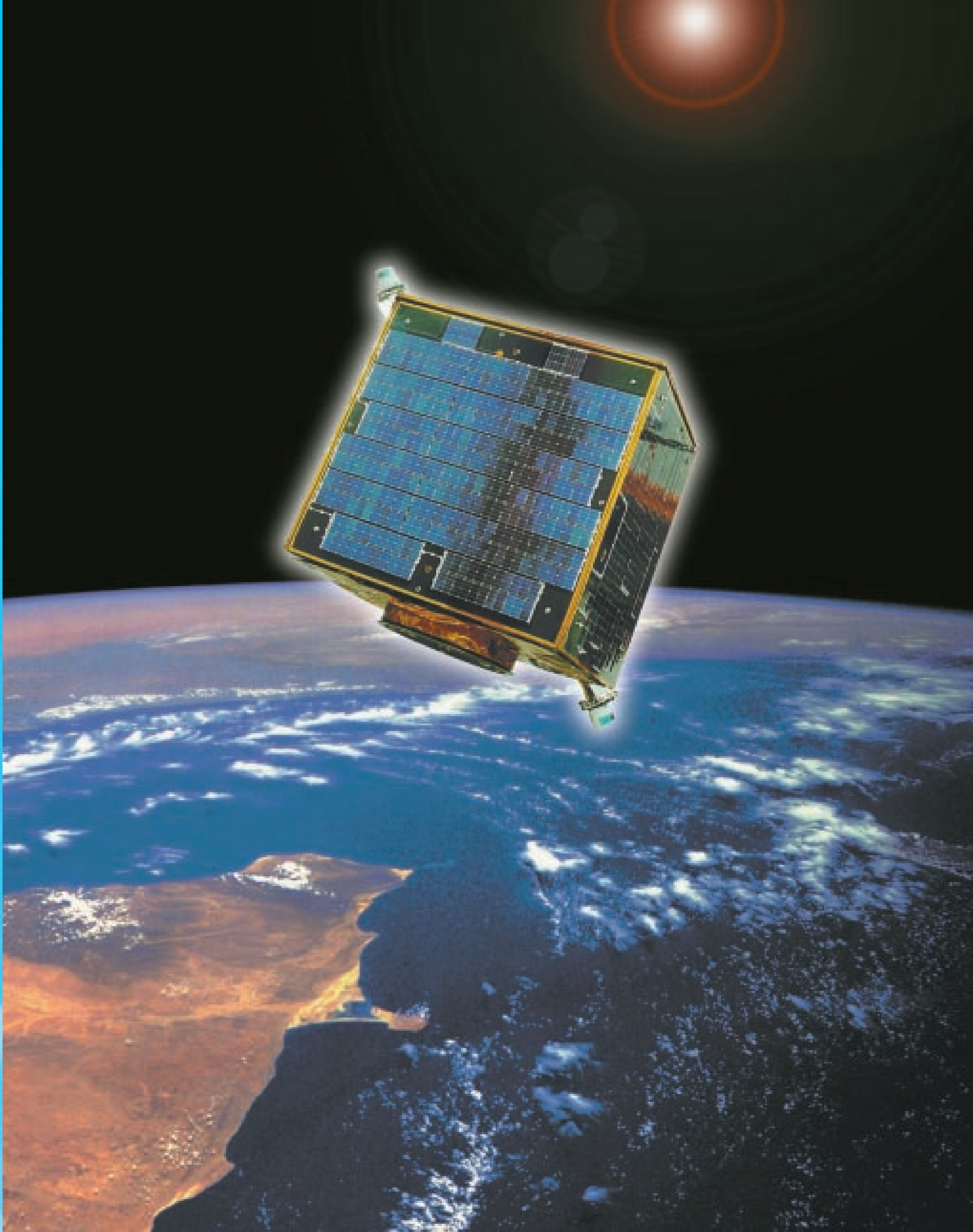
Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 1999



Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 1999

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)
Cdr.ir. D. van Dord	Minister of Defence
Gen.maj. D. Starink	Minister of Defence, for the Royal Netherlands Air Force (RNLAF)
Mr.drs. A.A.H. Teunissen	Minister of Economic Affairs
Drs. J.W.A. van Enst	Minister of Education, Culture and Science
Mr.drs. A.A.H. Teunissen *(acting)*	Netherlands Agency for Aerospace Programmes (NIVR)
G.H. Kroese	Air Traffic Control the Netherlands (LVNL)
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

General Secretary*

E. Folkers

* On 31 December 1999

Table of Contents

1 Introduction

At the threshold of the new millennium, the National Aerospace Laboratory NLR can look back on 80 years of successful operation in aerospace research and development. Started in 1919 as a government office, the *Rijksstudiedienst voor de Luchtvaart*, and transformed into an independent legal entity in 1937, NLR has grown from just three divisions, originally dedicated to aircraft design and use only, to seven divisions in 1999, providing technological support in all aspects of aircraft and spacecraft design and operations. NLR's growth is reflected not only in the number of divisions and the size of the staff but also in the revenues from contracts, which in 1999 showed the highest figure ever – with good prospects for the year 2000.

One major development in 1999 was the decision about the future of the national airport infrastructure. The government decided to allow the air traffic on Amsterdam Airport Schiphol to grow under strict conditions of safety, noise and emissions, with the airport at the present location in preference to constructing a totally new airport. At the request of the government and various other parties such as the Netherlands Department of Civil Aviation (RLD), Air Traffic Control the Netherlands (LVNL), Amsterdam Airport Schiphol and KLM Royal Dutch Airlines, NLR has supported the decision process with studies on airport and airspace capacity, air traffic management, safety, noise and the environment. The growth of the traffic at Schiphol is expected to continue requiring a great deal of support by NLR in the next several years.

In the international operation Allied Force over Yugoslavia, the Royal Netherlands Air Force (RNLAF) has successfully participated in air-to-air operations and air-to-ground missions. The campaign has demonstrated that advanced technologies – such as incorporated in the updated F-16 fighters – ensure highly effective missions with very limited collateral damage. Peacekeeping operations require the most advanced operational weapon and reconnaissance systems, experienced and well-trained crews, sophisticated command and control, and effective logistics. NLR has supported the RNLAF in various areas, such as the evaluation and certification of aircraft systems and weaponry, operations analysis, command and control, training and logistics.

NLR was actively engaged in studies in support of the RNLAF for a future successor of the F-16. Together with the Dutch industry, NLR has participated in several technology demonstration programmes sponsored by the Ministry of Economic Affairs. In addition, NLR has participated in other military research and development programmes for the Ministry of Defence, the Royal Netherlands Navy and the Royal Netherlands Army. In the coming years NLR will continue to participate in studies and technology development related to the future replacement of the F-16.

Industrial support was further given to the various divisions of the Stork Aerospace Group for possible participation in the future Airbus A3XX programme. These studies, partly funded by the Netherlands Agency for Aerospace Programmes (NIVR), concerned issues such as the application of new materials including metal fibre laminates, highly sophisticated avionics, ribbon-organized wiring and power distribution networks. Advanced bonding techniques and high-lift system aerodynamics were subjects of study. Support was also given to the space industry, in particular Fokker Space and Stork Product Engineering, and in the framework of the NIVR Space Technology Programme.

