
– Information Systems and Technology	IST
– Applied Vehicle Technology	AVT
– Human Factors and Medicine	HFM

The RTO's Research and Technology Agency (RTA), with headquarters in Neuilly, France, is responsible for carrying out the decisions of the R&T Board (RTB) and for implementing its guidance. Furthermore, the RTA provides planning, technical and administrative support concerning the RTO's scientific and technical programme.

In order to facilitate contacts with the military users and with other NATO activities, a small part of the RTA staff is located at NATO Headquarters in Brussels. In particular this staff provides liaison with the International Military Staff and with the Defence Support Division, and provides support to the R&T Panels. The main co-ordination of the efforts directed at the Partnership Nations is also located in Brussels. Co-ordination of R&T with other NATO bodies is further ensured by participation in the various Boards. This is in particular the case for the NATO C3 Board and the Science Committee. The directors of the NATO C3 Agency and of SACLANTCEN Research Centre are ex-officio members of the RTB.

Dr. M. Yarymovych (US, the last chairman of the AGARD National Delegates Board) was chairman of the R&T Board. The director of the RTA was Drs. E. van Hoek.

Netherlands Participation in RTO

R&T Board

The Netherlands members of the RTB were:

– Cdre. Ir. D. van Dord MSc	Ministry of Defence
– Ir. E.I.L.D.G. Margherita	TNO
– Dr.ir. B.M. Spee	NLR

R&T Panels

Each nation may provide three members per panel. The total number of panel members may be extended to fifty through the nomination of members-at-large.
The Netherlands was represented in all six panels by the maximum number of three members.
NLR was represented in five of the six panels, viz:

SAS	Ir. F.J. Abbink
SCI	Ir. J.T.M. van Doorn
SET	Ir. H.A.T. Timmers
IST	Ir. W. Loeve
AVT	Prof.ir. J.W. Slooff

National Co-ordinator

The national co-ordinator was Ir. L. Sombroek (NLR).

Highlights

- On 1 January 1998, the Charter of the NATO/RTO was published and came into operation.
- In 1998, draft operating procedures and a draft of a long-term strategy for NATO defence research and technology were published. Both documents were expected to be endorsed by the R&T Board at their Spring meeting in 1999.
- In October 1998, a symposium organized by the AVT panel on 'Fluid dynamics problems of vehicles operating near or in the air-sea interface' took place in Amsterdam.

6.2 The German-Dutch Wind Tunnel (DNW)

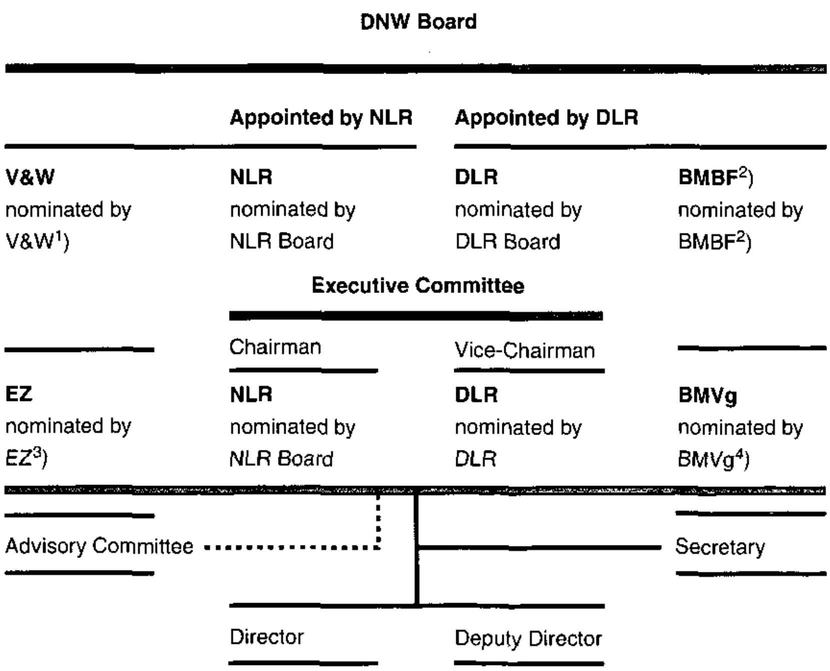
The Foundation German-Dutch Wind Tunnel (*Stichting Duits-Nederlandse Windtunnel/Stiftung Deutsch Niederländischer Windkanal – DNW)* was jointly established in 1976 by NLR and the German Aerospace Centre *(Deutsches Zentrum für Luft- und Raumfahrt – DLR)*. DNW operates the largest low-speed wind tunnel in Europe, the LLF located in the Noordoostpolder, in addition to the 3-m low-speed wind tunnels LST, located near the LLF, and NWB, located in Braunschweig, Germany.

Since July 1997 DNW also operates several other aeronautical wind tunnels owned by DLR and NLR under a joint organization agreement. These wind tunnels are grouped within business units. The legal responsibility for the business units resides in NLR and DLR while all operational aspects are managed by DNW.

The Board of DNW

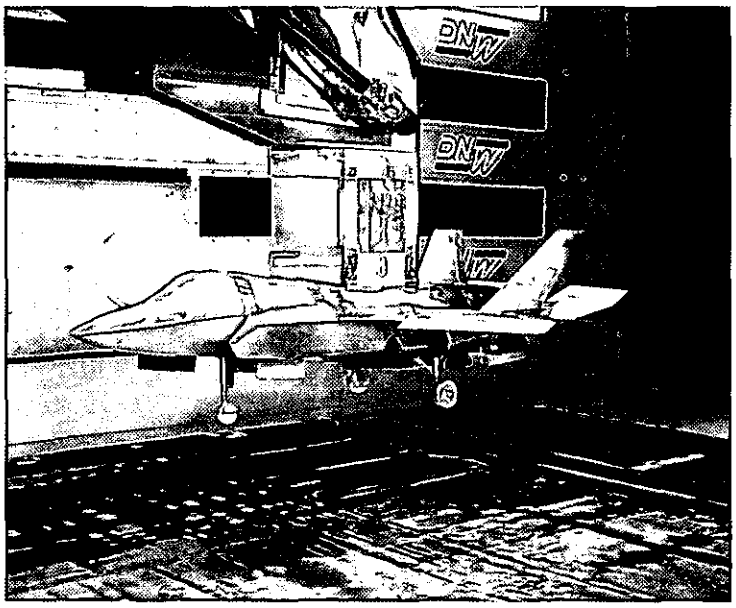
The Board of the Foundation DNW is formed by members appointed by NLR, DLR, and the German and Dutch governments. At the end of 1998 the Board consisted of:

Dr.ir. B.M. Spee, Chairman
NLR
Prof. V. von Tein, Vice-Chairman
DLR
Min.Rat Dr. J. Bandel,
German Ministry for Education and Research (BMBF)
Min.Rat W. Brechtelsbauer
German Ministry of Defence (BMVg)
Prof. Dr.-Ing. H. Körner
DLR
Drs. L.W. Esselman, R.A.
NLR
Ir. H.N. Wolleswinkel
Dutch Ministry of Transport (RLD)
Secretary: Dipl.Kfm. D. Smyrek



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

Schematic of the organization of the Foundation



*Joint Strike Fighter model of Lockheed Martin in the 9.5m*9.5m test section of the DNW-LLF*

The Advisory Committee

The Advisory Committee, representing the aerospace industry and research establishments, advises the Board of DNW about long-term needs of the industry. At the end of 1998 the Advisory Committee consisted of:

Prof.ir. J.W. Slooff (Chairman)
NLR
Prof. Dr.-Ing. P. Hamel
DLR
Dipl.-Ing. G. Mader
Airbus Industrie
Mr. A. Garcia
Airbus Industrie
Dr.-Ing. J. Szodruch
DaimlerChrysler Aerospace Airbus
Dipl.-Ing. B. Haftmann
DaimlerChrysler Aerospace Airbus
Dipl.-Ing. A. Rauen
DaimlerChrysler Aerospace
Dipl.-Ing. R. Birrenbach
Fairchild Dornier
Mr. A. Cassier
Eurocopter France
Prof.dr.ir. J.L. van Ingen
Delft University of Technology
Secretary: Dr.-Ing. G. Lehmann

The Board of Directors

The Board of Directors of the DNW consisted of:
Director: Dr.-Ing. G. Eitelberg (DLR)
Deputy Director: Ir. C.J.J. Joosen (NLR)

DNW-LLF

After a period of two years with low occupation, the LLF could log one of the most successful years since the operational start of the facility in 1980. Because of the very busy year it was necessary to operate the facility over long periods with more than one shift a day. Both aerospace and car/truck industries contributed to a business volume that was over 50% higher than the long-term average. Several test entries were devoted to the further development of the Airbus A340 into the new, bigger A340-500/600. Of the many projects a considerable number can be considered as highlights. A few of them are mentioned below.

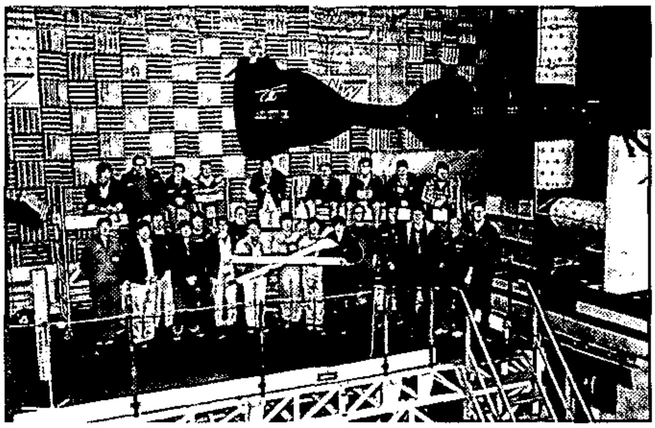
A complex test was carried out for ATIC, a Japanese helicopter research company founded by an industrial consortium headed by Kawasaki. ATIC has developed and built a test-rig capable of running different Mach-scaled rotor systems with up to 4 m rotor diameter. For the test campaign the rotor test rig was attached to the sting model support system and operated in the open-jet test section. Extensive acoustic measurements were made at several flight conditions, with basic rotor control as well as with higher-harmonic control. Another objective of the test was the measurement of the flow field in the rotor plane. For the first time at LLF such a flow-field measurement programme was completely done with Particle Image Velocimetry (PIV).

The second phase of an acoustic wind tunnel programme with a tilt-rotor model was carried out for the US Army and NASA. Although the programme was mainly aimed at establishing an acoustic database covering the complete "flight" envelope, it also provided some unique flow-field data including the first 3D-PIV measurements of rotor tip vortices at the DNW-LLF.
For Lockheed Martin a 12-percent scale model of the Joint Strike Fighter (JSF) was tested in two extensive test campaigns in the 9.5m*9.5m test section. This test section allows tests to be carried out down to very low speeds (15 kts) needed for testing Short Take-Off and Vertical Landing (STOVL) modes. The test section was not only selected because of its low speed but also because of its big size. STOVL testing with jet simulation, essential for this type of tests, requires a test section very large in comparison with the model size, to avoid interference of the recirculation jet exhaust with the model. The results showed that the 9.5m*9.5m test section is an excellent choice for this type of testing.

DNW-LST

The occupation of the LST with tests for the aircraft industry was low. An important project was the acceptance test of two sets of propellers and associated hubs including rotating shaft balances, all manufactured by NLR. These propellers will be used in the framework of a BRITE/EURAM

Propeller test in the DNW-LST in the EU APIAN (Advanced Propulsion Integration Aerodynamics and Noise) programme



*Customer and DNW staff with a rotor test set-up of ATIC, of Japan, in the DNW-LLF 8m*6m open-jet test section*

programme in subsequent tests in the ONERA S1 and the DNW-LLF. The same set-up as used for the acceptance test was used to investigate the feasibility of measuring the propeller flow field by means of PIV.

Bookings for non-aeronautical testing were at the same level as in previous years and concerned ships, offshore structures, buildings, trains and trucks. A drilling semi-submersible was tested for wind loads on the above-water part and current loads on the underwater part at various overturning angles. The scope of buildings investigated ranged from a large railway station, tested to optimise the design with regard to wind shelter, to a small garden house. The model of the latter, on scale 1:10, was tested to determine the pressure distribution on the roof at varying wind directions.

DNW-NWB

The NWB was well occupied with tests from the aerospace industry and from car manufacturers. As part of development programmes for Fairchild Dornier, powered full-span and semi-span models of the 328 Jet and the new 728 Jet were tested. A sophisticated test for DaimlerChrysler Aerospace Airbus was performed with a lightweight model of the A340. The model, built by DLR, was attached to the Mobile Oscillating Derivative balance (MOD) and operated in the open-jet test section with up to 3 Hz pitch-angle variation in order to determine the dynamic derivatives of the aerodynamic coefficients of this aircraft.

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.

Since also in 1998 the income from wind tunnel tests was below expectations, measures were taken to reduce the operating costs considerably. The ETW staff was reduced to 30 persons at the end of 1998. Discussions were started on additional funding for a limited period.

ETW Supervisory Board

At the end of 1998, the membership of the Supervisory Board was as follows:

France

ICA X. Bouis	ONERA
ICA E. Lisack	DGAC/DPAC
ICA A. Brémard	DGA/DSP/ SREA/PEA

Germany

Dr. J. Bandel	BMBF
Prof. V. von Tein	DLR
Dr.-Ing. H. Körner, *Chairman*	DLR

United Kingdom

S.I. Charik	DTI
Dr. D.J. Mowbray	DERA

The Netherlands

Ir. H.N. Wolleswinkel	V&W
Dr.ir. B.M. Spee	NLR

Mr. J.F. Moutte succeeded Mr. T.B. Saunders as Managing Director, following the latter's retirement. He was assisted by:
Dr. G. Hefer (G)
Manager Aerodynamics and Projects and
J.P. Hancy (F)
Manager Technical Operations

Ir. J.C.A. van Ditshuizen left ETW to join NLR.

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, Sweden in 1992 and Spain in 1996.

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 the costs of their part of the work.

Organization

The organization diagram shows three levels: the Council/Executive Committee, the Groups of Responsables and the Action Groups. Via the Industrial Management Group (IMG^3) of the *Association Européenne des Constructeurs de Matériel Aérospatial* (AECMA), Industrial Points of Contact in the Groups of Responsables and industry participation in Action Groups, GARTEUR has interfaces with the European aeronautical industry.

Council and Executive Committee

At the end of 1998 the GARTEUR Council was composed as follows.

France

IGA G. Bretscher	DGA/DSA/SPAé *)
ICA E. Lisack	DGAC/DPAC
ICA A. Brémard	DGA
Ms. Dr. D. Nouailhas	ONERA **)

Germany

Dr.-Ing J. Bandel	BMBF *)
LB Dir. K. Heyer	BMVg
Dr.-Ing H.-J. Schepers	DLR **)

United Kingdom

Dr. M.F. Steeden	DERA *)
Mr. S.I. Charik	DTI
Dr. D.E. Mowbray	DERA **)
Mr A.F. Everett	MOD

Spain

Prof. F. Aldana	OCT *)
Mr. P. Garcia Samitier	INTA **)

Sweden

Mr. L.B. Persson	FFA *)
A. Gustafsson	FFA **)
Mr. C. Heinegård	Nutek
Gen. S. Nässtrom	FMV

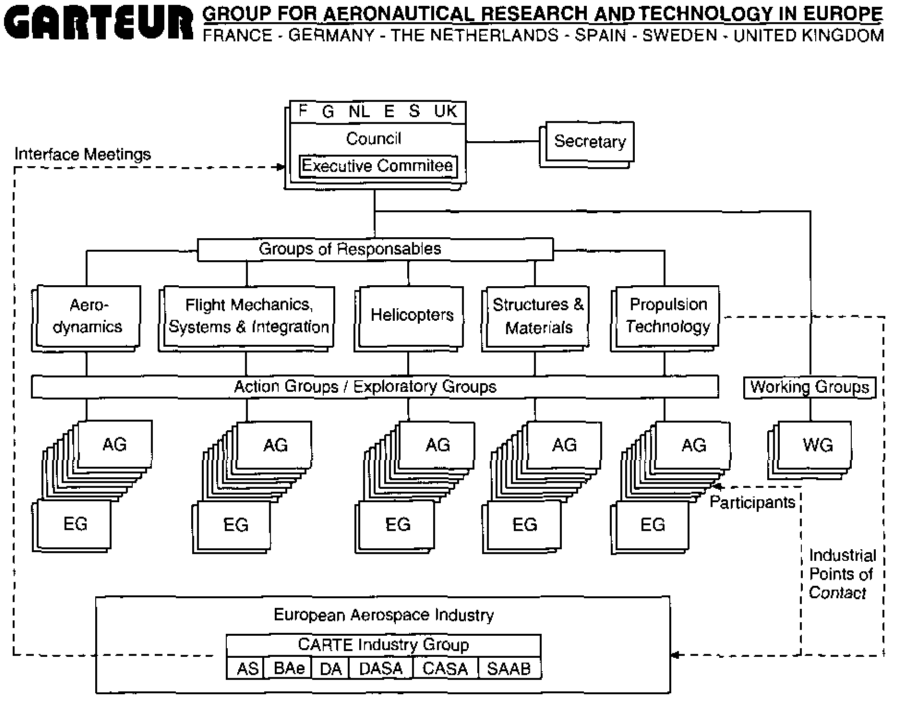
The Netherlands

Mr. J. van Houwelingen	NLR *)
Ir. F.J. Abbink	NLR **)
Dr.ir. B.M. Spee	NLR

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

In 1996 and 1997, Sweden provided the chairman for the GARTEUR Council and the chairman for the Executive Committee as well as the Secretary. In 1998 these positions were taken over by the United Kingdom for a period of two years. The persons involved are:

Dr. M.F. Steeden	*Council chairman*
Dr. D.E. Mowbray	*Executive Committee chairman*
Dr. O.K. Sodha	*Secretary*



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

Development and Strategy

Following the recommendations from the Report of the GARTEUR Task Force, the Council decided that:

- GARTEUR should develop – in close dialogue with AECMA and AEREA and after consultation of other organizations – a joint and co-ordinated approach to aeronautical Research and Technology (R&T) in Europe;
- for that purpose GARTEUR should establish an overview of the various relevant aeronautical R&T programmes, agencies, facilities and interests at both national and European levels;
- the Council has invited AECMA and AEREA to a high level 'dialogue forum' which was held in the early Spring of 1998.

The Council also adopted an initiative from the United Kingdom to define programmes for joint research in a number of technical areas (GARTEUR Intermediate Programme Initiative).

NLR Participation

NLR takes part in all activities of the GARTEUR Council, the Executive Committee and the Groups of Responsables. Table 1 shows the numbers of Action Groups and Exploratory Groups and the numbers of the Groups in which NLR has participated.

Table 1 – Numbers of Action Groups and Exploratory Groups

Group of Responsables	Action Group Total	Action Group NLR	Exploratory Group Total	Exploratory Group NLR
Aerodynamics	15	11	8	4
Flight Mechanics	-	-	5	5
Helicopters	2	2	3	3
Structures and Materials	5	5	1	1
Total	22	18	17	13

6.5 Co-operation with European Research Establishments in Aeronautics

DLR/NLR Partnership

Background

A formal partnership agreement between the Deutsches Zentrum für Luft- und Raumfahrt (DLR) and the National Aerospace Laboratory NLR is in force since 1994. This partnership is based on the good experience obtained with the co-operation within the German-Dutch Wind Tunnel (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 guide and control this task, a Joint Executive Board (JEB) and a DLR/NLR Board Working Group were set up, consisting of representatives of DLR and NLR.

DLR/NLR Executive Board at the End of 1998:

Prof. W. Kröll, *chairman*	DLR
Prof. V. von Tein	DLR
J. van Houwelingen (vice-chairman)	NLR
Dr.ir. B.M. Spee	NLR

The Board was assisted by Dr.U. Möller (DLR) and Drs. A. de Graaff (NLR).

To stimulate and monitor the DLR/NLR bilateral precompetitive research programme, a Programme Committee was set up.

The Programme Committee at the End of 1998:

Ir. F.J. Abbink, *chairman*	NLR
Dr.-Ing K.H. Haag	DLR
Ir. F. Holwerda	NLR
Prof.Dr.-Ing F. Breitbach	DLR
Prof.Dr.-Ing. H. Körner	DLR
Prof.ir. J.W. Slooff	NLR

Basic Research

DLR and NLR continued their bilateral precompetitive research projects in the field of aerodynamics on low-speed propulsion-airframe integration and CFD for complete aircraft and in the field of Structures and Materials on the development of the B-2000 computer code.

Furthermore, potential new topics for bilateral co-operation were discussed. These topics were in the fields of aerodynamics; aeroacoustics; structures and materials; flight mechanics; Air Traffic Management; and wind tunnel model design and manufacturing.

To further investigate the potential of DLR-NLR co-operation in the field of ATM and wind tunnel model design and manufacturing, Terms of reference for further investigations were drafted and agreed upon.

Extension

DLR and NLR were discussing possible broadened co-operation and integration with other organizations including ONERA of France and CIRA of Italy.

AEREA: Association of European Research Establishments in Aeronautics

Supported by the Commission of the European Communities, the seven European aeronautical research establishments have developed a joint vision on future co-operation. The aim of this co-operation is to create an effective and efficient aeronautical technology base in line with the integration of industries and governmental responsibilities on a European level. 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 specialization.

In 1994 the Association started a modest action plan comprising facilities, basic research, joint acquisition and personnel exchange. In 1998 it was decided to create a legal entity, in order to facilitate internal and external co-operation.

Organization

The Heads of Establishment Board is the highest body within the Association. At the end of 1998 the Heads of Establishment Board consisted of:

IGA M. Scheller, *Chairman*	ONERA
Prof. W. Kröll	DLR
Dr. D. Byrne	DERA
Prof. Dr. C. Golia	CIRA
J. van Houwelingen	NLR
B.Gen. H. Dellner	FFA
Mr. E. Varela	INTA

The Heads of Establishment Board is assisted by a Strategy and Co-ordination Group, chaired by Dr. G. Russo (CIRA), and of which Drs. A. de Graaff is the secretary.

Facilities

The Associates have established a policy of co-ordinated use of and investments in large facilities. This will result in rational utilization of existing and future facilities for common European needs. A Facilities Committee prepared this common policy. Ir. F.J. Abbink represents NLR in the Facilities Committee.

The Facilities Committee stimulated and monitored the progress of three Working Groups:

- Wind Tunnels
- Supercomputing and Networking
- Ground-based Flight Simulation

Research

The associates have also established a policy to stimulate co-operation in the area of basic research. To this end, a Programme Committee was established, in which Ir. F.J. Abbink represented NLR. The Programme Committee stimulated and monitored the progress of the following Action Groups (AG) and Exploratory Groups (EG):

- ETW AG
- Smart Aircraft AG
- Supersonic Transport EG
- Acoustics EG
- New Measurement Techniques EG
- Advanced Technology Cockpit EG
- Turbulence Modelling EG
- Safety EG

The Heads of Establishment Board decided that from 1999 co-operation in research projects will be delegated to GARTEUR, the European Union, the West European Armament Organization and other fora, as much as possible. AEREA will concentrate on the process of integration.

The concept of joint teams was developed, in which all capabilities of the AEREA partners on a specific research area will be integrated. This may lead to the establishment of virtual institutes on turbulence modelling and aircraft internal noise research in the near future. Furthermore, a system to identify opportunities for future integration of research activities and facilities was implemented.

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 Commission of the European Communities

Since 1989, the aeronautical research establishments have worked together in the Aeronautical Research Group (ARG) to facilitate the communication with the Commission of the European Communities (CEC) and industry as well as to promote the information exchange amongst the establishments on CEC-related issues. The ARG, chaired by Drs. De Graaff, is part of AEREA. Besides exchanging information and preparing project proposals for calls for tenders, the ARG was actively involved in the preparation of different key actions for the EU's Fifth Framework Programme (1998-2002).

6.6 Co-operation with Indonesia

Introduction

From 1981 until 1991 a Technical Assistance Project (TTA-79) was active between Indonesia and the Netherlands. This project has been followed from 1992 by an interim programme for education, research and technology (APERT), originally scheduled for the period 1992–1995, later extended as APERT 95 for the period 1995–1997.

APERT 95

The main objective of the programme is the continuation, if possible extension, of the long standing co-operation between Indonesia and the Netherlands. The participants on the Indonesian side are BPPT (Agency for the Assessment and Application of Technology), IPTN (Indonesian Aircraft Industry) and ITB (Institute Technology Bandung). The Netherlands' participants are NLR, the Delft University of Technology and Urenco Aerospace.

Organization

Within APERT 95 a governing group has been established, constituted as follows:

Indonesia

Prof.dr.ir. H. Djojodihardjo (BPPT)
Dr. Said Jenie (IPTN)
Prof.dr.ir. Sularso (ITB)
Dr.ir. S. Kamil

Project co-ordinator:
Ir. R. Mangkoesoebroto (IPTN)

The Netherlands

Mr. J. van Houwelingen (NLR)
Dr.ir. B.M. Spee (NLR)
Prof.ir. J.L. van Ingen (DUT)

Project co-ordinator:
Ir. L. Sombroek (NLR)

Programme

APERT covers three areas, viz:

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

- Laboratory Development:
  The main objective is to further improve the aerospace research capabilities and facilities in Indonesia.
- Joint Research:
  The main objectives are to increase the number of joint research subjects and to increase the number of participating institutes and industries.

The Netherlands Ministry of Education, Culture and Science (OC&W) supports this co-operation financially. The Royal Netherlands Academy of Science (KNAW) has to authorize, on behalf of OC&W, the proposed programmes.

Continuation

At the annual Preliminary Programme Meeting (PPM) on 15 December 1997 at NLR Amsterdam it had been decided to continue the aeronautical co-operation, but to adapt the priorities in order to comply with the needs of Indonesia. In short, this meant that human resources development as well as laboratory development should get the highest priority whereas joint research should get a lower priority.

In February 1998, a Netherlands delegation discussed proposals for the continuation of the aeronautical co-operation with the representatives of the Indonesian APERT governing group in Jakarta. These proposals were based on the premises discussed at the last PPM. Both parties agreed on the proposed way ahead.

Despite the agreed basis for a continuation of aeronautical co-operation as follow-up of APERT, no further progress could be accomplished in the year 1998. A main reason for this is the development of the Indonesian economy.

Status

In the course of 1997 the KNAW had authorized the APERT '95 Work Plan 1997. This was the final phase of APERT '95, which formally ended at the end of 1997.
The status of the programme at the end of 1998 was:

- Education:
  The last two PhD candidates were expected to obtain their doctor's degrees in February and December 1999, respectively.
- Laboratory Development:
  The Pilot High Speed Wind Tunnel (PHST) was expected to be shipped to Indonesia in the first quarter of 1999.
- Joint Research:
  The joint research programme was in the final stage, with draft reports to be ready in the first quarter of 1999.

Capita Selecta

1 Testing a Composite Stabilizer for the Fokker JetLine

NLR has carried out a full–scale certification test programme on a composite horizontal stabilizer for the Fokker 100 / Fokker 70 aircraft. The composite stabilizer was fabricated by Stork Fokker Aerostructures and SABCA Lummen N.V. The test programme, consisting of static and fatigue tests, was aimed at demonstrating the technology readiness of Stork Fokker Aerostructures to design, fabricate and certify composite primary structures.

Introduction

During the past decade, fibre reinforced plastics (composites) have been used successfully in primary aircraft structures. They are used for their excellent mechanical properties (e.g. high strength and stiffness) and low density. Nowadays the use of composites is also being considered because of potential cost reductions. These cost reductions can be realized because composite structures can be produced with a high level of automation and in the form of large subassemblies, resulting in reduced labour costs during fabrication and assembly.

In order to gain the knowledge required to apply composites in primary structures, the former Fokker Aircraft B.V. defined a composite stabilizer programme. This programme was carried out under contract to the Netherlands Agency for Aerospace Programmes (NIVR), as part of the Aircraft Technology Programme (VTP). The composite stabilizer programme was carried out in close collaboration with NLR. The programme comprised the development of a Carbon Fibre Reinforced Plastic (CFRP) horizontal stabilizer. In the programme, a building block approach was used, in which all aspects were addressed. It started at the material level (by testing thousands of small coupons), continued through the component level (e.g. by testing hundreds of small skin panels and spar details), and through sub–assemblies of increasing complexity (e.g. test boxes to test large skin panels), up to the level of a complete torsion box of the composite stabilizer.

All these building blocks were addressed in so–called Design Built Teams (DBTs). The Structures and Materials Division of NLR participated in several of these DBTs, such as: Skin Panels DBT, Spars and Ribs DBT and Test DBT.

The programme was concluded with the testing of a structurally complete centre section of the torsion box of a stabilizer for the Fokker 100. The tips of the centre section were not included, since they were considered not to be critical. This led to a torsion box with a length of 4 metres, named the four–metre box.

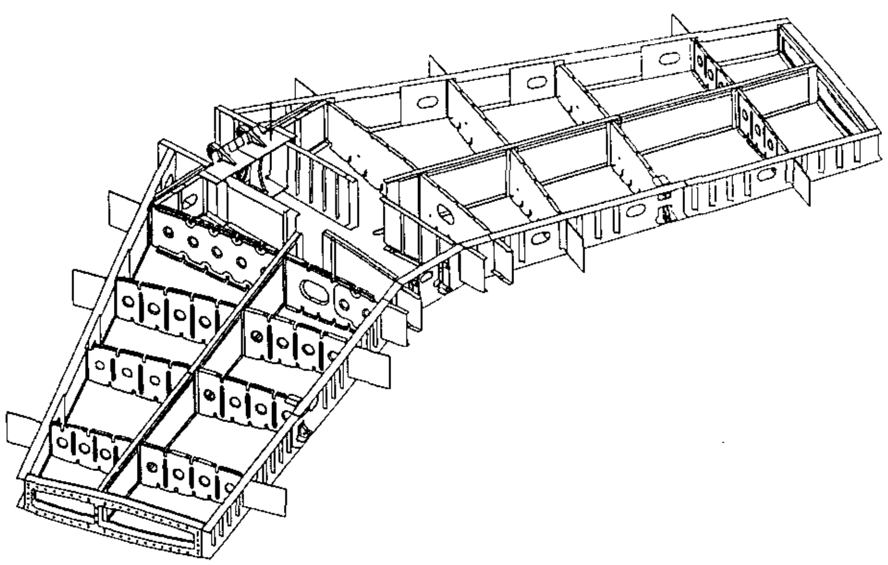


Fig. 1 – Open frame of the four-metre box; left-hand side: metal, right-hand side: Carbon Fibre Reinforced Plastic

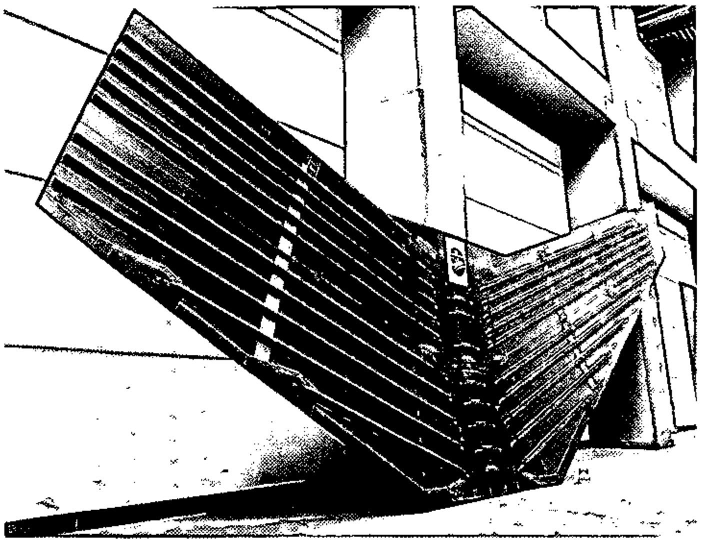


Fig. 2 – Skin panel of the four-metre box

The Four–metre Box

The four–metre box is a structurally complete centre section of a CFRP stabilizer torsion box for the Fokker 100 or Fokker 70 aircraft. The box is composed of CFRP blade–stiffened panels, CFRP L–stiffened spars and CFRP mini sandwich ribs on the right–hand side and aluminium ribs on the left–hand side. Figure 1 presents the four–metre box without the skin panels. Figure 2 presents one of the skin panels.