International technology programmes are considered crucial for the development of future European technology. NLR has participated in a substantial number of projects of the Fourth Framework Programme of the European Union. The prospect for international co-operation is further stimulated by Italy's entry to GARTEUR, the Group for Aeronautical Research and Technology in Europe. In addition, the co-operation between the seven national aerospace research institutes in Europe has been strengthened by the registration of the association of European Research Establishments in Aerospace (EREA) as a legal Association under Dutch law. This enables EREA to enter into co-operation with the European Union and NASA.
An important milestone was reached in the co-operation with the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) by the completion of the transfer of the operation of all wind tunnel facilities owned by NLR and DLR to the

foundation DNW (German-Dutch Windtunnels), as from 1 January 2000. This is expected to form the onset of further co-operation with DLR and other organizations in aeronautical research and testing areas in the coming years. The *Office National d' Etudes et de Recherches Aérospatiales* (ONERA) expressed interest in joining NLR and DLR in the DNW. As before, NLR will continue to support the operation of the four-nation (France, Germany, the Netherlands, the United Kingdom) European Transonic Windtunnel (ETW) in Cologne.

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, technical assistance and consultancy to aerospace industries, civil and military aircraft operators, government agencies and international organizations. A non-profit organization, NLR conducts a basic research and facilities development programme funded by the government to main-tain its capabilities of providing technological support.

With sites in Amsterdam and in the Noordoostpolder, NLR owns wind tunnels, research aircraft, research flight simulators, an Air Traffic Control research simulator and a tower research simulator under development. NLR has available an extensive set of equipment for gathering, recording and processing flight test data. NLR also has facilities for research and testing in the areas of structures and materials, space technology, remote sensing and avionics. NLR's extensive computer network includes a 64-GFlops NEC SX-5/8 supercomputer, tools for software development and advanced software for computational fluid dynamics and for calculations of aircraft and spacecraft structures.

NLR co-operates on an equal base with the DLR (*Deutsches Zentrum für Luft- und Raumfahrt*) in the foundation German-Dutch Wind Tunnels (DNW), which operates the Large Low-speed Facility in the Noordoostpolder. In addition to this LLF, the Foundation DNW operates the aeronautical wind tunnels owned by 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 1999

In 1999 NLR's turnover amounted to 169 million guilders compared to 153 million in 1998. The revenues from contracts totalled 127 million guilders, 13 million higher than in 1998. About 50% of NLR's activities were related to the development and 50% to the operation of aircraft and spacecraft; 85% of the activities were related to aeronautics and 15% to space. Civil and military research amounted to 60% and 40%, respectively. About 40% of the work under contract was carried out for international customers.

Services Provided under National Contracts

Activities under contract to customers from the Netherlands amounted to 77 million guilders. These contracts included work on aeronautics and space research and technology for the Netherlands Agency for Aerospace Programmes (NIVR). A number of research programmes were executed under contract to the Royal Netherlands Air Force (RNLAF), the Royal Netherlands Navy (RNLN), the Netherlands Department of Civil Aviation (RLD), Air Traffic Control the Netherlands (LVNL), Stork Aerospace and Fokker Space. NLR also carried out work to support the Ministry of Defence, the German-Dutch Wind Tunnels (DNW), the European Transonic Windtunnel (ETW) and several other government services and private companies.

Contracts from NIVR concerned basic research and technology development work in various areas at the request of the industry. Major parts of the work for the RLD were related to present and future ATC (Air Traffic Control) systems, to safety and environmental aspects of aeronautics, and to airworthiness and regulations. 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

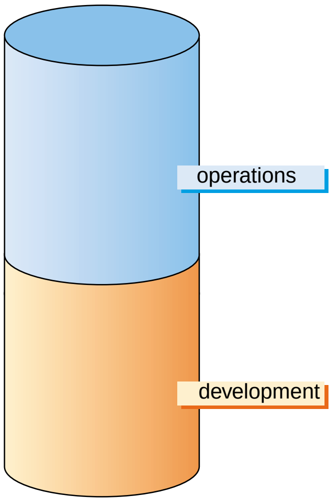
Research carried out under contract to international customers amounted to 50 million guilders. Major customers were the European Space Agency, the European Union and Eurocontrol. Work was also done for industries in Europe, North America and the far East.

Research and Equipment

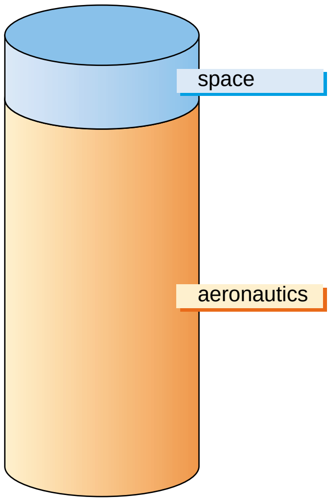
NLR spent 35 million guilders on its basic aerospace research programme supported by the government, aimed at preserving NLR's capability to support its customers in the future. Research aimed at the development and modernization of NLR's research facilities amounted to 12 million guilders. A total of 19 million guilders was used for capital investments, of which the procurement of a Scanning Electron Microscope, and investments in flight simulation facilities and environmental test facilities were the most important ones.

National and International Co-operation

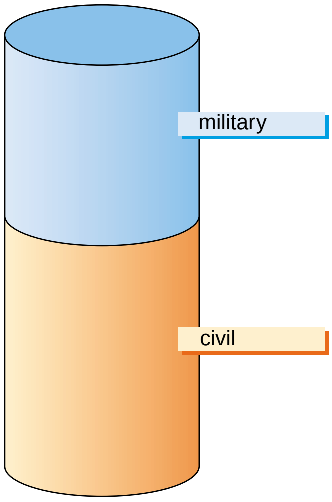
A large part of NLR's basic research is carried out as NLR's own contributions to European research projects both on the civil (European



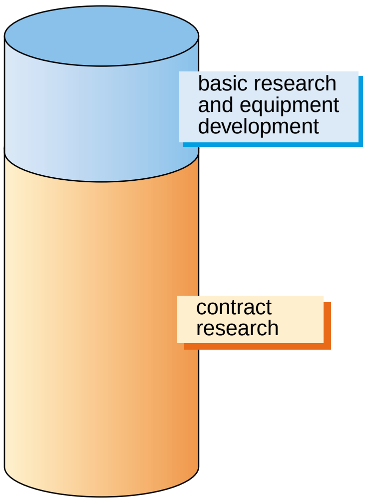
Division of the work into development and operations support



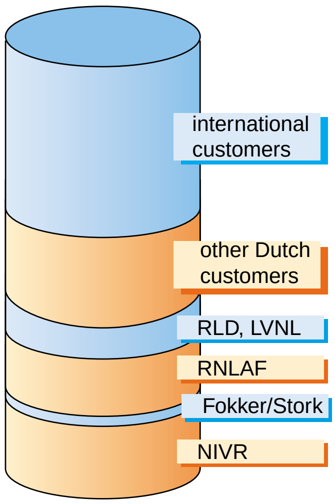
Division of the work into aeronautics and spaceflight support



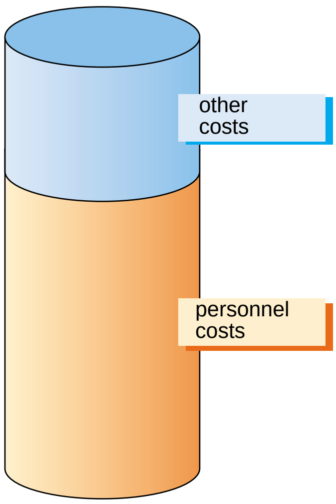
Division of the work into civil and military support



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

Union, Eurocontrol) and military (West European Armament Organization, under the European Co-operation for the Long Term in Defence) 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. At the end of the year Italy decided it would join GARTEUR.