The skin panels and the spars were laminated with the help of an automated tape–laying machine at SABCA Lummen of Belgium. The tape–laid skins and spars were transported to the former Fokker plant at Ypenburg, where the skins and spars were cured in an autoclave. The CFRP ribs were produced at the former Fokker plant at Schiphol. All metal parts were produced at Fokker Papendrecht. At this plant the four–metre box was assembled. During and after assembly the box was instrumented with 350 strain gauges and 12 thermocouples.

Load Cases and Test Programme

The four–metre box was subjected to ground vibration, static and fatigue tests.

The load cases to be applied during the static tests were specified by Fokker. They are summarized in Table 1, where V_a, V_c, V_d and V_f are design manoeuvring, cruising, diving and flap speed; S_L denotes Sea Level, PSD denotes Power Spectral Density and C.G. Centre of gravity.

For certification, CFRP structures have to be tested under the most severe environmental conditions. The material qualification programme (one of the building blocks of the technology programme) showed that 'hot/wet' conditions are the most severe test conditions for static load cases.

In the definition of the static test programme, two approaches were possible. First, the structure could be tested under 'hot/wet' conditions. Second, the structure could be tested under ambient conditions, applying an environmental knockdown factor. The second approach entails taking two hurdles. The determination of the environmental knock-down factor is time–consuming and expensive, since it requires a lot of coupon tests. In addition, this approach may only be used if the failure locations and failure modes under ambient conditions are the same as under 'hot/wet' conditions. This is very difficult to prove.

It was therefore decided to carry out the static tests under 'hot/wet' conditions, which in this case means 80 ^{0}C and 85% relative humidity.

Fokker also defined the number of flights and number of cycles per flight to be applied during the fatigue tests.

A sequence of condition codes was generated for the fatigue tests on the four–metre box. The basis for this sequence was the sequence NLR used in the damage tolerance test of the metal Fokker 100

Table 1 – Load cases applied in the static tests

Load case	Description
44–22–57–01–1	Checked elevator manoeuvre at V_a and S_L
46–21–67–01–1	Nonstationary manoeuvre at V_c and S_L
49–21–24–01–5	Nonstationary manoeuvre at 0.9 V_f and $a_{flap} = 25^0$
48–80–58–1–1	PSD lateral gust with active yaw damper for aft C.G. of aircraft
48–80–64–1–1	PSD lateral gust with active yaw damper for forward C.G. of aircraft
17–63–67–04–1	Out of trim, down gust at V_d with PSD overshoot

horizontal stabilizer (TA 22), including condition codes for thrust reverser operation. This sequence consists of 5000 flights: three 'normal' blocks of 1250 flights (block B) and one 'severe' block of 1250 flights (block A) in the order of B-B-A-B.

The purpose of the fatigue tests was to substantiate the no-growth concept of the composite elements of the four–metre box. The no–growth concept means that any damages that are not visible in the beginning of the fatigue test (e.g. Barely Visible Impact Damages) remain invisible.

Since composite material is considered to be insensitive to low amplitude fatigue cycles, the basic TA–22 condition code sequence was modified by eliminating a large number of these low–amplitude fatigue cycles. This resulted in a reduced fatigue spectrum in which the number of condition codes for 5000 flights decreased from 646,026 to 23,065.

The test spanned an equivalent of 90,000 flights (one lifetime of the Fokker 100). In order to reduce the time needed to carry out the fatigue tests, a load enhancement factor of 1.177 was used. With this load enhancement factor a life–factor of 1.0 is sufficient to prove B–basis reliability (see Table 2).

The fatigue tests were carried out at room temperature but with the four–metre box in aged (saturated) condition, since coupon tests showed this condition to be the most severe one for fatigue tests on composite structures.

Table 2 – Test duration for several load enhancement factors to demonstrate B–basis reliability

Test duration (x life time)	Load enhancement factor
1.0	1.177
1.5	1.148
2.0	1.127
3.0	1.099
13.3	1.0

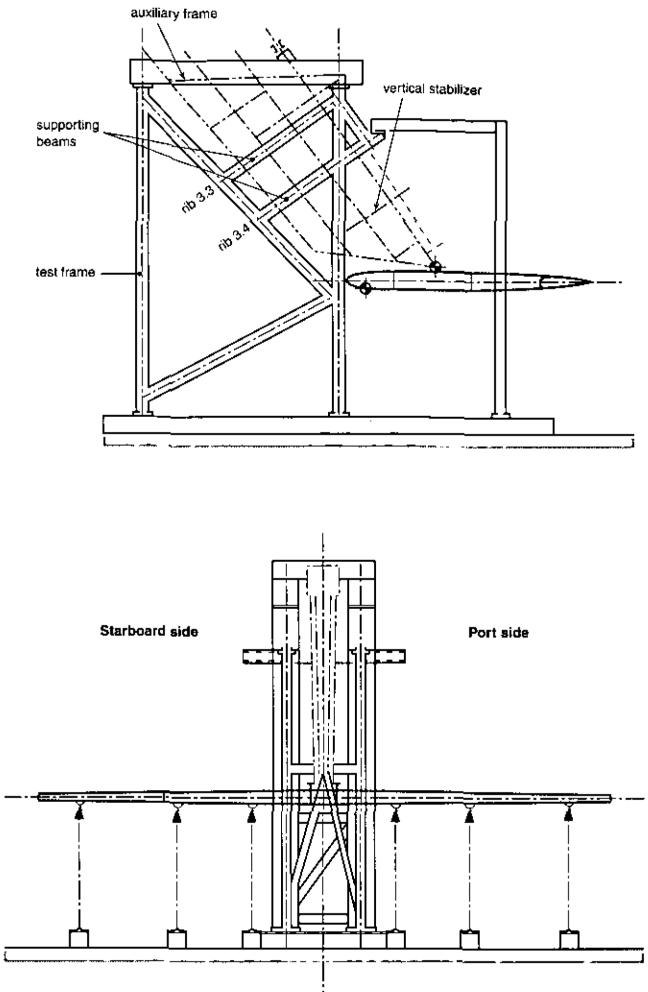


Fig. 3 – Schematics of the test set–up

The total test programme was as follows:

1. Ground vibration test to determine the eigenfrequencies of the four–metre box.
2. Static test to Limit Load at ambient conditions to compare calculated strain distributions with measured strains.
3. Fatigue test at ambient conditions but with the four–metre box saturated.
4. Static test to Ultimate Load (1.5 x Limit Load) with Barely Visible Impact Damages in the four–metre box at 80°C and 85% relative humidity.
5. Static Limit Load test with Visible Impact Damages in the four–metre box at 80°C and 85% relative humidity.
6. (Optional) Static test to failure at 80°C and 85% relative humidity.

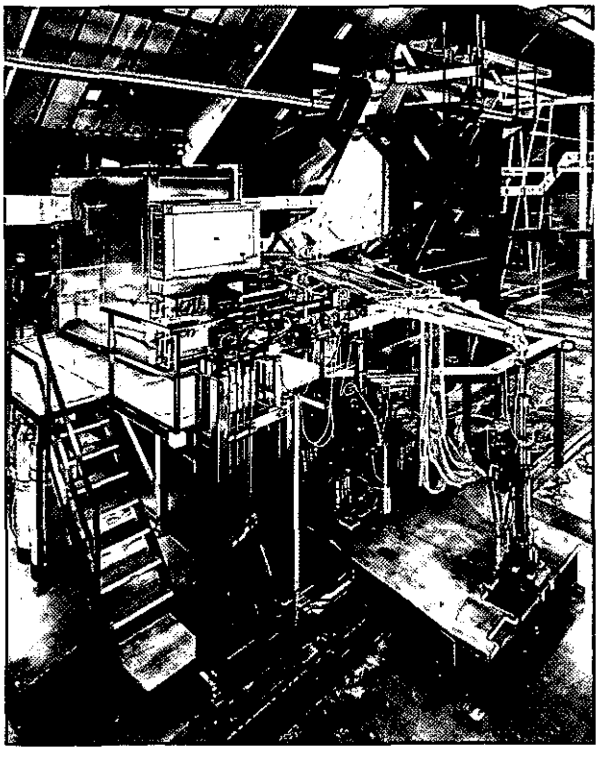


Fig. 4 – The test set-up

Definition of the Test Set-up

The four–metre box was attached to the metal vertical fin that had been used for the TA–22 tests. The vertical fin itself was connected to the test frame that had also been used for the TA–22 tests (see Figures 3 and 4).

Twelve hydraulic actuators were used to introduce the required loads to the four–metre box. Ten of them (five on each side) were mounted in vertical positions. The vertical loads were introduced via two elevator supports, six stainless steel clamps and two dummy outboard sections (see Fig. 5). These vertical actuators simulated in–flight load conditions. Two actuators (one on each side) were mounted horizontally to simulate thrust reverser loads.

The external loads were distributed over the four–metre box in such a manner that the spanwise load and moment distributions of the selected load cases were simulated as well as possible. These load distributions were determined by NLR and approved by Fokker.

Before each test, all transducers (strain gauges and load cells) were software balanced by equalizing their output in the mass-compensated situation to zero. In this way the actuators apply loads to the four–metre box which are equal to the weight of the four–metre box including its loading system and instrumentation wires.

Since a number of tests were carried out at elevated temperature and humidity, all metal load introduction systems were made of stainless steel, to avoid corrosion of metal parts.

If the stainless steel clamps (see Fig. 5) would have been connected rigidly to the composite four–metre box, unacceptable strain levels would be introduced into the box due to the different coefficients of thermal expansion of the stainless steel clamps and the composite box. Therefore the clamps were configured with a built–in sliding mechanism. This sliding mechanism guarantees that deformation of the steel clamps due to thermal expansion will not introduce stresses into the four–metre box (see Fig. 5).

The stainless steel dummy outboard sections will also introduce thermal stresses into the four–metre box. However, the section between the dummy outboard section and the tip rib of the box is considered not to be representative of a section of the composite stabilizer because of the thick aluminium interface rib and the doublers, which are applied to the skins in this section. The strain distribution, including strains due to thermal stresses, in this section therefore does not have to be representative for the strain distributions in the full scale stabilizer, and the dummy outboard sections were designed without built–in sliding mechanisms.

Because most of the static tests were carried out at elevated temperature and humidity values, the four–metre box was positioned in a large environmental chamber during the tests (see Fig. 6).

Test Results

The ground vibration test and the Limit Load test at ambient conditions were carried out successfully.

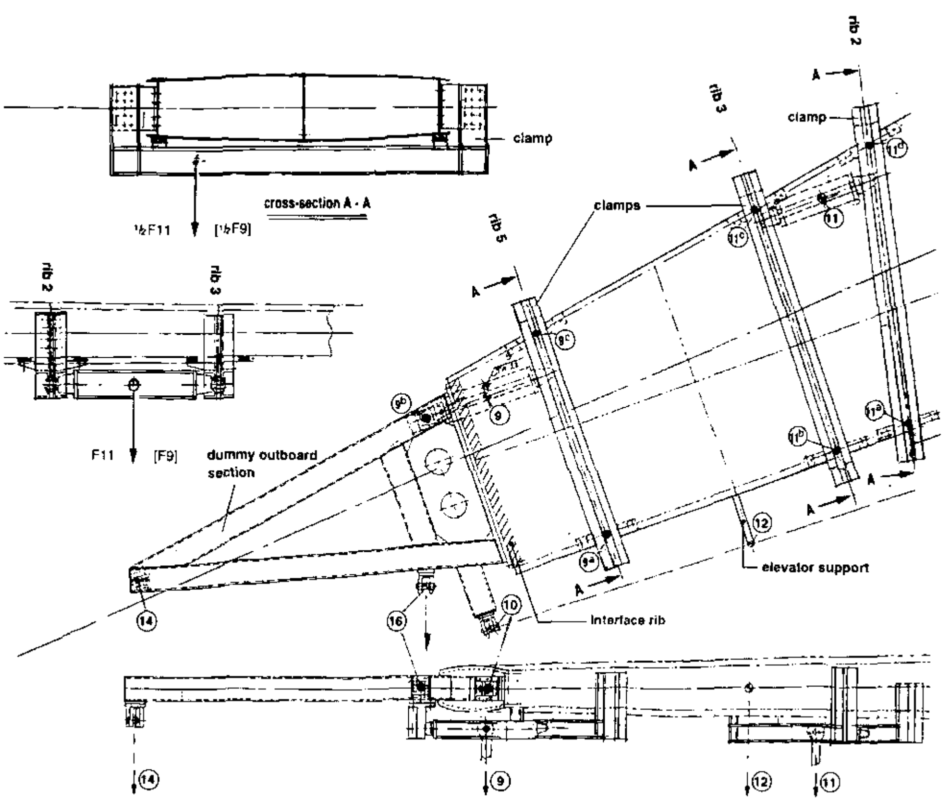


Fig. 5 – Schematics of load introduction in the four-metre box using clamps with built-in sliding mechanisms

After that, the four–metre box was saturated with humidity in the environmental chamber at 80°C and 85% relative humidity. The saturation level of the box was monitored by periodically weighing a number of composite traveller specimens with thicknesses and lay–ups equal to the material at different locations in the box. The box was considered to be saturated as soon as the traveller specimens showed no further weight increase as a function of time. The saturation of the box took nine months.

The fatigue tests successfully demonstrated the four–metre box to comply with the no–growth fatigue requirements.

After the fatigue tests, the four–metre box was successfully subjected to a static test to Ultimate Load. No damage occurred during this test.
At the moment of writing the box is being prepared for the final test: Static test to Limit Load with visible impact damages at 80°C and 85% relative humidity. This test is expected to take place in the first quarter of 1999.

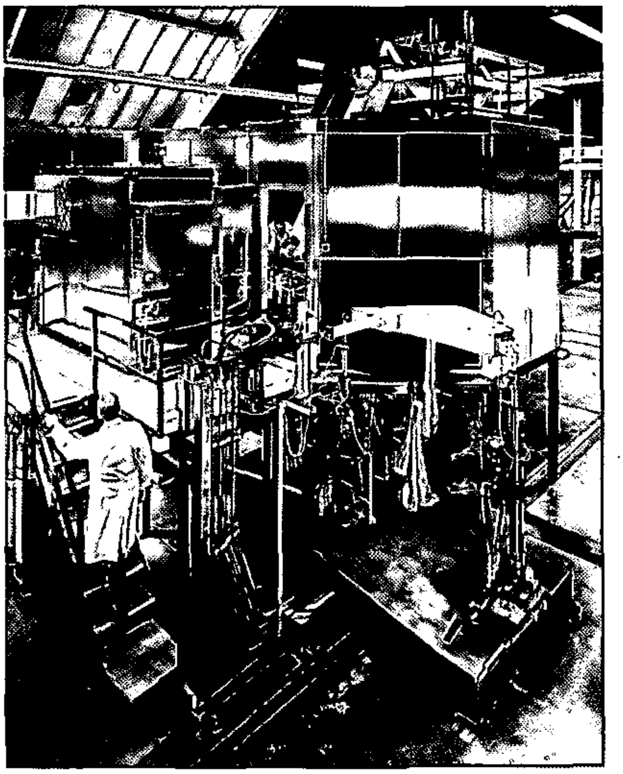


Fig. 6 – Environmental chamber with four–metre box inside

2 Development and Evaluation of Radar Trackers

Since April 1998, a novel Air Traffic Control (ATC) Radar Tracker And Server (ARTAS) has been in operational use, supplying aircraft track data to the Amsterdam Airport Schiphol Advanced ATC (AAA) system. ARTAS is an advanced radar data processing system developed for Eurocontrol in the framework of the European Air Traffic Control Harmonization and Implementation Programme (EATCHIP).

Introduction

Trackers are real–time systems that process measurements (range, bearing and possibly height) from radars. They employ filtering methods to calculate reliable and accurate position, ground speed and course angle information for each and every aircraft, which is required for safe Air Traffic Control.

From mid–1993 onwards, NLR has been working on the ARTAS system, in particular on the ARTAS Tracker, as a sub–contractor of Thomson AIRSYS. Other subcontractors are the Netherlands company HITT and SYSECA, responsible for the ARTAS Server and the ARTAS Human/Machine Interface (HMI), respectively. On–going activities are the implementation of change requests from administrations, evaluation support and a feasibility study for the integration of aircraft–derived data with classical radar data.

NLR investigated advanced filtering methods for the processing of raw radar data as early as 1980. Results showed substantial improvements on existing tracking methods. In 1986, the implementation of a prototype mono–radar tracker using these advanced filtering methods was started. In 1988, the prototype was extended to a multi–radar tracker, called JUMPDIF. Air Traffic Control the Netherlands (LVNL) evaluated JUMPDIF, and the results of this evaluation were used for the specification of the ARTAS tracker performance figures.

Major problems of radar data processing systems were:

- Non–optimum use of all available radar information;
- Inadequate capability to estimate the full aircraft state vector with sufficient accuracy;
- Insufficient capability to follow all types of aircraft manoeuvres;
- Insufficient capability to suppress tracks from various false radar reports;
- Inaccurate methods of co–ordinate transformation and projection.

ARTAS has been designed to surmount these problems.

The ARTAS Tracker

The ARTAS Tracker processes the data of up to 30 Primary (PR), Secondary (SSR) and Mono–pulse secondary (M–SSR) surveillance radars in an area of 1024 by 1024 NM (Nautical Miles) and provides a clean air–picture to, for example, air traffic controllers. The ARTAS tracker uses advanced probabilistic filtering techniques such as the Interacting Multiple–Model (IMM) filter, Probabilistic Data Association (PDA), Joint–Probabilistic Data Association (JPDA) and Multiple–Hypothesis Tracking (MHT) to obtain maximum tracking accuracy, while being capable of following expedite manoeuvres of military aircraft without track loss. Other features of the ARTAS tracker are on–line systematic error estimation for all radars, false plot classification and track–type classification. Systematic radar errors, including range bias, range gain bias, azimuth bias and time–stamping bias, are assessed continuously. This is a pre–requisite for optimum multi–radar state vector estimation in a continuously changing radar environment.

ARTAS units are connected to a Wide–Area Network (WAN) as shown in Fig. 1. Also connected to this WAN are the radar sensors, ATC centres, Flightplan Data Processing Systems (FDPS), etc. Over the WAN, ARTAS receives data from the radar sensors, data from adjacent ARTAS units and data from FDPS units. Furthermore, all track data generated by the ARTAS unit are distributed via this WAN. ARTAS is designed as a track data server. Track data users can register as a client of the ARTAS unit to obtain a certain track data service. They can individually specify the content of the track data and the frequency at which the track data needs to be sent. Normal clients are ATC centres (for the controller working positions), FDPS units and Air Traffic Management units such as the Central Flow Management

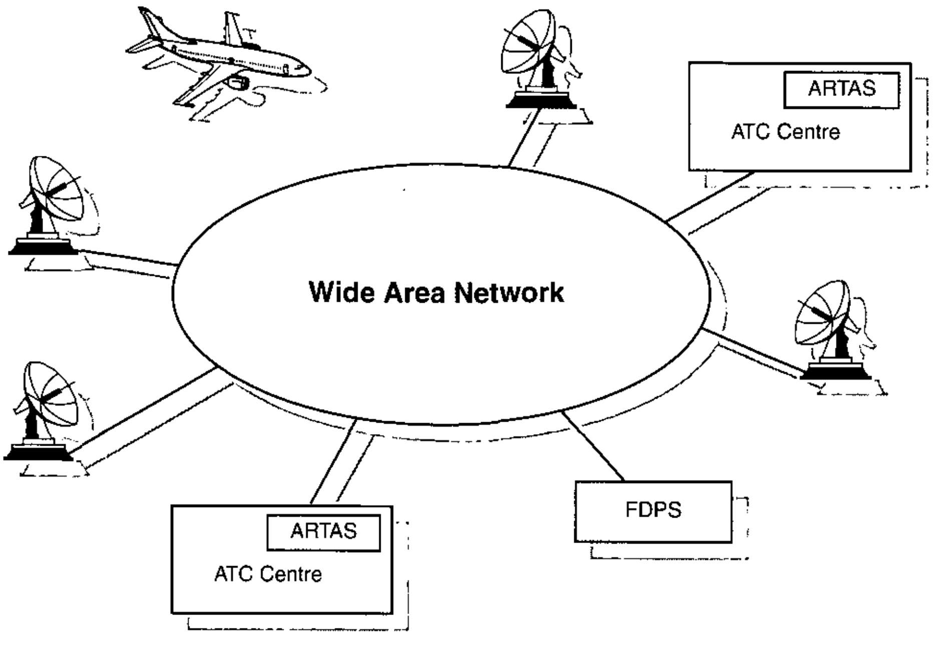


Fig. 1 – ARTAS Environment

Unit in Brussels. Special clients are adjacent ARTAS units. These units exchange track data to guarantee smooth transition of tracks from one ARTAS domain of interest to another, adjacent, domain. In case of contingency, that is the failure of one unit, adjacent ARTAS units can take over the tracking and the track data distribution of the failing unit.

Main Components of the ARTAS Tracker

The ARTAS Tracker consists of four main modules: Track Initiation, Track Continuation, Multi–Radar Environment Assessment and Track Dressing Management (see Figure 2). The Tracker receives radar (position) reports from the radars in 32 pie–shaped sectors of 11.25° wide and 75 NM to 300 NM long per radar revolution. As soon as a sector with radar reports is received, tracks within that area are updated with the new information. Radar reports that cannot be associated to any track are either the starts of new tracks or false reports. The Track Initiation module makes the distinction between these two cases. The Multi–Radar Environment Assessment module estimates radar systematic errors, radar accuracy and probability of detection, and keeps maps of false reports to aid the Track Continuation and Track Initiation modules. The Track Dressing Management module classifies tracks as being aircraft or non–aircraft (in the latter case, the track consists of false reports). It corrects track swaps in the unlikely event that tracks could not be resolved uniquely by the radar and their identities have been swapped. It also maintains track identity continuity when a track is terminated and re–initiated due to radar detection problems. Track identity continuity is not only important to air traffic controllers, but also for further automated processing of track data.

ARTAS Track Data

Fig. 3 shows radar data of an aircraft departing from runway 22 at Amsterdam Airport Schiphol. The area is covered by three radars, the TAR3 PR/SSR terminal area radar, the long–range Den Helder SSR radar and the long–range Leerdam PR/SSR radar. PR radar reports, mainly from TAR3, are shown in blue, SSR–only reports are red and PR/SSR, primary reinforced, reports are green. On the right, the track position updates are shown as squares; the vector, tied to each update, indicates the estimated ground speed and track angle.

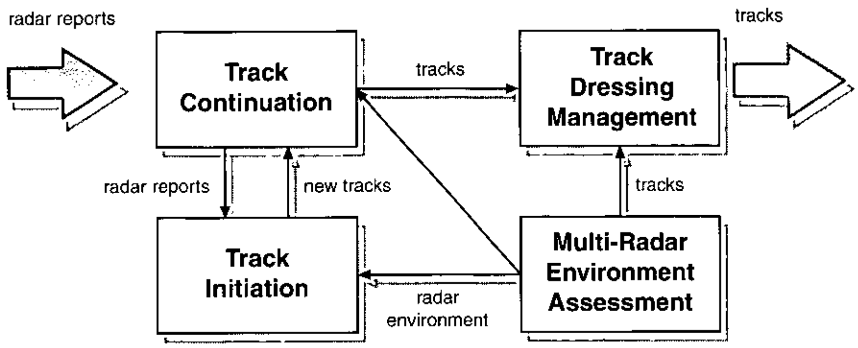


Figure 2 – ARTAS Internal Structure

Testing the ARTAS Tracker

The ARTAS tracker has been developed, tested and verified using the NLR Tracker Development Facility (TRADEF). TRADEF contains tools for the simulation of air traffic and the radar environment, tools for the replay of simulated radar data and recorded live radar data and recording of the generated track data, various tools for visualization of radar data and track data and statistical analysis tools. TRADEF also contains the Eurocontrol SASS-C software for radar data analysis.

The ARTAS tracker has extensively been tested and evaluated by NLR, Eurocontrol UAC Maastricht and the national administrations participating in the ARTAS project, namely Air Traffic Control The Netherlands (LVNL), the French CENA on behalf of STNA and, for some time, the German DFS. Testing consisted of both formal tests on simulated data and evaluation of a number of mutually agreed recorded live scenarios, representative of the operational ATC environment of the administrations.

The formal ARTAS tracker qualification tests can be subdivided into several categories:

1. Functional tests, for determining whether the system can process the specified inputs, perform the specified functions and provide the required output;
2. Capacity tests, for determining if the system can handle the required input and output data rates, the

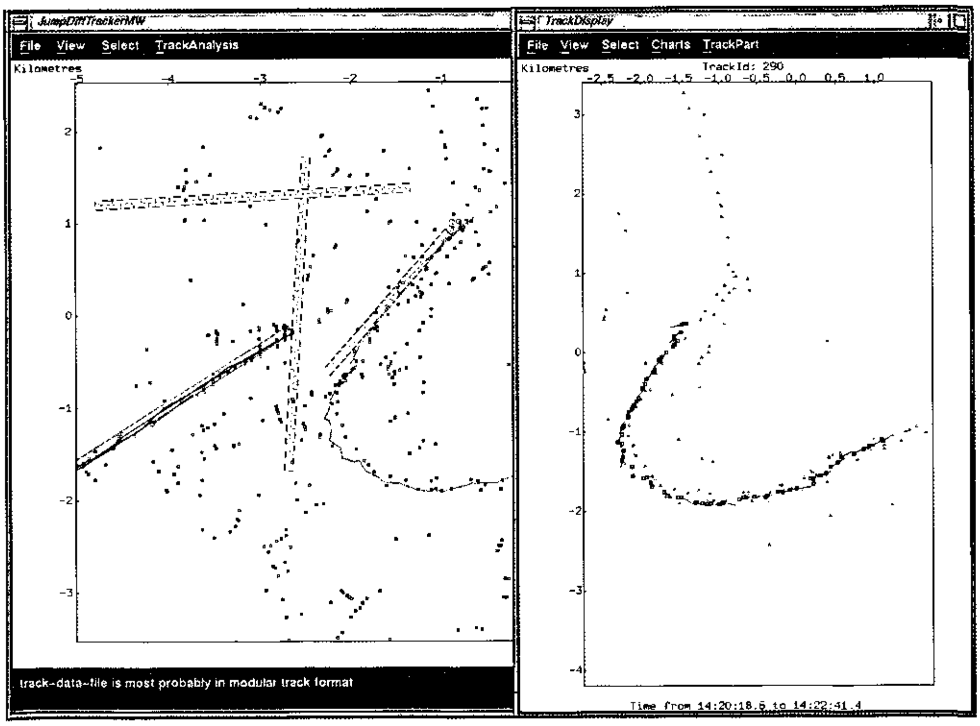


Fig. 3 – Aircraft departing from Amsterdam Airport Schiphol, tracked by ARTAS

required number of input data sources and output data sinks, can handle the required maximum load and provide the output data in time;

3. Track detection analysis, i.e. track initiation, track drop, track swap and track deletion, SSR–code acquisition, SSR–code change event analyses;
4. Track accuracy analysis, i.e. the comparison of the track state vector against a reference state vector.

The tests of categories 1 and 2, although important, are conceptually straightforward. The approach followed for the tests of categories 3 and 4 is to perform a statistical analysis of the tracker results under different circumstances. The scenarios used are all described in the specification of the ARTAS system and consist of mono–radar PR, SSR and mono–pulse SSR scenarios, with various revolution times; mono–radar PR scenarios with low, medium and high false report densities; and multi–radar scenarios. In the last–mentioned case, the performance is specified in terms of an improvement on the mono–radar scenarios. The flights in the scenarios all contain typical aircraft manoeuvres performed at a particular distance and with a specific orientation with respect to the radar.

Fig. 4 shows the TRADEF test environment that has been used for testing the ARTAS tracker. The scenarios are generated by means of the Simulator for Multi–Radar Analysis for Realistic Traffic (SMART), and stored on disk. They are replayed in real–time and the output track data is captured and recorded on disk. The analysis starts with chaining the radar reports of each trajectory by the Object Correlator. These chains are also correlated with the track data, resulting in track–to–chain associations. All further statistical analyses make use of these associations. In the case of live data, the Muratrec–II Trajectory Reconstruction is used to obtain reference trajectories. Muratrec–II uses a Mode Of Flight (MOF)–based Kalman smoother. Apart from the reference state vectors, Muratrec–II then also calculates the horizontal and vertical Mode Of Flight probabilities.

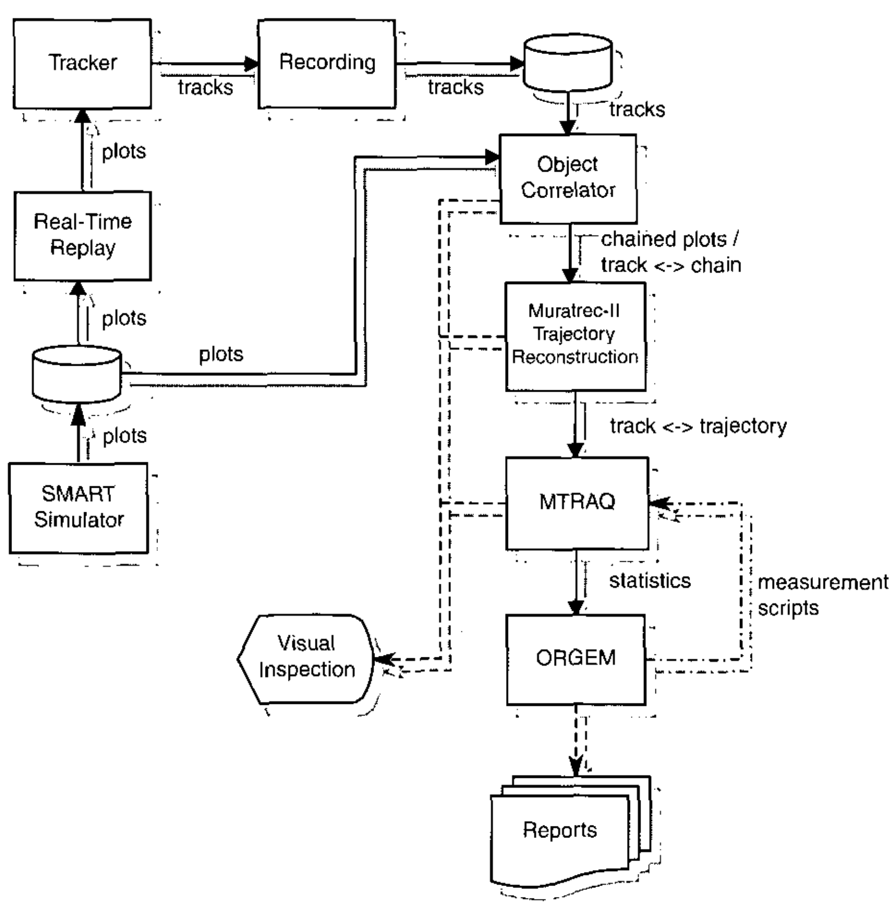


Fig. 4 – TRADEF Testbed

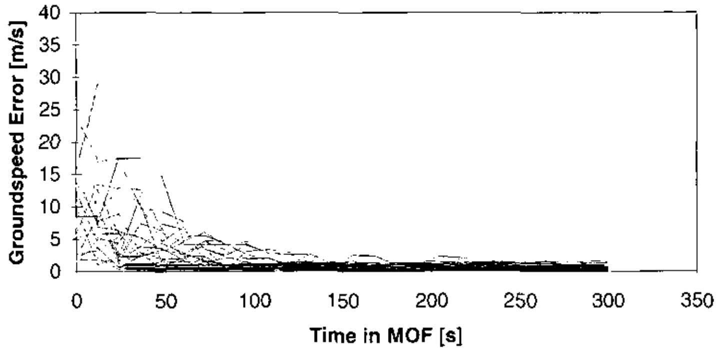


Fig. 5 – Ground speed error statistics

The MTRAQ (Multi–Radar Tracker Quality Analysis) tool has been used to obtain the statistics of the tracker behaviour. It calculates Root–Mean–Square errors, Peak errors and Convergence errors as a function of time and time–in–MOF for each of the state vector components. Furthermore, it calculates the convergence time of the error. The MTRAQ analyses are 'Black box' analyses in that the tracker under test is considered as a 'Black box' and only the response of the tracker on the input data is measured. Examples of input data are typical aircraft manoeuvres, such as a straight flight followed by a typical left turn, and a straight flight followed by a typical descent.
Fig. 5 shows a typical result of MTRAQ. In this case, the scenario contains straight flights right after track initiation. What is shown is the ground speed convergence behaviour after track initiation for each individual track. From an averaged statistic, the root–mean–square convergence value can be determined (in this case, about 1.6 m/s), which is well below the required figure from the ARTAS Specifications (2.05 m/s)

The ORGEM report generator tool, finally, takes care of all repetitive work if a large number of tests have to be executed. This was the case for the formal qualification of the ARTAS tracker, where the final Software Verification and Validation Test Report was issued only on CD–ROM just because of the size of the report.