NLR and DLR *(Deutsches Zentrum für Luft- und Raumfahrt)* jointly govern the foundation German-Dutch Wind Tunnels *(Stichting Duits-Nederlandse Windtunnels – Stiftung Deutsch-Niederländische Windkanäle)*, which has been operating the Large Low-speed Facility in the Noordoostpolder and low-speed wind tunnels owned by DLR and NLR. It was agreed that all aeronautical wind tunnels owned by DLR and NLR would be also operated by the foundation DNW as of 1 January 2000.

The European Transonic Windtunnel (ETW) located near Cologne, Germany, was extended with an external balance enabling semi-span models to be tested.

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 (EREA). A legal entity was created for the association.

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 employed as 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 DUT and *Institut Teknologi Bandung* were continued under the aegis of the Dutch-Indonesian Aerospace Programme for Education, Research and Technology (APERT 95). The co-operation is co-ordinated by NLR and IPTN.

Like in 1998, 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, Free Flight and external safety studies.

Quality Assurance

New ISO 9001/AQAP-110 quality assurance certificates were obtained for the Flight Division, the Air Transport Division and the Technical and Engineering Services, completing the quality certification of NLR's divisions. In addition, NLR holds several accreditations, for example for EMC (Electromagnetic Compatibility) testing and for the calibration of forces, pressures and electronic quantities. NLR began preparations for obtaining a quality assurance certificate for its entire organization, including the services and support staff.

Two images of a region west of Utrecht made by PHARUS, a Synthetic Aperture Radar on the Citation II research aircraft, with differences between the left (older) and right image revealing building activities

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 the Chairman of the Scientific Committee NLR/NIVR, Prof.dr.ir. P.J. Zandbergen, 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.

The Minister of Defence appointed Gen. Maj. D. Starink as a member of the Board of the Foundation NLR, for the Royal Netherlands Air Force. Gen. Maj. Starink succeeded Gen.maj.ir. M.R.H. Wagevoort. The Minister of Education, Culture and Science appointed Drs. J.W.A. van Enst as a member of the Board of the Foundation NLR. Drs. Van Enst succeeded Dr. P.A.J. Tindemans.

The laboratory was headed by the directors mentioned on page 3.
Drs. A. de Graaff was Associate Director.
As mentioned in the Annual Report 1998, Mr. E. Folkers was appointed as General Secretary as of 1 January 1999.

The Board of Directors was further assisted by Ir. J.C.A. van Ditshuizen, Head Marketing and Communication.

The Flight Division was split into the Air Transport Division and a new Flight Division, as of 1 January 1999.

On 31 December 1999 the Heads of Divisions and Services were:

Prof.ir. J.W. Slooff
Fluid Dynamics Division
Prof.drs. P.G.A.M. Jorna
Flight Division
Ir. J. Brüggen
Air Transport Division
Ir. F. Holwerda
Structures and Materials Division
Ir. B.J.P. van der Peet
Space Division
Ir. W. Loeve
Information and Communication Technology Division
Ir. H.A.T. Timmers
Avionics Division
Ir. J. van Twisk
Engineering and Technical Services
Ir. W.F. Wessels
General Services
Drs. L.W. Esselman R.A.
Administrative Services

As of 1 July 1999 the work areas of the Aerodynamic Engineering and Elasticity Department and the Theoretical Aerodynamics Department were redistributed over the new Aerodynamic Engineering and Vibration Research Department and Computational Fluid Dynamics and Aeroelastics Department.

The organization of the laboratory on 31 December 1999 is shown on page 14.

At the end of 1999 NLR employed a staff of 938 (compared with 903 at the end of 1998), of whom 427 (409) were university graduates. Of the total, 819 (777) were employed on a permanent basis, and 119 (126) had temporary appointments. About 60 per cent of the staff were posted in Amsterdam, and nearly 40 per cent in the Noordoostpolder. A breakdown of the staff is given on page 15.

Organization Diagram

31 December 1999

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

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

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

General Secretary
E. Folkers **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 MBA	CPD
- *Aircraft Development Projects*	Ing. P. Kluit	CPO
- *Spaceflight Projects*	Drs. J.C. Venema	CPR
- *Air Transport and Aircraft Operations Projects*	Ir. B.W.G. Schute	CLV
- *Basic Research and Facility Development*	Ir. F.J. Sonnenschein	CEW
- *Quality Assurance NLR*	H. Blokker	CKZ

Legal	Ms. I.P.G. Ahlers	**DJ**
Filing and Security	E. Folkers	**DB**
Personnel	Ms. W.J. van Druten	**DP**
Company Welfare Work	Ms. J.H. van Dijk-Bol	DW
	Ms. C. Diekema-Schipaanboord	DW

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

- **Transonic and Supersonic Wind Tunnels** — Ir. W.M. van der Poel **AF**
- **Aerodynamic Engineering and Vibration Research** — Ing. J.A. van Egmond **AE**
- **Computational Fluid Dynamics and Aeroelastics** — Dr. B. Oskam **AT**
- **Aeroacoustics** — Dr. H.H. Brouwer **AK**

Flight
Prof.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** — Ir. R.N.H.W. van Gent **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** — Ms. Dr.ir. M.E.S. Vogels **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 **E**

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

Engineering and Technical Services
Ir. J. van Twisk **T**

- **Technical Design** — A. van den Berg **TO**
- **Technical Projects** — Ir. H.B. Vos **TP**
- **Production Workshop** — Ing. W.A.M. Schrijver **TW**
- **Production Control** — Ir. J. van Twisk **TV**
- **Service Workshop** — F. Hofman **TS**

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

- **Electrical Engineering** — A.M.G. Reijntjens **GE**
- **General Facilities** — R. Raterink **GF**
- **Library and Information Services** — R. Lammers **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**

Breakdown of the staff at the end of 1999

(Cat. I: university graduates, Cat. II: advanced technical college graduates, Cat. III: others; between brackets the numbers at the end of 1998)