The ARTAS2 Tracker

The ARTAS2 (Air Traffic Management Surveillance Tracker and Server), an evolution of the ARTAS system, is tailored for the future CNS/ATM (Communication, Navigation, Surveillance / Air Traffic Management) environment. The ARTAS2 Tracker integrates aircraft–derived data, which is downlinked via Automatic Dependent Surveillance (ADS) or Mode–S sub–networks, with classical radar data. Aircraft–derived data items of particular interest are the aircraft technical address that uniquely identifies each aircraft, the ground–referenced state vector from the on–board flight management computer, and intention data such as next waypoint information, also from the on–board flight management computer. Furthermore, the Tracker takes into account the Mode–S enhanced altitude resolution of 25 feet.
A feasibility study that demonstrates the potential of new algorithms to integrate this aircraft–derived information at report–level within the tracking filters is in progress. The study includes extensive simulations and the implementation of a prototype tracker based on the existing ARTAS tracker.

Tracker Evaluation Support

Apart from the involvement in tracking, NLR also has been extensively involved in radar and tracker evaluation software. In the early 1980s NLR developed Muratrec (Multi–Radar Trajectory Reconstitution), a software suite for the evaluation of radar systematic errors and flight–path reconstruction on the basis of recorded live data. Muratrec is based on B–spline, least–squares flight–path estimation. It is used extensively by, amongst others, the UK Civil Aviation Authority (CAA) to monitor radar accuracy. The successor Muratrec–II, developed by NLR in 1988, features improved flight–path reconstruction, using a Mode Of Flight–based Kalman smoothing algorithm.

Apart from position estimates, Muratrec–II also provides accurate estimates of ground speed, course angle and transversal and longitudinal accelerations.
The capability of quantitatively specifying and measuring tracker quality became important in the period just before the inception of the ARTAS specification. Extensive evaluations were done by Air Traffic Control the Netherlands (LVNL) on the basis of a prototype Jump–Diffusion tracker and a system called TRAQUME (Tracker Quality Measurement), which calculates statistics of tracker output data with respect to aircraft manoeuvres. This type of analysis requires advanced aircraft flight path and radar environment simulations facilities. This requirement led to the development of the Simulator for Multi–Radar Analysis of Realistic Traffic (SMART), where NLR was responsible for the radar environment simulation sub–system (see Fig. 6). SMART has been extensively used for the preparation of ARTAS test scenarios.

Tracker Accuracy Analysis

TRAQUME was a prototype system for testing the feasibility of objective statistical analysis of tracker performance. As a prototype, it had limitations including the restriction to mono–radar analyses. MTRAQ (Multi–Radar Tracker Quality Analysis) was developed in parallel to the development of the ARTAS tracker. The aim was to produce a system that allowed top–down navigation in tracker analysis results, from the results for an individual track to an overall result, comparing a tracker against specifications. MTRAQ has been used extensively during the formal qualification of the ARTAS tracker and proved to be invaluable for producing qualification test results. This extensive use also revealed a number of limitations of the concept, most importantly the inability to deal with measurement aberrations and the rigid analysis structure. These led to the development of the TAA (Tracker Accuracy Analysis) tool, consisting of three modules. The basic measurement computation module calculates accuracy figures for the relevant tracker state vector components. The calculated accuracy statistics can be presented geographically, as shown in Fig. 7. Colours indicate the level of accuracy of a selected state vector component. In this way, accuracy problems can easily be identified.

After that, selected parts of the displayed data can be analysed in more detail by means of the statistical display module. The third module is the statistical display module as shown in Fig. 8. The statistical module is used to determine the detailed tracker performance. It displays tracker state vector components, reference state vector components and error statistics. It also has extensive classifica-

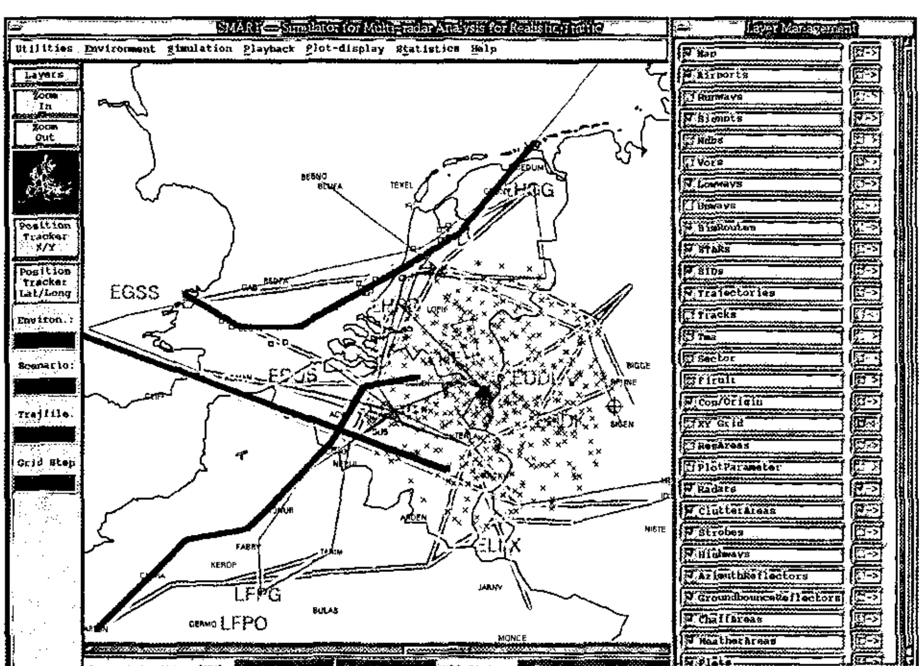


Fig. 6 – SMART simulated radar scenario

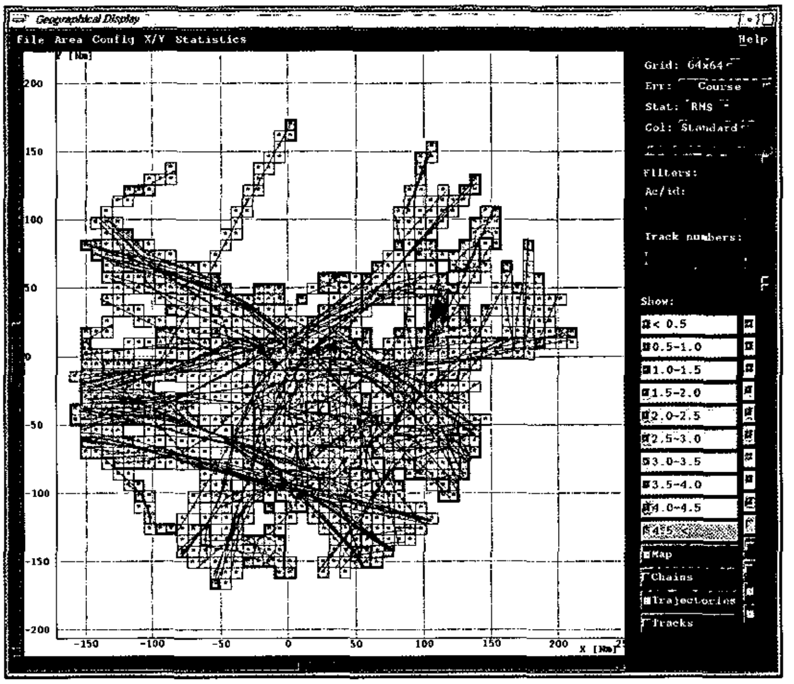


Fig. 7 – Geographical display of track accuracy measurement results

tion functions in order to easily obtain tracker performance figures for typical aircraft manoeuvres. Filtering functions can be used to remove data outside the scope of interest, such as from manoeuvring military aircraft, and erroneous measurements.

TAA has already been used for the tuning of the ARTAS system at Amsterdam Airport Schiphol, and is currently being used for the evaluation of the ARTAS2 tracker prototype.

Concluding Remarks

The advanced filtering methods introduced by NLR in multi–radar tracking have contributed to the development of the successful ARTAS tracker. The development, testing and evaluation of state–of–the–art multi–sensor trackers requires a sophisticated environment. TRADEF is such an environment. It contains the tools to produce and maintain high–reliability software such as the ARTAS tracker.

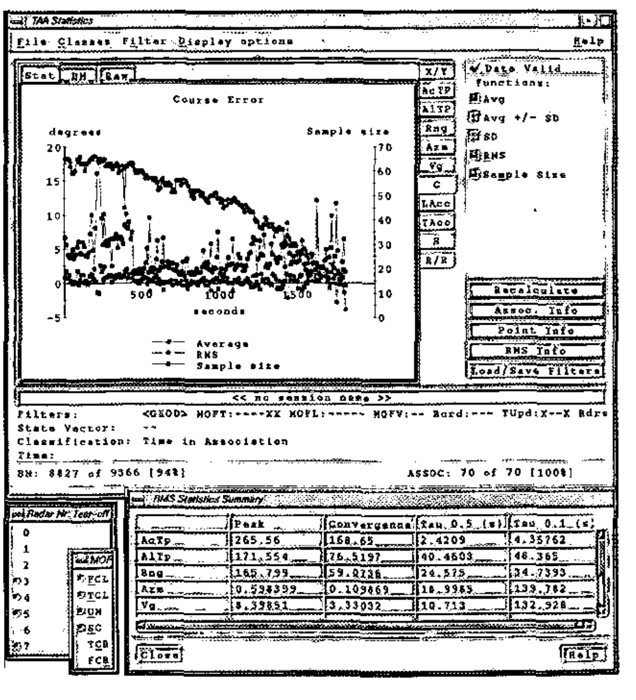


Fig. 8 – Improved track accuracy measurement: statistical display

3 Flight Control Display Module: Development of a Safety-critical Avionics System

NLR has participated in the development of the Flight Control Display Module (FCDM), a safety-critical part of a new generation of helicopter avionics systems. The FCDM supports essential guidance and navigation functions for the pilot. Based on customer specifications, NLR has developed the software for the FCDM using guidelines provided by document RTCA DO-178B, whose application is mandated by the certifying authorities. Part of the software conforms to the highest software level, whereas other parts are classified at lower levels. Partitioning software has been developed to guarantee that software parts classified at different levels do not interfere under any circumstances. The FCDM software has been written in the C programming language and has been verified with the aid of among other things a commercially available software verification tool that also provides detailed structural code coverage information.

Introduction

The word 'avionics', derived from a combination of 'aviation' and 'electronics', refers to any system in an aircraft that is dependent on electronics for its operation. Avionics systems may differ in many ways from ground-based equipment carrying out similar functions, in particular concerning reliability, safety and integrity under harsh environmental conditions. The nature of these systems is safety critical if the occurrence of a failure leads to conditions that prevent an aircraft from performing a continued safe take-off, flight or landing.

Today's avionics systems are characterized by increasing degrees of integration and complexity, while development time shortens and budgets are reduced. Here, the term 'integration' refers to systems that perform or contribute to multiple aircraft-level functions, and 'complexity' refers to systems whose safety cannot be shown by testing only and whose logic is difficult to understand without the aid of analytical tools. To demonstrate to the certification authorities that systems meet the airworthiness requirements, high quality must be maintained throughout the complete development process, which has to be documented and repeatable. Validation of final and intermediate products is performed during each phase of the development process. This involves among other things extensive analysis and testing including environmental testing.

Development of Avionics Systems

The Systems Integration Requirements Task group of the Society of Automotive Engineers (SAE) has developed document ARP4754: 'Certification considerations for highly-integrated or complex aircraft systems'. Document ARP4754 provides designers, manufacturers, installers, and certification authorities with guidelines for demonstrating compliance with airworthiness requirements applicable to highly integrated or complex systems.

Document ARP4754 introduces a conceptual aircraft function development process, shown in a simplified way in Fig. 1. The aircraft function development process may consist of multiple system development processes. Each system development process may consist of multiple item development processes. The term 'item' is used to describe any equipment. Since an item consists of hardware and may also contain software, any item development process may include both multiple hardware life cycles and multiple software life cycles. ARP4754 does not prescribe a specific aircraft function development process, nor does it prescribe a particular development organization or distribution of responsibilities. For the purpose of common understanding, ARP4754 does, however, provide a generic guide for aircraft function development, listing the following activities:

- Identification of aircraft level functions, functional requirements, and functional interfaces
- Determination of functional failure consequences and implications
- Allocation of functions to systems and people
- Design of system architecture and allocation of requirements of items
- Allocation of item requirements to hardware and software
- Hardware/software design/build
- Hardware/software integration
- System integration

The main contribution of ARP4754 is the definition of a set of development assurance processes (supporting processes in Fig. 1). Within these processes, planned and systematic activities are carried out that provide confidence that errors and omissions in requirements or design have been identified and corrected. Most development assurance processes are iterative processes that continue throughout system development. The rigor in which these activities have to be carried out depends on the system development assurance level, which is assigned on the basis of the most severe failure condition classification associated with the applicable aircraft functions (see Table 1). Depending on the selected system architecture, parts of the system may be developed at lower assurance levels.

The Safety Assessment process determines and categorizes the failure conditions of the system according to their effects (See Table 1). Within the system safety assessment process, an analysis of the system design defines safety–related requirements that specify the desired immunity from, and system responses to, these failure conditions. These requirements are defined for hardware and software in order to preclude or limit the effects of faults, and may provide fault detection and fault tolerance. As design decisions are being made during the hardware and software development processes, the resulting system design is analysed in the system safety assessment process to verify that it satisfies the safety–related requirements.

The Requirements Validation process ensures correctness and completeness of the requirements and assumptions. Ideally, requirements should be validated before design implementation starts. However, in practice, all implications of the requirements may not be visible until the system implementation or an early prototype is available and can be tested in its operational context. Validation methods include the application of traceability, analysis, modelling, test, similarity, and sound engineering judgement.

The Implementation Verification process ensures that the system implementation satisfies the validated requirements. Basic verification methods are inspection and review, analysis, test, and similarity/service experience.

The Configuration Management process provides technical and administrative control of the configuration of system requirements, items that implement the system, applicable certification data, and facilities and tools. Configuration management controls the changes to these items and assures that physical archiving, recovery and control are maintained for relevant system data.

The Process Assurance process ensures that the system development and supporting processes are appropriate, maintained, and followed. The

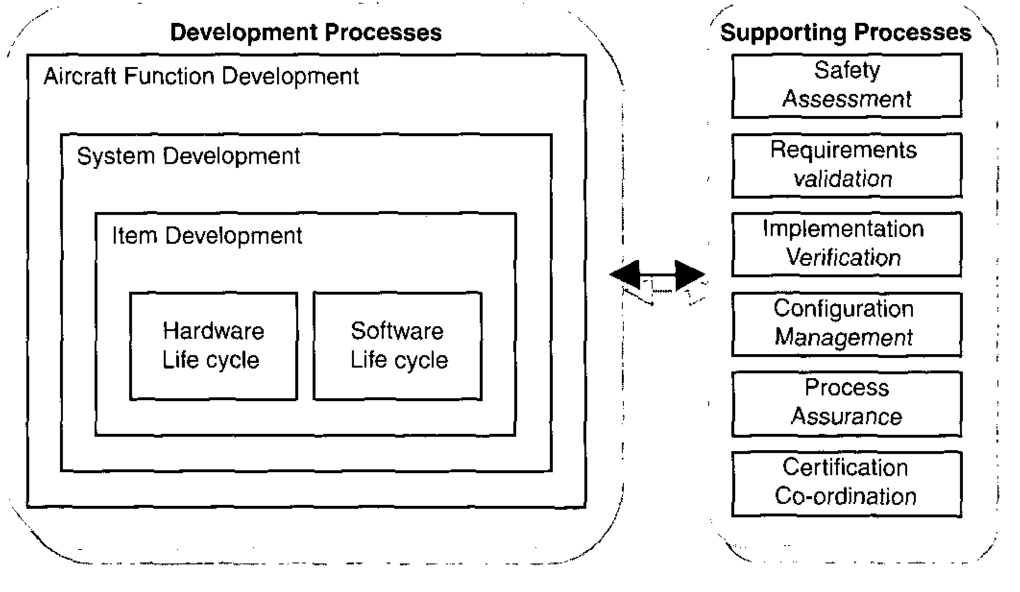


Fig. 1 – Aircraft function development processes

Table 1 – Failure condition classifications and system development assurance levels
(This table combines information from advisory material to JAR 25.1309 and document ARP4754)

Failure condition	Effect on aircraft and occupants	Failure condition classification	JAR–25 probability (per flight hour)	Assurance Level
Failure conditions which would prevent continued safe flight and landing	Multiple deaths, usually with loss of aircraft	Catastrophic	Extremely improbable ($< 10^{-9}$)	A
Failure conditions which would reduce the capability of the aeroplane or the ability of the crew to cope with adverse conditions	Large reduction in safety margins; crew extended because of workload or environmental conditions; serious injury or death of a small number of occupants	Hazardous/ Severe Major	Extremely remote ($10^{-7} - 10^{-9}$)	B
	Significant reduction in safety margins; difficult for crew to cope with adverse conditions; passenger injuries	Major	Remote ($10^{-5} - 10^{-7}$)	C
Failures/occurrences which would not impair continued safe flight and landing	Operating limitations: emerency procedures	Minor	Probable ($>10^{-5}$)	D
		No Safety Effect		E

process assurance activities consist of assessing all project plans and providing evidence to show that the development activities take place in accordance with those plans.

The objective of the Certification Co-ordination process is to substantiate that the aircraft and its systems comply with the airworthiness requirements. This is achieved by communicating plans and results with the authorities.

Development of Software for Avionics Systems

The RTCA[2] Special Committee 167 and the European organization for Civil Aviation Equipment Working Group 12 have developed document DO–178B: 'Software considerations in airborne systems and equipment certification'. Document DO–178B identifies five software levels A – E, which have a one–to–one correspondence with the development assurance levels defined by document ARP4754 (see Table 1). The software level, which is a result of the Safety Assessment process at system level, implies a level of confidence in safety compliant with the airworthiness requirements.

DO–178B describes the software life cycle as a number of processes (Fig. 2). Each process is built up of activities that need to be performed. Processes exist during one or more phases of the software life cycle; some processes may be applied several times, or may be applied iteratively.

The Software Planning process produces the software plans and the standards that direct the software development processes and the integral processes. Examples of plans are the plan for software aspects of certification, the software development plan and the verification plan.

[2] *Requirements and Technical Concepts for Aeronautics (formerly: Radio Technical Commission for Aeronautics).*

The Software Development process consists of four subprocesses: the software requirements process, the software design process, the software coding process and the integration process. These processes may be reiterative and their sequence is determined by characteristics of the project, such as complexity, software size and availability of previously developed results. In the software requirements process, high–level requirements are developed from the system requirements. In the software design process, high–level requirements are translated into low–level requirements and software architecture. The software architecture basically consists of a structure of interrelated modules. The modules contain coherent sets of functions and definitions of data structures. In the coding process, the source code, which is traceable, verifiable, consistent and correct, is implemented. The integration process produces the application executables by using the target computer, the source code from the coding process and the software architecture from the design process.

The purpose of the Software Verification process is to detect and report any errors that may have been introduced during the Software Development process. Verification is defined in DO–178B as the evaluation of the results of a process to ensure correctness and consistency with inputs and standards of that process. Verification can be accomplished by review, analysis, test or any combination of these three methods. Review provides a qualitative assessment of correctness. Analysis is a detailed examination of a software component. It is a repeatable process that can be supported by tools. Testing is the process of exercising a system or system components to verify that they satisfy specified requirements and to detect errors. For level A software, DO–178B requires that the objectives of the Software Verification process are satisfied with independence, which in practice means that other persons than the developers perform the verification activities.

The Software Configuration Management process includes the activities of configuration identification, baseline establishment, problem reporting, change control, change review, configuration status accounting, and archiving, retrieval and release of the software product. Also the tools that establish the software life cycle environment are subjected to configuration management.

The Software Quality Assurance process assesses the software life cycle processes and their outputs to obtain assurance that the objectives are satisfied,

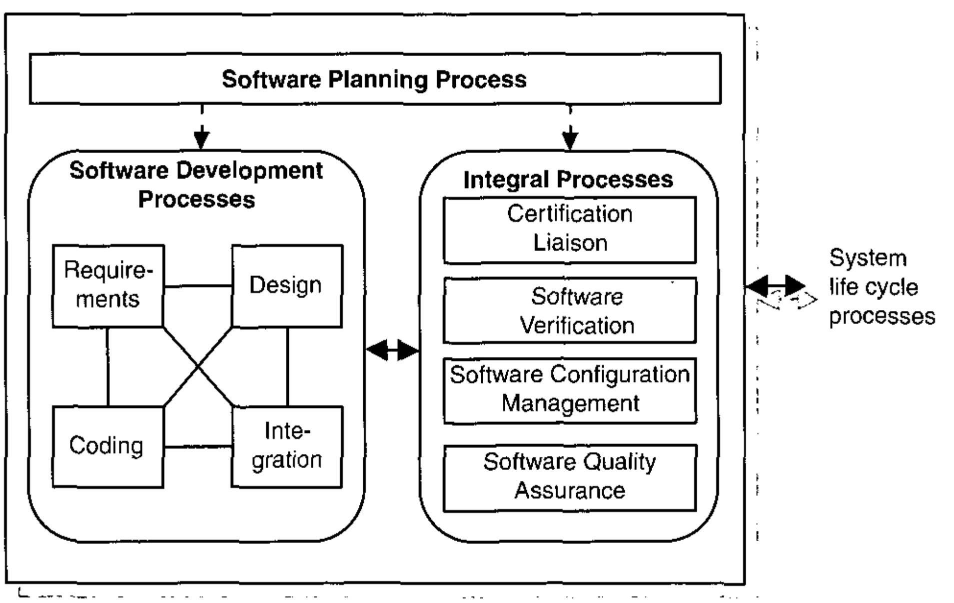


Fig. 2 – Software life cycle processes

that deficiencies are detected, evaluated, tracked and resolved, and that the software product and software life cycle data conform to certification requirements.

The Certification Liaison process establishes communication and understanding between the applicant and the certification authority throughout the software life cycle to support certification.

Example: Development of the Flight Control Display Module

Functional Overview

The Flight Control Display Module (FCDM) is a safety–critical part of the Flight Control Display System (FCDS), a helicopter avionics system of a new generation. The FCDS provides pilots with guidance and navigation functions, and is designed to operate under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). Under VFR, the FCDS supports the pilot during flight, whereas under IFR the FCDS is necessary for the pilot to be able to fly. Consequently, the correct functioning of the FCDS is safety–critical. To achieve the required failure rates, a number of items in the FCDS are duplicated. Apart from one or two FCDMs, the FCDS is made up of display units, Instrument Control Panels (ICPs) and a Reconfiguration Control Unit (RCU). The FCDM is the interface between the on–board sensors and the displays (Fig. 3). The sensors and some aircraft subsystems send flight parameters via digital ARINC 429 data buses to the FCDM, which validates the parameters and sends them to the displays. A number of flight parameters are computed by the FCDM itself. Another important function of the FCDM is central maintenance of the complete FCDS.

During normal operation, the FCDM processes about 100 different flight parameters, originating from some 10 different sensors. The delay times within the FCDM are guaranteed to be less then 30 ms. Parameters are classified as:

- Critical: loss or undetected error could lead to a catastrophic failure condition. Examples of critical parameters are the attitude parameters pitch, roll and heading. The software that handles these parameters is classified as level A.
- Essential: loss or undetected error could lead to a major failure condition. An example of an essential parameter is the VOR (VHF Omnidirectional Range for aircraft position determination). The software that handles these parameters is classified as level B.
- Non–essential: loss or undetected error could lead to a minor failure condition. Examples of these parameters are the long–term navigation parameters, such as the flight plan. The software that handles these parameters is classified as level D.

Depending on the criticality of a flight parameter, the FCDM performs validation in four different ways:

- Coherency test: a check on correct length and parity of data.
- Reception test: a check on the timely arrival of the data.
- Sensor discrepancy test: a comparison between two data values produced by two independent redundant sensors.
- Module discrepancy test: a comparison between two parameter values produced by the same sensor; one value directly read by the system from the sensor, and one obtained from the redundant FCDM via a cross–talk bus.

In case of a failure of an item, or a discrepancy between two sensors, the RCU permits the crew to choose between different display configurations. When a sensor is reconfigured, it is logically switched off.

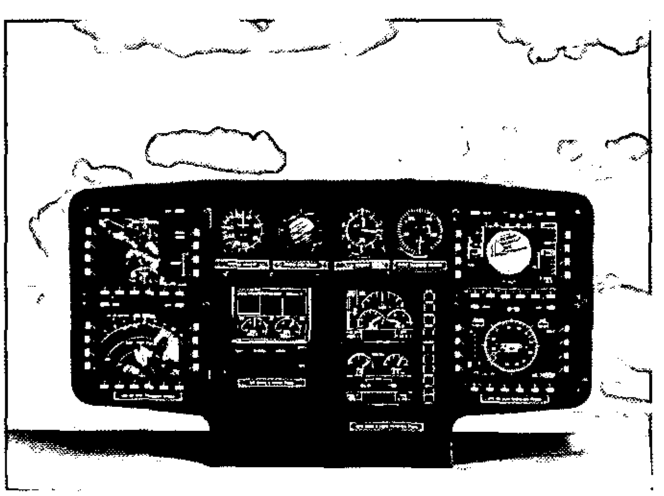


Fig. 3 – FCDM environment (photograph: Sextant Avionique)

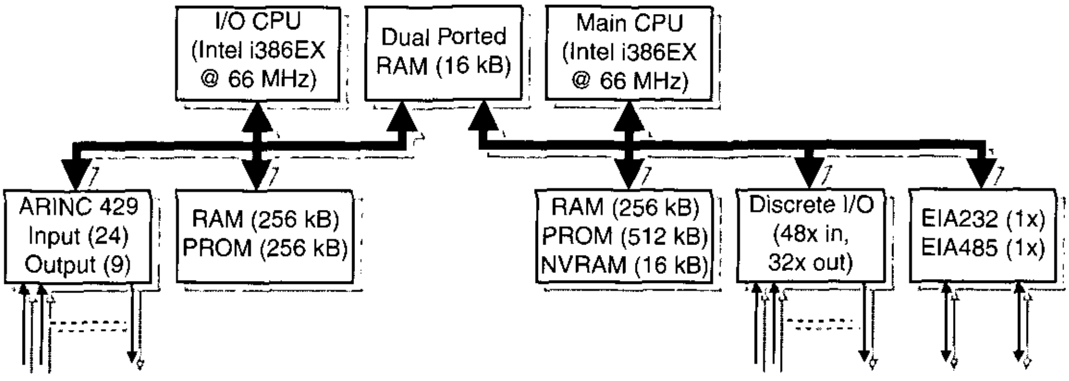


Fig. 4 – FCDM hardware architecture

Hardware Architecture

Figure 4 depicts the architecture of the FCDM hardware. It is based on two Central Processor Units (CPUs). One CPU (the I/O processor) is dedicated to all ARINC 429 input and output (I/O) handling, the other CPU (the Main processor) is dedicated to discrete I/O handling, data processing, data validation, flight control, etc. The I/O processor and the Main processor are linked through shared memory. Figure 5 shows a photograph of the FCDM hardware.

Software Architecture

The FCDM software is subdivided into three software components: a bootstrap loader, firmware for the I/O processor (FCDM/IO), and software for the Main processor (FCDM/Main). The bootstrap loader is stored in Programmable Read Only Memory (PROM) of the Main processor. It is used to download data and/or application software (e.g. a hardware production test/acceptance procedure or the main application software) and to start application software.

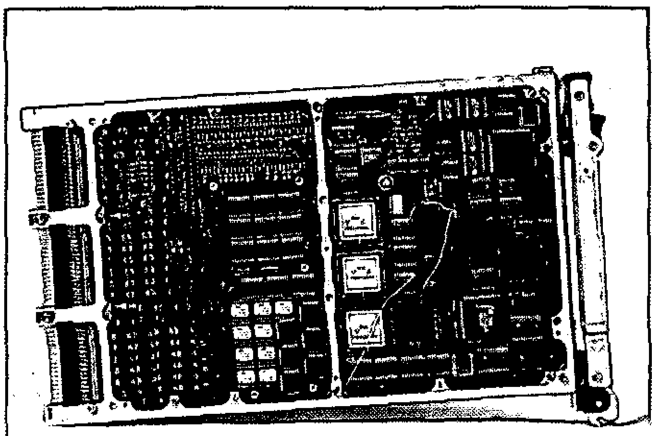


Fig. 5 – FCDM hardware

The FCDM/IO firmware receives, selects and performs basic validation of all ARINC 429 data, and transmits processed ARINC 429 data. At start-up, configuration data is transferred from FCDM/Main to FCDM/IO through the shared memory. This data is used to initialize the ARINC 429 controllers and the I/O processing. This mechanism makes possible a flexible configuration of all ARINC 429 inputs and outputs.

In operational mode the FCDM/Main software processes all ARINC 429 data. It uses tables for all input/output processing, reconfigurations, calculations and monitoring activities. At start-up these tables are optimized (adding redundant data from other tables) and updated with data from the FCDS configuration file to speed up the real-time processing as far as possible. A new FCDS configuration file can be downloaded in maintenance mode through the EIA485 serial link.

Software Partitioning

One may choose between developing all software components at the highest software level assigned to any of the software components and developing each component at its own assigned level. In the latter case, the total verification effort may be substantially lower, since lower level software components require less verification rigor. On the other hand, it is then necessary to ensure that more-critical software components are not affected by less-critical components, which generally increases the development effort.

It was decided to use partitioning in the FCDM/Main software to provide isolation between functionally independent software components. Isolation between software components is achieved by using spatial partitioning and temporal partitioning. FCDM/Main implements spatial partitioning by using the paging mechanism and protection levels provided by the Main processor hardware. Pages can be individually protected from being read or written, and can be shared selectively. Kernel software has been developed that manages access to the pages. Temporal partitioning is achieved by scheduling activities via the kernel as well. Scheduling is driven by timer interrupts and by software components, which return control to the kernel after completion of their periodical tasks.