		Cat. I		Cat. II		Cat. III		Total	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
- Support Staff		18	(16)	9	(9)	12	(11)	39	(36)
		21	(19)	9	(9)	12	(11)	42	(39)
Fluid Dynamics Division	A	4	(4)	2	(2)	2	(2)	8	(8)
- Transonic and Supersonic Wind Tunnels	AF	9	(5)	23	(17)	4	(8)	36	(30)
- Aeroacoustics	AK	8	(8)	4	(4)	1	(1)	13	(13)
- Computational Fluid Dynamics and Aeroelastics	AT	18	(14)	–	(–)	–	(–)	18	(14)
- Aerodynamic Engineering and Vibration Research	AE	8	(11)	3	(3)	–	(–)	11	(14)
- German-Dutch Wind Tunnel	AD	4	(4)	20	(19)	19	(17)	43	(40)
		51	(46)	52	(45)	26	(28)	129	(119)
Flight Division	V	3	(2)	1	(1)	1	(1)	5	(4)
- Flight Simulation	VS	10	(10)	15	(14)	2	(2)	27	(26)
- Operations Research	VO	23	(23)	5	(5)	2	(2)	30	(30)
- Man Machine Integration	VE	20	(23)	1	(1)	1	(2)	22	(26)
- Helicopters	VH	15	(14)	1	(1)	–	(1)	16	(16)
- Flight Mechanics	VM	13	(12)	–	(–)	1	(1)	14	(13)
		84	(84)	23	(22)	7	(9)	114	(115)
Air Transport Division	L	2	(–)	–	(–)	1	(–)	3	(–)
- Flight Testing and Safety	LV	15	(16)	6	(6)	2	(2)	23	(24)
- Airports	LA	12	(11)	2	(1)	–	(–)	14	(12)
- Air Traffic Management	LL	25	(27)	5	(5)	1	(–)	31	(32)
- Transport and Environmental Studies	LT	10	(9)	7	(7)	1	(1)	18	(17)
		64	(63)	20	(19)	5	(3)	89	(85)
Structures and Materials Division	S	1	(1)	3	(1)	1	(–)	5	(2)
- Loads and Fatigue	SB	18	(15)	6	(8)	1	(1)	25	(24)
- Structures Technology	SC	13	(11)	5	(4)	1	(1)	19	(16)
- Laboratory Facilities	SL	1	(1)	24	(22)	17	(19)	42	(42)
		33	(28)	38	(35)	20	(21)	91	(84)
Space Division	R	1	(2)	–	(–)	2	(2)	3	(4)
- Remote Sensing	RR	8	(6)	4	(5)	–	(–)	12	(11)
- Systems	RS	17	(17)	–	(–)	–	(–)	17	(17)
- Labatories and Thermal Control	RL	10	(10)	5	(7)	–	(–)	15	(17)
		36	(35)	9	(12)	2	(2)	47	(49)
Information and Communication Technology Division	I	1	(1)	1	(1)	3	(4)	5	(6)
- Mathematical Models and Methods	IW	17	(17)	–	(–)	–	(–)	17	(17)
- Software Applications	IA	19	(19)	6	(6)	1	(1)	26	(26)
- Data and Knowledge Systems	ID	24	(21)	11	(9)	–	(–)	35	(30)
- Information and Communication Services	IC	15	(17)	14	(12)	9	(8)	38	(37)
- Embedded Systems	IS	12	(12)	7	(7)	–	(–)	19	(19)
		88	(87)	39	(35)	13	(13)	140	(135)
Avionics Division	E	2	(2)	–	(–)	2	(–)	4	(2)
- Avionics Systems	EA	21	(18)	7	(9)	–	(–)	28	(27)
- Electronics	EE	6	(6)	21	(19)	5	(4)	32	(29)
- Instrumentation	EI	8	(8)	19	(19)	5	(5)	32	(32)
		37	(34)	47	(47)	12	(9)	96	(90)
Engineering and Technical Services	T	4	(4)	–	(–)	1	(1)	5	(5)
- Technical Projects	TP	2	(2)	4	(3)	–	(1)	6	(6)
- Technical Design	TO	1	(1)	7	(6)	1	(1)	9	(8)
- Production Workshop	TW	–	(–)	7	(7)	11	(11)	18	(18)
- Production Control	TV	–	(–)	6	(5)	–	(1)	6	(6)
- Service Workshop	TS	–	(–)	3	(3)	5	(5)	8	(8)
		7	(7)	27	(24)	18	(20)	52	(51)
General Services	G	1	(1)	1	(1)	–	(–)	2	(2)
- Electrical Engineering	GE	–	(–)	5	(6)	6	(5)	11	(11)
- General Facilities	GF	–	(–)	4	(2)	41	(35)	45	(37)
- Library and Information Services	GB	1	(1)	3	(3)	5	(5)	9	(9)
- Document Processing	GT	–	(–)	5	(4)	27	(29)	32	(33)
		2	(2)	18	(16)	79	(74)	99	(92)
Administrative Services	O								
- Administration	OA	2	(2)	19	(20)	11	(10)	32	(32)
- Stores and Dispatch	OM	–	(–)	–	(1)	–	(4)	–	(5)
- Purchasing	OI	2	(2)	5	(5)	–	(–)	7	(7)
		4	(4)	24	(26)	11	(14)	39	(44)
Grand total		427	(409)	306	(290)	205	(204)	938	(903)

3 Research Activities

The research activities of NLR have been carried out by seven divisions (Fluid Dynamics, Flight, Air Transport, Structures and Materials, Space, Information and Communication Technology, Avionics) and the Engineering and Technical Services. Continuously growing demand, both national and international, for activities on the operational use and societal impact of civil and military aircraft, on air traffic management, and on environmental and safety considerations necessitated the splitting of the previous Flight Division into an airborne-related and a ground-related part. As of 1 January 1999, the activities related to airport design and operations, Air Traffic Management, third party safety and environmental impact have been clustered in a new Air Transport Division, whereas technical and scientific support for the design, procurement, simulation, operation, certification, maintenance and manning of aircraft is provided by a new Flight Division.

This Chapter, Research Activities, is subdivided along the areas of technology of the NLR 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. Aspects of related activities in different projects may be described in different sections of this Chapter.

3.1 Fluid Dynamics

Summary

With a total volume of contract research and development support activities exceeding the level of 1995, when the development of transport aircraft in the Netherlands was still in place, the year 1999 was surprisingly good for fluid dynamics at NLR. The occupation level of the transonic wind tunnel DNW-HST was at an all-time high. The DNW-HST has been operated by the foundation German-Dutch Wind Tunnels (DNW) since mid-1997, with full operational responsibility transferred to DNW per 1 January 2000. The demand from customers of the DNW-HST for Computational Fluid Dynamics (CFD) and Computational Aeroelastics (CAE) support increased.

Participation in a large number of projects of the Fourth Framework Programme of the European Union was continued, while partly established, good prospects for a high level of participation in projects of the Fifth Framework Programme were attained for 2000 and beyond.
A relatively large volume of defence-related research was carried out, with good prospects for the future.

Dornier 728 model in DNW-HST wind tunnel

Contributing to the all-time high occupation level of the DNW-HST were in particular configuration wind tunnel tests for the Boeing JSF, the Fairchild-Dornier 728, the Aermacchi/YAK-130, and Ariane 5 unsteady baseflow experiments.

NLR participated in as many as seventeen aerodynamics, aeroelastics and aeroacoustics projects of the Fourth Framework Programme of the European Union (EU). These projects concerned research in the areas of air vehicle configuration aerodynamics (including wing-in-ground-effect vehicles), propulsion system related aerodynamics, wake vortex aerodynamics, helicopter aerodynamics and aeroelastics, propulsion system aeroacoustics, airframe noise and wind turbine noise.

In the area of aerodynamics, NLR also contributed to eight Action Groups and five Exploratory Groups of the Group for Aeronautical Research and Technology in Europe (GARTEUR), in addition to two joint activities initiated by the association of European Research Establishments in Aeronautics (EREA), and a collaborative programme of the Western European Armament Organization (WEAO). Most of these activities concerned the application, comparison and validation of CFD codes, and wind tunnel testing and measurement techniques.

CFD development benefited from the introduction at NLR of a new supercomputer, an NEC SX-5 replacing the existing SX-4; the year saw the first CFD simulation of the flow about an aircraft configuration with a high-lift system fully deployed and with turbofan engines running.

The bilateral collaborations with DLR in the areas of propulsion/airframe integration aerodynamics at low speed and the development of CFD codes for complete aircraft were continued.

Support to the DNW organization for further development of measurement techniques in wind tunnel testing was continued. Subjects addressed included the application of Particle Image Velocimetry (PIV) in wind climate investigations, correction methods for wind tunnel wall interference, techniques for acoustic measurements in open and 'hard-walled' test sections, and the calibration of turbine powered simulators (model engines).

Research was continued in such areas as high-lift system configuration aerodynamics and aeroacoustics, computational aeroelastics, improvement and extension of CFD codes including time accuracy, weapon-bay acoustics, and the theoretical modelling of acoustic liners for engine intakes. This research was all partly funded by the NIVR.

Other research areas included road traffic tunnel ventilation aerodynamics, for the Ministry of Transport; investigations of the aerodynamic and acoustic characteristics of engine test-run facilities, for the Royal Netherlands Air Force (RNLAF); Radar Cross-Section prediction methods, for the Ministry of Defence; and CFD for helicopter rotors, for Boeing.

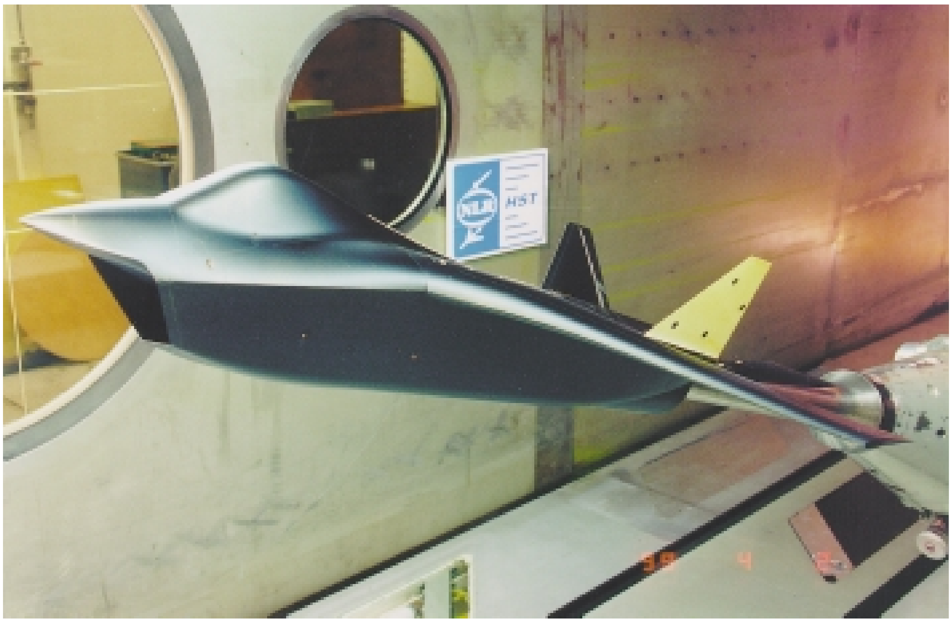
The stationing of a senior aerodynamicist with the Large Aircraft Division of Airbus in Toulouse, to support Fokker Aerostructures' envisaged participation in the A3XX aircraft project, was continued.

The supersonic wind tunnel DNW-SST was subjected to a major overhaul.

Applied Aerodynamics

Aerodynamics of Civil Transport Aircraft

In the framework of the NIVR Basic Research Programme, the effects of thickening the trailing edge of the flap of a wing are being studied. The objective of this investigation is to explore the magnitude of possible aerodynamic penalties as well as the possible savings in flap structural weight. For this purpose, CFD simulations using the NLR Fully Automatic Navier-Stokes (FANS) code as well as wind tunnel tests in the DNW-HST have been performed on a 2D model of a modern transport wing section with flap and slat. Effects on low-speed high-lift characteristics with different flap settings, including Reynolds number effects, have been investigated. In addition, aerodynamic and aeroacoustic measurements were performed in the DNW-LST on a 3D semi-span model.



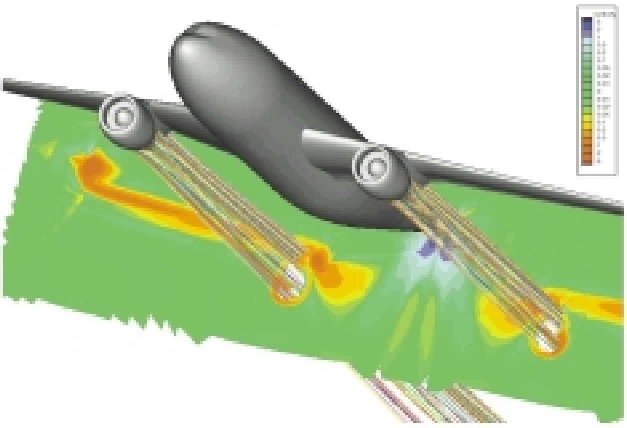
Model of the Boeing Joint Strike Fighter, possible successor of the F-16 of the RNLAF, in the DNW-HST wind tunnel at NLR Amsterdam

Following a computational study on the aerodynamics of flap tip devices performed earlier, an experimental exploration of the effects of flap tip devices on the low-speed wing aerodynamics and airframe noise characteristics of a low-speed transport aircraft wing-body configuration was started in the DNW-LST. The first results indicate a potential for a significant reduction of airframe noise with only a small penalty in aerodynamic low-speed performance as well as a change in the near-field trailing vortex signature. The consequences of the latter for the far-field trailing vortex signature are, as yet, unknown.

NLR contributed to the preparation, by the GARTEUR Exploratory Group (AD) EG-38, of a proposal for establishing an Action Group, (AD) AG-36, on '3D High Lift Computations'. In this context, RANS (Reynolds-Averaged Navier-Stokes) computations will be conducted for a swept wing configuration with slat and flap.

NLR continued the co-ordination of the project AIRDATA (Aircraft Drag And Thrust Analysis) of the EU. This project is targeted towards the analysis, employing CFD technology, of the aerodynamic performance of jet-powered transport aircraft. Using NLR's ENFLOW CFD system, the effects of a number of physical and modelling aspects (e.g. engine boundary conditions, turbulence models, computational grids, numerical schemes) on predicted drag values are evaluated. Furthermore, methodology is developed to decompose the drag in its physical components of vortex drag, associated with lift generation; wave drag, due to the formation of shock waves; and viscous drag, due to viscous flow effects such as boundary layers. Numerical results for a number of wing-body-pylon-nacelle configurations are compared with experimental results obtained in the EU project ENIFAIR (Engine Integration for Future Aircraft).

Participation in the GARTEUR Action Group (AD) AG-26 'Navier-Stokes Computations of Transonic Flows About Wing-Bodies with High Aspect Ratio Wings' was continued. Two flow conditions for the AS28G wing/body configuration have been computed using the ENFLOW CFD system. The results have been compared with those of the other participants and with experimental data obtained from the S1 wind tunnel of ONERA. The computational results all show similar deviations from the experimental data, probably as a result of uncertainties in wall interference corrections and/or model deformation. The difference between computational results of the various participants can, to a large extent, be contributed to differences in turbulence modelling. Nevertheless it can be concluded that the computational results are in close mutual agreement.



Vorticity derived from computation in the EU project Aircraft Drag and Thrust Analysis

Research on the high-lift aerodynamics of 2D multi-element airfoils and wing design for improved buffet onset of transport aircraft wings, in the framework of the collaborative Aerospace Programme for Education, Research and Technology (APERT) between Indonesia and the Netherlands, was completed.

Propulsion-Airframe Interaction

NLR continued participating in the EU project ENIFAIR (ENgine Integration for Future AIRcraft). The objective of this project is to improve the understanding of the effects of the application of Very-High and Ultra-High By-pass Ratio (VHBR/UHBR) turbofan engines on the aerodynamic performance of transport aircraft. For this purpose wind tunnel measurements and CFD analyses are performed for a generic configuration of a civil transport aircraft (the DLR ALVAST model). The model is equipped with three different engine simulators; including a conventional turbofan (by-pass ratio 5), a VHBR engine (by-pass ratio 10), and a UHBR engine (by-pass ratio 15). NLR has contributed by performing CFD simulations using the ENFLOW system and model engine calibrations in the DNW-ECF for the wind tunnel tests in the DNW-LLF wind tunnel.