Aspects of the FCDM Software Life cycle

Software Development

The software development life cycle of the FCDM was based on the military standard DOD–STD–2167A, which specifies a traditional waterfall development model. The Software Requirements were established using the Structural Analysis/Real Time (SA/RT) method supported by the Teamwork tool. The SA/RT process specifications contain the high level requirements in plain English, including a copy of the relevant system requirement number to ensure traceability. Control is specified by means of decision tables and state transition diagrams. The Software Design was established by writing the module specifications in pseudo code. These module specifications were inserted in the source code files. The design documentation was generated automatically from the source code files, by derivation of the call–tree (software architecture) and extraction of the module specifications. The customer prescribed the C programming language for the Software Coding. NLR's proprietary C–coding standard, with project specific enhancements, was used and enforced by a commercially available static code analysis tool.

Software Verification

An important aspect of the verification of software classified at DO–178B level A is to achieve a one hundred per cent code coverage. This consists of statement coverage (every statement must be executed) and decision coverage plus Modified Condition/Decision Coverage (MC/DC), where MC/DC requires the demonstration of the effect of every condition within a decision on the outcome of the decision. A commercially available automated test tool was used to aid in the construction and cost effective repetition of functional tests and code coverage tests. The test tool is used to generate test harnesses in the C programming language, which can be cross-compiled or compiled and run on the target computer or a host computer, respectively. This approach enables the source code to be tested without having the target computer available.

Concluding Remarks

DO–178B is known to be a highly mature and proper guideline, which was confirmed in its practical use in the FCDM software development. It provides the flexibility required in commercial applications development, without compromising the safety requirements.

The FCDM software development faced not only a short time to market but also evolving system requirements. Apart from applying pragmatic approaches in the software development process to cope with these challenges, it was decided to transfer the FCDM software development activities to the site of the FCDS developer. This resulted in short communication lines, it increased understanding between system and software developers, and it improved the ability to incorporate software changes resulting from changes in system requirements in a short time.

The development of the software for the safety–critical FCDM module has led to successful certification of the FCDS for the Eurocopter EC–135 helicopter.

Appendices

Appendices

1 Publications

In 1998, NLR produced a total of 633 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

TP 95659 U

Joint probabilistic data association methods avoiding track coalescence
Presented at the 34th IEEE Conference on Decision and Control, New Orleans, Louisiana, USA, December 1995
Bloem, E.A.; Blom, H.A.P.

TP 95661 U

Joint probabilistic data association avoiding track coalescence
Presented at the IEE Colloquium on Algorithms for Target Tracking, London, 16 May 1995
Blom, H.A.P.; Bloem, E.A.

TP 97032 U

Context simulation: An interactive methodology for user centred system design and future operator behaviour validation
To be published in "Cognitive Engineering in the Aviation domain", Sarter and Amalberti, eds., Lawrence Erlbaum Inc. Publishers (in press)
Jorna, P.G.A.M.

TP 97127 U

Physical aspects of separation in three-dimensional flows
Presented at the Seminar "Boundary-Layer Separation in Aircraft Aerodynamics", Delft University of Technology, February 1997
Berg, B. van den

TP 97147 U

The phase 2 up-grade of the NLR high speed tunnel HST
Presented at the European Forum on Wind Tunnels and Wind Tunnel Test Techniques, organized by the Confederation of European Aerospace Societies (CEAS), Cambridge, UK, 14–16 April 1997
Jaarsma, F.; Elsenaar, A.

TP 97151 U

Separation in transonic flow: a shocking experience
Presented at the Seminar "Boundary-Layer Separation in Aircraft Aerodynamics" at the special occasion of the retirement of Prof. J.L. van Ingen, Delft University of Technology, 6 February 1997
Elsenaar, A.

TP 97153 U

Review of aeronautical fatigue investigations in the Netherlands during the period March 1995 - March 1977
Presented at the 25th ICAF Conference, Edinburgh, United Kingdom, 16–17 June 1997
Jonge, J.B. de

TP 97159 U

Crew laptop for payload operation
Presented at the "First Symposium on the Utilisation of the International Space Station" ESOC, Darmstadt, 30 September- 2 October 1996
Visser, F.B.; Wolf, M. (ESA)

TP 97224 U

Network middleware illustrated for enterprise enhanced operation
Presented at Sixth International Conference for Worldwide Industrial Research on Global Enterprise Computer Applications in Production and Engineering CAPE '97, Detroit, Michigan, USA, 5-7 November 1997
Loeve, W.; Ven, H.van der; Vogels, M.E.S.; Baalbergen, E.H.

TP 97229 U

Classical HPCN geared to application in industry
Loeve, W.; Verwer, J.; Snijdoodt, E.; Dam, A. ten

TP 97239 U

A new test facility for the study of interacting pressure waves and their reduction in tunnels for high speed trains
Contribution to the 9th International Conference on Aerodynamics and Ventilation of Vehicle Tunnels, Aosta Valley, Italy, 6–8 October 1997
Wolf, W.B. de; Demmenie, E.A.F.A.

TP 97241 U

Discontinuous Galerkin finite element method with anisotropic local grid refinement for inviscid compressible flows

Submitted to the Journal of Computational Physics

Vegt, J.J.W. van der; Ven, H. van der

TP 97249 U

Experimental study of the flow around two scaled 3D swept wings

Gooden, J.H.M.; Gleyzes, C.; Maciel, Y.

TP 97255 U

Computation of flow about fighter aircraft

Presented at the Conference on Analysis, Numerics and Application of Differential and Integral Equations, Stuttgart, 9–11 October 1996

Schippers, H.; Berg, J.I. van den

TP 97256 U

High performance computing in simulation that fulfils user-driven quality criteria

Presented at the Conference DASIA 97, organized by Eurospace, Sevilla, Spain, 6–29 May 1997

Loeve, W; Baalbergen, E.H.; Vogels, M.E.S.; Ven, H. van der

TP 97259 U

New attempts to solve an old problem: Aerodynamic measurements in new vehicle tunnels

Presented at the 9th International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels, Aosta Valley, Italy, 6–8 October 1997

Bruin, A.C. de; Maarsingh, R.A.; Swart, L.

TP 97261 U

Flow visualization and particle image velocimetry on a semi-span straked delta wing, stationary and oscillating in pitch

Presented at the European Forum on Wind Tunnel Test Techniques, Cambridge, United Kingdom, 14–16 April 1997

Geurts, E.G.M.

TP 97270 U

Controlled flight into terrain (CFIT) accidents of air taxi, regional and major operators

Presented at the Flight Safety Foundation's 9th European Aviation Safety Seminar, Amsterdam, 4–5 March 1997, and at the International Aviation Safety Conference, Rotterdam, 27–29 August 1997

Khatwa, R.; Roelen, A.L.C.

TP 97278 U

Full scale glare fuselage panel tests

Presented at ICAF97, Edinburgh, UK, 16–20 June 1997

Vercammen, R.W.A.; Ottens, H.H.

TP 97281 U

Analysis of computational aeroelastic simulations by fitting time signals

Presented at the CEAS International Forum on Aeroelasticity and Structural Dynamics, Rome, Italy, 17–20 June 1997

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

TP 97282 U

Components for aerospace thermal control and propellant systems

Presented as SAE 97248 at the 27th International Conference on Environmental Systems, Lake Tahoe, NV, USA, 13–17 July 1997 and – in abbreviated form (ESA SP–400) – at the 6th European Symposium on Space Environmental Control Systems, Noordwijk, Netherlands, 19–22 May 1997

Delil, A.A.M.; Pauw, A.; Put, P.A.G. van, Voeten, R.G.H.M.

TP 97283 U

In-orbit demonstration of two-phase heat transport technology status of TPX II: reflight of the European two-phase experiment

Presented as SAE 972478 at the 27th International Conference on Environmental Systems, Lake Tahoe, NV, USA, 13-17 July 1997 and as ESA SP–400 at the 16th European Symposium on Space Environmental Control Systems, Noordwijk Netherlands, 19–22 May 1997

Delil, A.A.M. et al

TP 97286 U

Slot allocation by column generation

Published in the European Journal of Operational Research

Akker, J.M. van den; Nachtigall, K.

TP 97288 U

First results from operating the Dutch National Simulation Facility NSF

Presented at the 1997 International Training Equipment Conference (ITEC), Lausanne, Switzerland, 22–25 April 1997

Offerman, H.A.J.M.

TP 97304 U

Determination of transonic unsteady aerodynamic loads to predict the aeroelastic stability of fighter aircraft

Presented at the International Forum on Aeroelasticity and Structural Dynamics, Rome, Italy, 17–20 June 1997

Meijer, J.J.

TP 97329 U

Partitioning and parallel development of an unstructured, adaptive flow solver on the NEC SX-4

Presented at the Parallel Computational Fluid Dynamics '97 Conference, Manchester, England, 19–21 May 1997

Ven, H. van der; Vegt, J.J.W. van der

TP 97347 U

A frequency dependent structural damping model

Presented at the 15th International Model Analysis Conference, Tokyo, Japan, 1–4 September 1997

Boer, A. de

TP 97351 U

Miniature rotating amplifier system for wind tunnel application packs 256 pre-conditioning channels in 187 cubic inch

Presented at the 17th International Congress on Instrumentation in Aerospace Simulation Facilities (ICIASF), Monterey, California, USA, 29 September – 2 October 1997

Versteeg, M.H.J.B.; Slot, H.

TP 97359 U

P-Band SAR mission dedicated to global monitoring of forests

Presented at the 48th International Astronautical Congress, Turin, Italy, 6–10 October 1997

Algra, T.; Looyen, W.J.; Brouwer, M. de; Venema, J.C.

TP 97360 U

Mass storage device developed for application in the space station

Presented at the 48th International Astronautical Congress, Turin, Italy, 6–10 October, 1997

Algra, T.

TP 97374 U

Computation of aircraft noise propagation through the atmospheric boundary

Paper 389438 in the Proceedings of the Fifth International Congress on Sound and Vibration, University of Adelaide, Australia, 15–18 December 1997

Schulten, J.B.H.M.

TP 97379 U

A matlab program to study gust loading on a simple aircraft model

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

TP 97389 U

Network middleware for enterprise enhanced operation

Presented at the 4th International Conference on Computer Integrated Manufacturing, Singapore, 21–24 October 1997

Loeve, W.; Vogels, M.E.S.; Ven, H. van der; Baalbergen, E.H.

TP 97413 U

Design, fabrication, test and analysis of a crashworthy troop seat

Presented at the 23rd European Rotorcraft Forum, Dresden, Germany, 16–18 September 1997

Wiggenraad, J.F.M.; Vries, H.P.J. de; Frijns, R.H.W.M.; Veul, R.P.G.; Lupker, H.A. (TNO); Dekker, M.J. den (TNO); Fountain, M.A. (TNO)

TP 97423 U

Query optimization to support data mining

Published in the Proceedings of the DEXA '97 8th Int. Conference and Workshop on Database and Expert Systems Applications, IEEE Computer Society Press, Los Almitos, CA, USA, 1997

Choenni, S.; Siebes, A.

TP 97425 U

Further evaluation of the ASCOR test for stress corrosion testing of aluminium alloys

Submitted to the Journal of Testing and Evaluation.

Schra, L.; Wanhill, R.J.H.

TP 97451 U

Sloshsat Flevo motion sensing subsystem

Presented at the International Workshop on Spacecraft Attitude and Orbit Control Systems, International Federation of Automatic Control, ESA/ESTEC, Noordwijk, The Netherlands, 15–17 September 1997

Dujardin, P.G.J.P.

TP 97478 U

Kruip in gasturbines en straalmotoren (in Dutch)

Bestemd voor het tijdschrift "Materialen"

Kolkman, H.J.

TP 97483 U

Development of a position reference system for flight tests based on GPS

Presented at the 9th World Congress of the International Association of Institutes of Navigation, Amsterdam, 18–21 November 1997

Kannemans, H.; Storm van Leeuwen, S.

TP 97489 U

Aircraft structural health and usage monitoring, prospects for smart solutions from a European viewpoint

Presented at the International Workshop on Structural Health Monitoring, Stanford University, USA, 18–20 September 1997

Bartelds, S.

TP 97502 U

The European two-phase experiments TPX I & II

Proceedings of the Xth International Heat Pipe Conference, presented in the Two-Phase Heat Transport Session, Stuttgart, Germany, 21–25 September 1997

Delil, A.A.M. et al

TP 97503 U

Characterisation of the dielectric properties of the propellants MON & MMH

Proceedings of the Space Technology & Applications International Forum (STAIF), American Institute of Physics, presented at the 1st Conference on Orbital Transfer Vehicles, Albuquerque, New Mexico, USA, 25–29 January 1998

Delil, A.A.M.

TP 97504 U

Sensors and components for aerospace thermal control, life sciences and propellant systems

Proceedings of the Space Technology & Applications International Forum (STAIF), American Institute of Physics, presented at the 2nd Conference on Applications of Thermophysics in Microgravity, Albuquerque, New Mexico, USA, 25–29 January 1998

Delil, A.A.M. et al

TP 97511 U

The description of crack growth on the basis of the strip-yield model for computation of crack opening loads and the crack tip stretch and strain rates

Presented at the Second Symposium on 'Advances in Fatigue Crack Closure Measurement and Analysis', San Diego, California, USA, 12–13 November 1997

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

TP 97517 U

Anechoic wind tunnels

Paper presented at the VKI Lecture Series 'Aeroacoustic and Active Noise Control', Rhode-Saint-Genese, Belgium,15–18 September 1997

Brouwer, H.H.

TP 97556 U

FASTFLO Automatic CFD system for three-dimensional flow simulations

Presented at the Conference on Industrial Technologies and 3rd Aero Days, Toulouse, France, October 1997

Burg, J.W. van der; Oskam, B.

TP 97563 U

A framework for multi-query optimization

Appeared in the Proceedings of the OMAD '97 8th Int. Conference on Management of Data, published by Springer Verlag, 1997

Choenni, S.; Kersten, M.

TP 97564 U

Comparison of measured and predicted airfoil self-noise with application to wind turbine noise reduction

Presented at the European Wind Energy Conference & Exhibition 1997, Dublin, Ireland, 6–9 October 1997

Dassen, T.; Parchen, R.; Guidati, G.; Wganer, S. ; et al

TP 97592 U

High-level versus low-level DO-loop parallelization: Results for one test case of a multi-block solver on a shared memory parallel vector computer

Presented at the High Performance Computing and Networking Europe '98 Conference, Amsterdam, the Netherlands, 21–23 April 1998

Wijnandts, P.; Vogels, M.E.S.

TP 97594 U

Free flight in a ground controlled ATM environment

Presented at the 10th European Aerospace Conference "Free Flight", Amsterdam, 1997

Post, W.; Jonge, H.W.G.

TP 97601 U

SPINE: A practical and holistic approach to metacomputing

Presented at the HPCN '98 Europe Conference, Amsterdam, 21–25 April 1998

Baalbergen, E.H.

TP 97604 U

The electrical architecture of a parafoil technology demonstrator

Presented at the 14th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, San Francisco, USA, 3–5 June 1997

Hollestelle, P.M.N.

TP 97619 U

Large time step aero-structural coupling procedures for aeroelastic simulation

Presented at the CEAS International Forum on Aeroelasticity and Structural Dynamics, Rome, Italy, 17–20 June, 1997

Prananta, B.B.; Hounjet, M.H.L.

TP 97630 U

Overview of the NH90 wind tunnel test activities and the benefits to the helicopter development

Presented at the American Helicopter Society 53rd Annual Forum, Virginia Beach, Virginia, USA, 29 April – 1 May 1997

Hermans, C.; Hakkaart, J.; Preatoni, G. (Agusta); Panosetti, G. (Agusta); Mikulla, V. (Eurocopter Deutschland); Chery, F. (Eurocopter); Serr, C (Eurocopter)

TP 97631 U

The NH90 helicopter development wind tunnel programme

Presented at the Confederation of European Aerospace Societies Conference on Wind Tunnels and Wind Tunnel Test Techniques, Cambridge, UK, 14–16 April 1997

Hermans, C.; Hakkaart, J.; Panosetti, G. (Agusta); Preatoni, G. (Agusta); Mikulla, V. (Eurocopter Deutschland); Chéri, F. (Eurocopter France); Serr, C. (Eurocopter France)

TP 97632 U

NH90 helicopter model rotor and engine installation wind tunnel test in DNW

Presented at the 23rd European Rotorcraft Forum, Dresden (Germany), 16–18 September 1997

Hermans, C.; Hakkaart, J.; Kooi, J.; Langer, H.J.