In the framework of the DLR-NLR Programmatic collaboration, calibrations have been executed in the DNW-ECF for a CRUF (Counter Rotating Ultra-high by-pass Fan) type engine simulator. This activity included cubic nozzle, bellmouth and TPS (Turbine Powered Engine Simulator) calibration.
Within this framework NLR also performed CFD simulations, using the FASTFLO unstructured grid code (in 'Euler mode'), for a transport aircraft configuration powered by CRUF-type engines with slat and flaps deflected at take-off conditions. Adaptive grid refinement was applied to resolve the shear layers at the jet boundaries. This work confirmed the feasibility of short-turn-around CFD for complex configurations.

Aerodynamics of Air Combat Vehicles

The development of CFD technology for fighter aircraft applications was continued as part of the collaborative TA-15 programme 'Computational Methods in Aerodynamics' of the Western European Armament Organization (WEAO). This programme is partly financed by the Ministry of Defence. The main activities can be summarized as follows:

- Improvement of the two-equation (k-omega) turbulence model in the ENFLOW CFD system with respect to capturing the turbulence in leading edge vortices. These vortices play an important role in the aerodynamics of fighter aircraft. Modifications to the model have been validated for the transonic flow about a sharp-edged delta wing, and turned out to be rather successful.
- Time-accurate inviscid flow computations around a sharp-edged delta wing in roll motion using the HEXADAP flow solver. The computations have been carried out in the framework of a common exercise. Comparison with results of other participants show reasonable agreement in capturing the unsteady vortices emanating from the leading edge and the occurrence of 'vortex burst'. The latter is one of the presumed causes of 'roll-instabilities' occurring for fighter aircraft at high angles of attack.
- Extension of the ENFLOW CFD system to a time-accurate method, to enable unsteady viscous flow about 'rigid' manoeuvring aircraft to be computed. One validation test case is the sharp-edged delta wing in pitch motion that has been the subject of a previous common exercise for unsteady inviscid flow computations within the TA-15 programme. Comparison of the results

with experimental data obtained by DLR/TU-Braunschweig in the DNW-NWB low-speed wind tunnel shows the improvements in capturing the unsteady vortex dominated flow expected from the introduction of the modelling of viscous effects.

– Wind tunnel experiments for a sharp-edged delta wing at high angles of attack, including effects of side slip, carried out in the transonic wind tunnel DNW-HST during an earlier phase of the TA-15 programme have been analysed in detail. The measurements comprise surface pressure measurements, flow field measurements in several planes with a 5-hole probe as well as with ‘Particle Image Velocimetry’ (PIV), surface oil-flow pattern visualization, and Schlieren visualization. The analysis aims, on the one hand, at providing a comprehensive experimental database for the validation of CFD methods for high speed vortex dominated flow typical for fighter aircraft and, on the other hand, at obtaining better insight in the occurrence of physical phenomena such as vortex burst as a function of angle-of-attack and/or side slip angle.

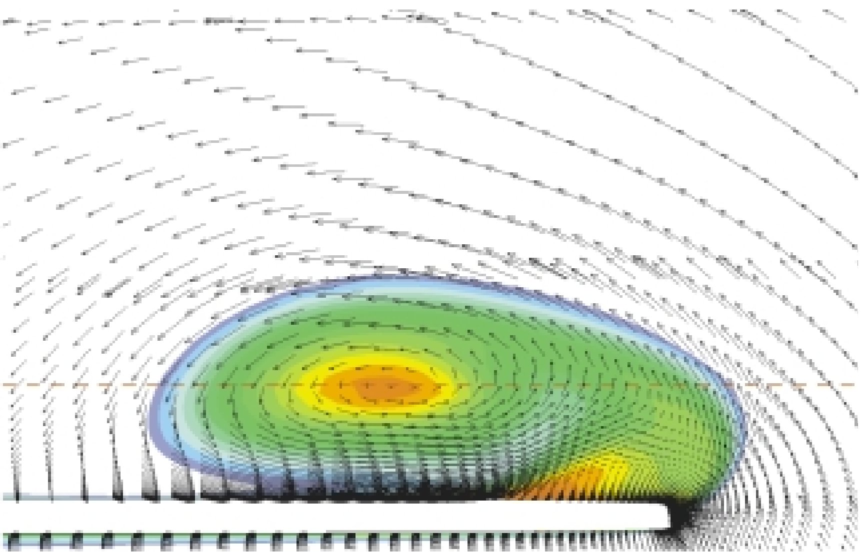
NLR participates in the GARTEUR Action Group (AD) AG-24 on Missile Aerodynamics. The objective of this research is to assess the performance of CFD codes for slender, missile-type configurations in supersonic flow. NLR has contributed by providing results obtained with the ENFLOW block-structured grid CFD system for all of three selected test cases.

The aerodynamic characteristics of a ‘bump diverter’ type of air intake as applied to combat aircraft with low radar signature are being studied in the framework of the GARTEUR Action Group (AD) AG-34 ‘Aerodynamics of Supersonic Air Intakes’. Flow computations based on the RANS equations, employing the ENFLOW CFD system, are performed in order to assess the range of flow conditions where a bump diverter can aerodynamically perform satisfactorily.

Helicopter Aerodynamics

NLR’s participation in the Design and Development Phase of the NH90 helicopter included support with the manufacturing of a wind tunnel model and testing in the DNW-LST.

NLR participates in the EU Fourth Framework projects EROS (Development of a Common European Euler Code for Helicopter Rotors) and ROSAA (Integration of Advanced Aerodynamics in Comprehensive Rotorcraft Analysis), the objective of which is to create a common platform for the prediction of the aerodynamic characteristics of helicopters by the development, verification and validation of common computer codes. In the EROS project NLR has completed the development of the rotor blade-tailored, ‘chimera’/’oversets’-based grid generator code GEROS, with the publication of its users guide.



Navier-Stokes computations for the vortical flow around a sharp-edged delta-wing configuration

In the ROSAA project NLR has co-ordinated the final development of the grid generator and the flow solver, which is based on full potential flow theory supplemented with a correction method for viscous effects.

The time-accurate Euler CFD solver HEXADAP, based on a discontinuous Galerkin finite element method, was applied to a helicopter rotor for the analysis of blade/vortex interactions in the hover condition. This work was partly funded by the Boeing (Mesa) Company. Using local grid refinement, the decay, due to numerical dissipation, of the blade tip vortex was reduced spectacularly as compared to other, more conventional CFD methods. The method also has prospects for the resolution of fixed-wing trailing vortices in studies of wake vortex encounter.

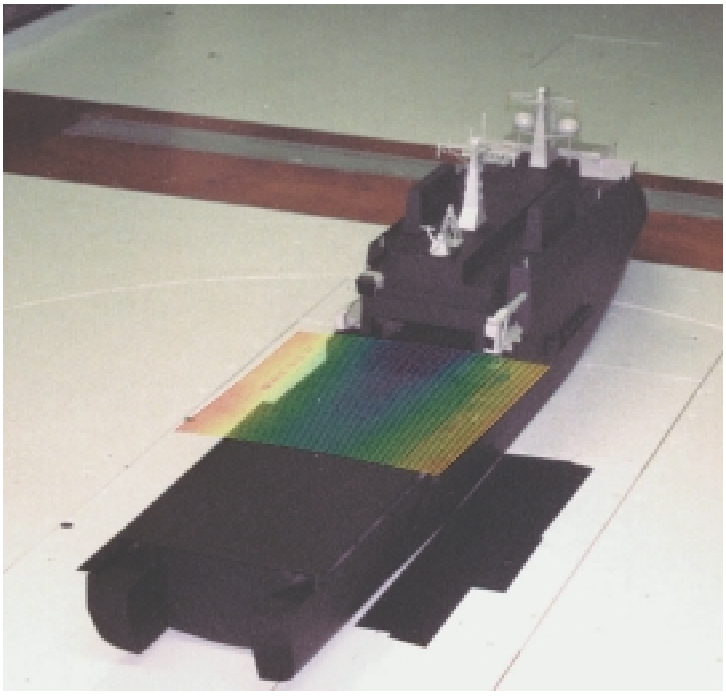
Operations- and Safety-related Aerodynamic Research

As co-ordinator of the EU project WAVENC (Wake Vortex Encounter), NLR has been editing the final report of this collaborative research on the potential hazards of aircraft wake vortex encounters.

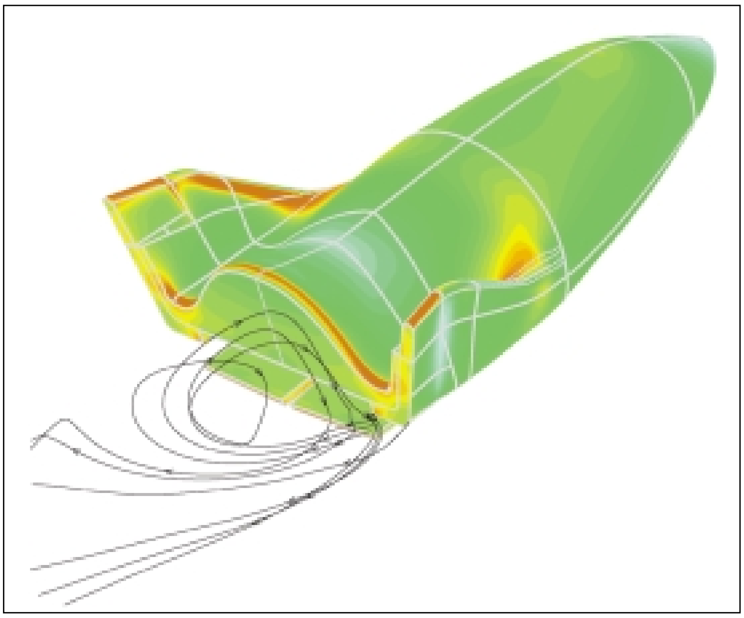
The GARTEUR Action Group (AD) AG-32 ‘Aircraft Icing Effects’ has the objective to update and validate prediction methods for the aerodynamic effects of ice accretion. NLR has contributed by selecting and documenting available experimental databases.

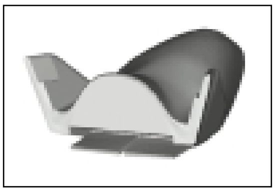
The possibilities of applying the Particle Image Velocimetry (PIV) measurement technique have been explored for the quantification of the wind climate around the helicopter flight deck of a model of a frigate class ship of the Royal Netherlands Navy (RNLN) in the DNW-LST wind tunnel. The results indicate that important information for both the steady and the instantaneous time-varying airflow characteristics can be obtained in this way.

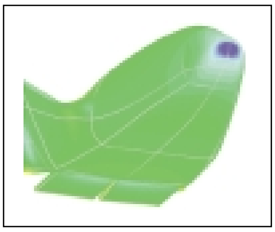
A test set-up for simulating the aerodynamic characteristics of propellers in a confined environment was being developed for the DNW-LST wind tunnel, in order to be able to support investigations into the aerodynamic and acoustic properties of engine test run facilities for the RNLAF.



The Particle Image Velocimetry measurement technique was applied in the DNW-LST using a model of a frigate class ship of the Royal Netherlands Navy (RNLN)







Calculation of the transonic flow about the X38 Crew Rescue Vehicle

Hypersonic and Space Vehicle Aerothermodynamics

NLR concluded its contribution to the 'Step 1 extension' phase of the X-38 Crew Rescue Vehicle demonstration programme of NASA (US National Aeronautics and Space Administration) and ESA (European Space Agency), and continued with the 'Step 2 lifting body' phase. A contribution has been made to the pre-flight aerodynamic data base for the X-38 with body flaps deflected under transonic and hypersonic flow conditions by the application of an in-house developed CFD code as well as by using CFD codes of Dassault Aviation. Both code-to-code and code-to-wind tunnel (DNW-HST and FFA T1500) comparisons have been made.

As part of the NIVR Space Technology (NRT) programme and in support of the industrial partners in the Netherlands AEOLUS consortium, engineering methods were developed for the prediction of the heat loads on control surfaces of re-entry vehicles. The methods are similar to those used in the design of the NASA Space Shuttle Orbiter and were tuned to flight results.

Under contract to CIRA (Centro Italiano Richerche Aerospaziali) a preliminary design study was performed for a wind tunnel model of the European Vega launch vehicle, to be tested in the DNW-HST and DNW-SST.

Aerothermodynamics of Turbofan Engines

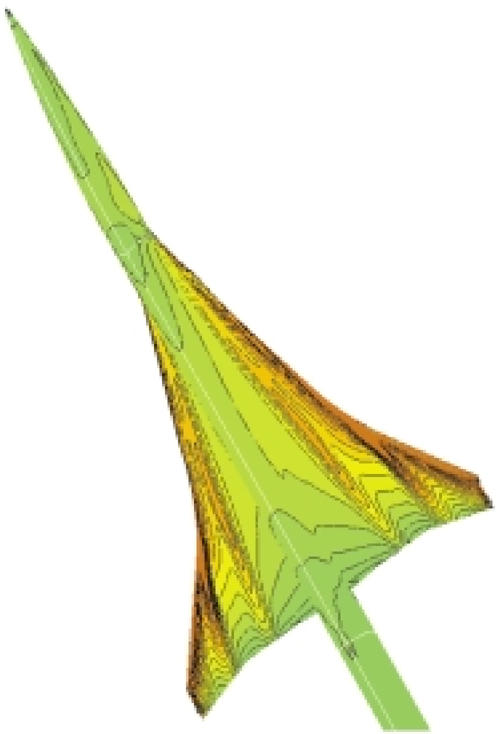
Under contract to the Ministry of Defence, an engineering method has been formulated and applied for the prediction of the aerodynamic heat load at the first stage turbine blades of a turbofan engine. This study was performed in support of thermal load studies also carried out by NLR.

In the framework of the NIVR Basic Research Programme, a study has been conducted with the objective to assess the capabilities of a commercial CFD code (FINE/Turbo), based on the Reynolds-averaged Navier-Stokes equations, for the prediction of surface heat transfer of aeroengine turbine components (stators and rotors). A heat transfer prediction capability is needed in order to support industry and aircraft operators in analysing the fatigue life of hot aeroengine components and their coatings.
The FINE/Turbo code has been applied to a two-stage part of the high pressure turbine of the Pratt & Whitney F-100 model 200 military turbofan engine, which powers the F-16 A/B among other aircraft. The assessment of the code was being continued.

Non-Aerospace Aerodynamics

NLR continued its contribution to the aerodynamic design of a Wing-In-Ground effect vehicle in the framework of the EU technology development project SEABUS-HYDAER. The concept of the vehicle features a large aerodynamic wing in proximity of the water surface, in combination with small hydrodynamic control surfaces and a water jet propulsion system. NLR has performed preliminary design calculations for the layout of the wing in order to investigate whether the requirement for the speed at which the vehicle becomes fully airborne can be met. The results indicate that, in order to carry the maximum take-off weight, a very large wing with a span well above 100 metres and a very thick airfoil section will be required. The aerodynamic performance of the wing was analysed by means of the PDAERO panel CFD method.