TP 97646 U

D-sight technique for rapid impact damage detection on composite aircraft structures

Presented at the 17th European Conference on Non-Destructive Testing, Copenhagen, Denmark, 26–29 May 1998

Heida, J.H.; Bruinsma, A.J.A.

TP 97647 U

Brittle archaeological silver, identification, restoration and conservation

Presented at the XVth International Congress of Classical Archaeology, Amsterdam, July 1998

Wanhill, R.J.H.

TP 97665 U

NLR-TU Delft experience in unsteady aerodynamics and aeroelastic simulation applications

Presented at the RTO Workshop "Unsteady Aerodynamic Computations and Computational Aeroelastic Simulation", Aalborg, Denmark, 14–15 October 1997

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

TP 97669 U

Safety and commercial realities in an avionics application

Presented at the Second World Congress on Safety of Transportation, Delft, The Netherlands, 18–20 February 1998

Kesseler, E.; Sluis, E. van de

TP 97670 U

Boundary integral equation methods for screen problems in acoustic and electromagnetic aerospace research

Journal of Engineering Mathematics, Vol. 34, pp. 143–162, 1998

Schippers, H.

TP 98002

Impact energy absorbing surface layers for protection of composite aircraft structures

Presented at the European Conference on Composite Materials, ECCM-8, Naples, Italy, 3–6 June 1998

Hart, W.G.J. 't

TP 98005

Design, fabrication and testing of a dyneema/polyethylene radome for airborne remote sensing

Presented at the SAMPE/JEC Conference, Paris, April 1998

Vries, H.P.J. de

TP 98007

Development of a metal test box configuration to test a range of skin panels of a composite horizontal stabilizer

To be published in 'Composite Structures' by Elsevier Applied Science

Rijn, J.C.F.N. van; Thuis, H.G.S.J.

TP 98013

Non destructive investigation of the condition of gas turbine blades

To be published in "Materialwissenschaft und Werkstoffetechnik", by VCH Verlagsgesellschaft GmbH

Kolkman, H.J.; Kool, G.A.

TP 98022

The influence of stitching fibre and stitching density on the mechanical performance of CFRP fabrics

Presented at the European Conference on Composite Materials ECCM-8, Naples, 3–6 June 1998

Thuis, H.G.S.J.; Herzberg, I.; Loh, A.; Bannister, M.K.

TP 98024

Design optimization of stiffened composite panels with buckling and damage tolerance constraints

Presented at the 39th AIAA-SDM Conference, Long Beach, California, USA, 20–23 April 1998

Wiggenraad, J.F.M.; Arendsen, P.; Silva Pereira, J.M. de

TP 98037

Reliability, maintainability and safety applied to a real world avionics application

Presented at the European Safety and Reliability Conference 1998, Trondheim, Norway, 17–19 June 1998

Kesseler, E.; Sluis, E. van de

TP 98040

Significance of dwell cracking for IN718 turbine discs

To be published in the Proceedings of the Fourth International Conference on Low Cycle Fatigue and Elasto-Plastic Behaviour of Materials, Garmisch-Partenkirchen, Germany, 7–11 September 1998

Wanhill, R.J.H.

TP 98066

Research on noise abatement procedures

Presented at Aviation-2000 Prospects, Zhukovsky, Russia, 19–24 August 1997 and at the 10th CEAS Conference on Free Flight, Amsterdam, the Netherlands, 20–21 October 1997

Erkelens, L.J.J.

TP 98079

An automatic in-flight data acquisition system for the RNLN Lynx helicopter

Presented at the 9th International Symposium on Aircraft Integrated Monitoring Systems (AIMS98), Garmisch-Partenkirchen, Germany, 4–7 May 1998

Vergroesen, A.L. (RNLN); Have, A.A. ten; P.R. Hoek, P.R. (RNLN); Carati, F.J. (RNLN); Dominicus, J.A.J.A.; Have, A.A. ten; D. Schütz, D. (Swift GmbH)

TP 98085

Competence management in engineering environments with HPCN

Presented at the HPCN '98 Europe Conference, Amsterdam, 21–25 April 1998

Loeve, W.; Vogels, M.E.S.

TR 98098

Safety evaluation of an initial free flight scenario with TOPAZ (Traffic Organization and Perturbation AnalyZer)

Daams, J.; Bakker, G.J.; Blom, H.A.P.

TP 98099

Overview of in-flight laser anemometer applications

Presented at the First Braunschweiger Symposium für Flugmesstechnik", Braunschweig, Germany, 31 March – 1 April 1998

Jentink, H.W.

TP 98135

Avionics development in a concurrent engineering environment from virtual prototyping to testing

Presented at the 5th European Concurrent Engineering Conference, organized by the Society for computer Simulation, Friedrich Alexander University, Erlangen

Aartman, J.L.; Eveleens, L.C.; Wellink, S.

TP 98144

Airframe inspection reliability using field inspection data

Presented at the 88th Meeting of the RTO Structures and Materials Panel, Brussels, Belgium, 11–15 May 1998

Heida J.H.; Grooteman F.P.

TP 98148

Full-scale fuselage panel tests

Presented at the 21th ICAS Congress, Melbourne, 13–18 September 1998

Vercammen, R.W.A.; Ottens, H.H.

TP 98163

Embedding safety critical software in an airframe

Presented at the Embedded Systems Symposium, Eindhoven University of Technology, 19 May 1998

Kesseler, E.; Sluis, E. van de

TP 98168

Control of the joint runaway hazard for the European Robotic Arm

Presented at the International Conference on Safety and Reliability ESREL '98, Trondheim, Norway, 16–19 June 1998

Bos, J.F.T.; Bosman, R.A.

TP 98170

Aerospace heat and mass transfer research for spacecraft thermal control systems development

Invited Keynote Lecture, 11th International Heat Transfer Conference, Kyongju, Korea, 22–28 August 1998

Delil, A.A.M

TP 98172

F-16 loads / usage monitoring

Presented at the NATO RTO Specialist's meeting on Structures and Materials, Brussels, Belgium, 11–12 May 1998

Spiekhout, D.J.

TP 98198

An algorithm to check the Topological Validity of Multi-block Domain Decompositions

Presented at the 6th International Conference on Numerical Grid Generation in Computational Field Simulations, University of Greenwich, London, England, 6–9 July 1998

Spekreijse, S.P.; Boerstoel, J.W.

TP 98212

An accurate and robust algorithm for the in-sphere criterion for automated Delaunay-based tetrahedral grid generation

Presented at the 6th International Conference on Numerical Grid Generation for Computational Field Simulation, University of Greenwich, London

Burg, J.W. van der

TP 98216

Supercooled large droplets in icing conditions

Presented at the European Geophysical Society (EGS) General Assembly Meeting, Nice, France, 20 – 25 April 1998

Jentink, H.W.

TP 98220

Know-how management in distributed engineering environments

Presented in The Globalization of Manufacturing in the Digital Communications Era of the 21st Century: Innovation, Agility, and the Virtual Enterprise, by Chapman & Hall, 1998

Vogels, M.E.S.; Loeve, W.

TP 98225

A novel approach for all-optical packet-switching in wide-area networks

Presented at the SYBEN '98 International Symposium on Broadband European networks, Zürich, Switzerland, 18–20 May 1998

Wedzinga, G.; Chlamtac, I,; Fumagalli, A.

TP 98227

A preliminary model to simulate the impact of a frangible approach light structure by an aircraft wing section

Presented at the International Crashworthiness Conference IJCRASH'98, Dearborn, Michigan, USA, 9–11 September 1998

Frijns, R.H.W.M.

TP 98230

A NICE HPCN centre for flow simulation

Presented at the HPCN Europe '98 Conference, Amsterdam, 21–23 April 1988

Groothuizen, R.J.P.; Ven, H. van der

TP 98234

Generic design optimization involving parallel CFD analysis

Presented at the ECCOMAS '98 Conference, Athens, Greece, 7–11 September 1998

Vankan, W.J.; Ven, H. van der

TP 98235

2D maximum lift prediction of a three element airfoil

Presented at the Symposium on Computational and Experimental Methods in Mechanical and Thermal Engineering, University of Gent, Belgium, 7–8 May 1998

Cock, K.M.J. de

TP 98236

Test and verification equipment for the attitude & orbit control system of the XMM satellite

Presented at DASIA 98 Conference, DAta Systems In Aerospace, organized by EUROSPACE, Athens, Greece, 25–28 May 1998

Ingen Schenau H.A. van; Rijn, L.C.J. van; Spaa, J.

TP 98240

A stochastic simulation procedure compared to deterministic methods for PSD gust design loads

Vink, W.J.

TP 98241

Instrumentation for the ESA parafoil technology demonstrator test vehicle

Presented at the 10th SFTE European Chapter Symposium, Linkoping, Sweden, 15–17 June 1998

Klijn, J.M.

TP 98249

Competence management with EuroSim centred CACE working environments

Presented at the DASIA '98 – DAta Systems In Aerospace Conference, Athens, Greece, 25–28 May 1998

Dam, A.A. ten; Groothuizen, R.J.P.

TP 98260

On vehicle allocation to targets in mission planning

To be published in the Proceedings of the RTA SCI 9th Symposium on the Application of Information Technologies to Misssion Systems, by NATO RTA, 1998

Choenni, R.

TP 98264

Failure criterion for the skin-stiffener interface in composite aircraft panels

Published in the Proceedings of the Thirteenth Technical Conference of the American Society for Composites, Baltimore, Maryland, 21-23 September 1998

Rijn, J.C.F.N. van

TP 98265

Outline and application of GEROS: A European grid generator for rotorcraft simulation methods

Presented at the ECCOMAS '98 Conference, Athens, Greece, 7–11 September 1998

Hounjet, M.H.L.; Allen, C.B.; Vigevano, L (Politecnico di Milano); Trivellato, N (Politecnico di Milano); Pagano, A (CIRA); D'Alascio, A. (CIRA); Jobard, N. (CIRA)

TP 98268

On thermal-gravitational modelling, scaling and flow pattern mapping issues of two-phase heat transport systems

Presented at the 28th International Conference of Environmental Systems, Danvers, MA, USA, 13–16 July 1998

Delil, A.A.M.

TP 98279

Evolutionary 3D-air traffic flow management

Proceedings of Parallel Problem Solving from Nature IV, Berlin, 22–26 September 1996

Akker, J.M. van den; Kemenade, C.H.M.; Kok, J.N.

TP 98282

Avionics application development, coalesce certifiability with business opportunity

Presented at DASIA '98, DAta System In Aerospace Conference, Athens, Greece, 25–28 May 1998

Kesseler, E.; Sluis, E. van de

TP 98326

Low cost local ground stations: the way to go?

Presented at the European Microwave week, 5–9 October 1998

Looyen, W.J.; Oostdijk, A.; Kamp, A. van der; Downey, I.D. (NRI); Williams, J.B. (NRI); Stephenson, J. (Bradford University); Stephenson, R. (Bradford University)

TP 98356

Design, test and analysis of tensor skin panels for improved crashworthiness in case of water impact

Presented at the AHS Crashworthiness Specialists' Meeting "Crash Safety Challenges and Innovative Solutions", Phoenix, Arizona, 14–16 September 1998

Michielsen, A.L.P.J.; Wiggenraad, J.F.M.; Ubels, L.C.; Frijns, R.H.W.M.

TP 98358

Aircraft noise exposure: the cycle of modelling, monitoring and validation

Presented at the seventh International Conference on the Development and Application of Computer Techniques to Environmental Studies, ENVIROSOFT 98, Las Vegas, USA, 10–12 November 1998

Veerbeek, H.W.; Have, H.B.G. ten

TP 98375

Experimental pressure wave research at NLR for high-speed rail tunnels

Demmenie, E.A.; Bruin, A.C. de; Klaver, E.

TP 98380

Coarse-grain parallelization of a multi-block Navier-Stokes solver on a shared memory parallel vector computer

Presented at the Vector and Parallel Processing '98 Conference, Porto, Portugal, 21–23 June 1998

Wijnandts, P.; Vogels, M.E.S.

TP 98397

Planning aircraft movements on airports with constraint satisfaction

Presented at the IMA Third International Conference on Mathematics in Transport Planning and Control, Cardiff, UK, 1–3 April 1998

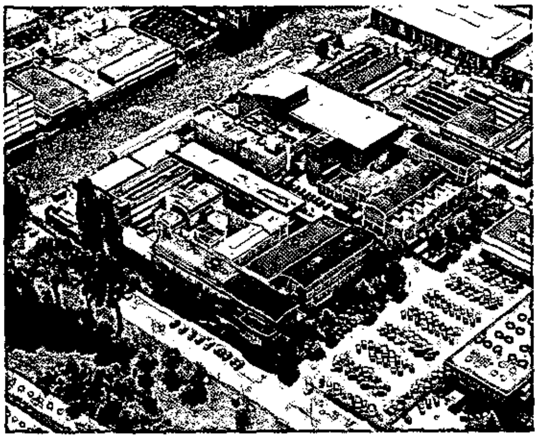
Hesselink, H.H.; Paul, S.

2 Abbreviations

AECMA	Association Européenne des Constructeurs de Matériel Aérospatial (The European Association of Aerospace Industries)
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
ATC	Air Traffic Control
BCRS	Beleidscommissie Remote Sensing (Netherlands Remote Sensing Board)
BMBF	Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (Federal Ministry for Education, Science, Research and Technology)
BMVg	Bundesministerium für Verteidigung (Federal Ministry for Defence)
BRITE	Basic Research in Industrial Technologies for Europe
CAE	Computer-Aided Engineering
CARTE	Collaboration on Aeronautical Research and Technology in Europe
CIRA	Centro Italiano Ricerche Aerospaziali
DERA	Defence Evaluation and Research Agency
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DNW	Duits-Nederlandse Windtunnel (German-Dutch Wind Tunnel)
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
EU	European Union
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)
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 Aeroespacial (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)
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control the Netherlands)
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
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programmes)
NKO	*Nederlandse Kalibratie Organisatie (Netherlands Calibration Organization)*
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory NLR)
NPOC	National Point of Contact
NSF	Nationale Simulatie Faciliteit (National Simulation Facility)
ONERA	Office National d'Etudes et de Recherches Aérospatiales (Aerospace Research Institute of France)
PHARUS	Phased Array Universal Synthetic Aperture Radar
RLD	Rijksluchtvaartdienst (Netherlands Department of Civil Aviation)
RNLAF	Royal Netherlands Air Force
RTCA	Requirements and Technical Concepts for Aeronautics (formerly: Radio Technical Commission for Aeronautics)
RTO	Research and Technology Organization (NATO)

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
WEAO	Western European Armament Organization
WL	Waterloopkundig Laboratorium (Delft Hydraulics)



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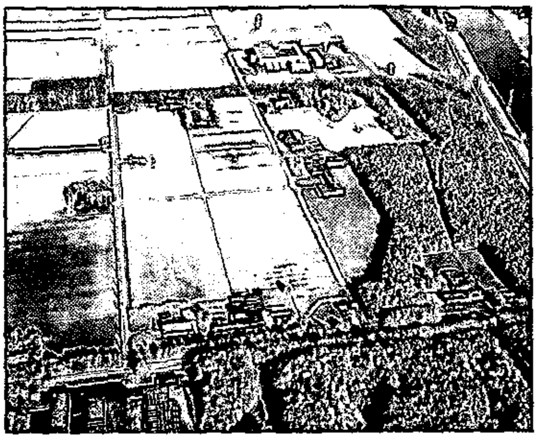

NLR Noordoostpolder

photography: KLM Aerocarto

NLR Amsterdam

Anthony Fokkerweg 2
1059 CM Amsterdam
P.O. Box 90502
1006 BM Amsterdam
The Netherlands
Telephone: +31 20 5113113
Fax: +31 20 5113210

NLR Noordoostpolder

Voorsterweg 31
8316 PR Marknesse
P.O. Box 153
8300 AD Emmeloord
The Netherlands
Telephone: +31 527 248444
Fax: +31 527 248210