Under contract to the Ministry of Transport, several studies were performed on the aerodynamics aspects of the ventilation of road traffic tunnels. Measurements of the airflow characteristics in road traffic tunnels were performed both on reduced scale and on full scale, on-site. Time histories of local velocities have been measured, and stored for further processing and analysis. They may serve as a database for new ventilation systems to be installed in other traffic tunnels.



Pressure distribution on supersonic civil transport configuration in low-speed design condition

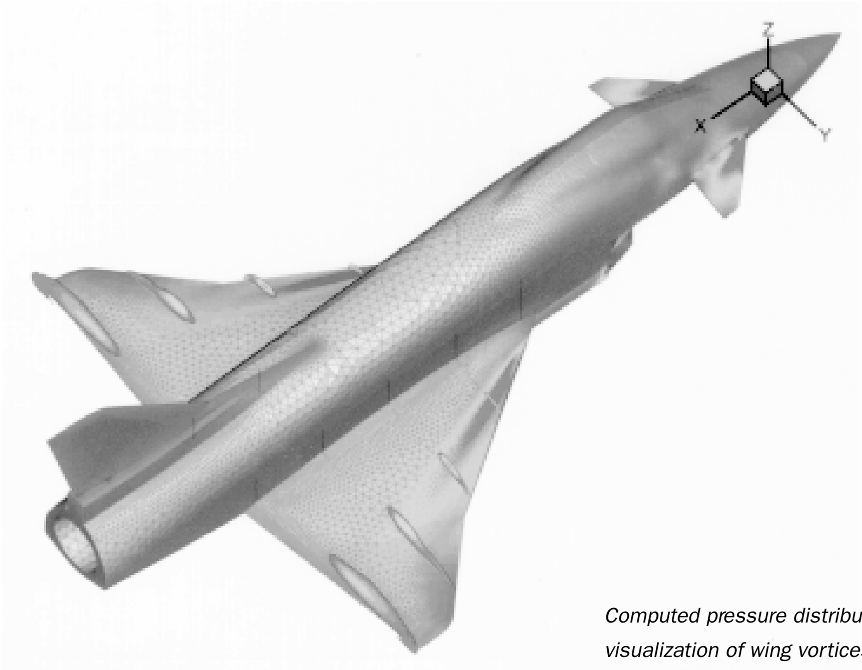
Another subject addressed was the applicability of a commercial CFD code in studies on road traffic tunnel ventilation. It was found that while it was possible to model some characteristics with reasonable accuracy, other flow parameters differed by almost an order of magnitude from experimental results.

Basic Aerodynamic Research and Computational Fluid Dynamics

Reynolds-Averaged Navier-Stokes Methods

The development of the unstructured grid CFD system FASTFLO (Fully Automatic System for 3-D Flow simulations) was continued in the framework of the EU project FASTFLO II. This project, which is co-ordinated by NLR, is the successor of FASTFLO I, which resulted in a reduction by an order of magnitude of the problem turn-around time for complex configurations, compared to classical multi-block technology, for CFD simulations based on the Euler equations. The objective of FASTFLO II is to demonstrate a similar reduction of the problem turn-around time for simulations based on the Reynolds-averaged Navier-Stokes equations. For an accurate resolution of viscous flow phenomena, FASTFLO uses prismatic volume elements in the parts of the flow field that are dominated by viscous effects and tetrahedral elements in the remaining parts. Both one-equation and two-equation (k-omega) type turbulence models have been implemented. The code has been evaluated through applications to several generic aircraft and space vehicle configurations. An observation from these applications is that while the reduction of problem turn-around time is indeed spectacular as a result of the reduction of the grid generation effort, the efficiency of the flow solver is lower than that of classical, multi-block methods.

As part of the NIVR Basic Research Programme, the unstructured grid CFD code FANS, for two-dimensional, multi-component airfoils was extended with a mix of transition prediction criteria. The capability to account for different ‘routes to transition’ is important for accurate and automated prediction of the maximum lift. An evaluation has been conducted for a multi-component airfoil in the landing configuration.

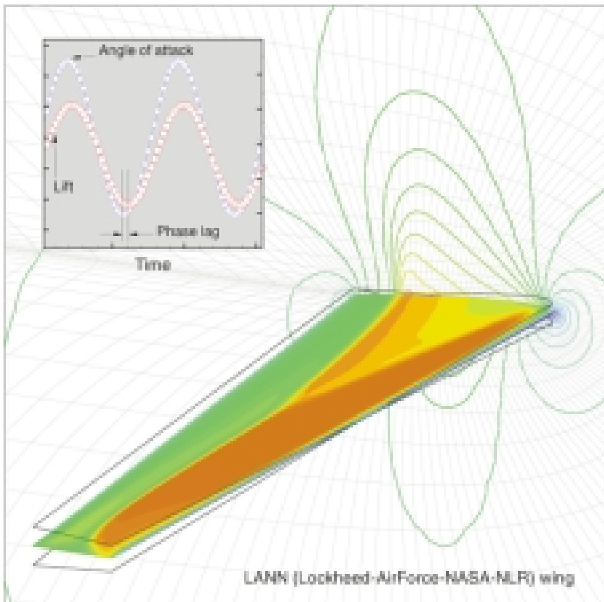


Computed pressure distribution and visualization of wing vortices

The well-established ENFLOW system, based on the concept of multi-block structured grids, was improved further. With the objective of further reducing the turn-around time of a complete flow simulation, a method was developed for generating grid blocks intended to capture the boundary layers on a configuration efficiently. For the k-omega two-equation turbulence model, a new set of so-called TNT (Turbulent-Non-Turbulent) coefficients was implemented. Part of this work was financed through the NIVR Basic Research Programme.

A major extension of the ENFLOW system concerns the introduction of the possibility of time-accurate viscous flow simulation. For this purpose, as a first step, a dual time-stepping algorithm was implemented in the ENSOLV flow solver. The method was verified for transonic buffet and Von Karman vortex street simulations for non-moving, rigid bodies. Subsequently, the capability to analyse moving rigid bodies such as manoeuvring rigid aircraft or oscillating rigid wings, was added. Several test cases were analysed.
Because of anticipated long running times for unsteady flow, the parallelization of ENSOLV was also carried out. The technique follows coarse grain parallelization where blocks are assigned to a number of processors to be processed concurrently. Satisfactory speed-up has been obtained both on the NEC SX-4 supercomputer and on the new NEC SX-5.

NLR participates in the EU project AVTAC (Advanced Viscous flow simulation Tools for complete civil AirCraft design). As part of a baseline validation of the steady-flow simulation



Computation of unsteady transonic flow about a vibrating LANN (Lockheed, Air Force, NASA, NLR) wing tools of the respective partners, the ENFLOW system, extended with an improved k-omega two-equation turbulence model and a simplified procedure for prescribing the location of laminar/turbulent transition, was used to simulate the flow around the AS28G wing/body configuration including pylon and flow-through nacelle.

NLR and DLR continued their collaboration in the area of the pre-development of 'CFD tools for Complete Aircraft'. One of the topics studied is the introduction of local, structured-grid-like elements in a globally unstructured grid with the objective to improve the accuracy of unstructured grid, viscous flow simulations in regions where gradients and diffusion are large.
Another activity comprised the parallellization of unstructured-grid generation algorithms to facilitate the efficient generation of large-scale hybrid grids.

Turbulence Modelling
NLR continued participating in the EREA Joint Activity 'Transition and Turbulence Modelling'. The objective of this activity is the joint development and implementation of 'EARSM' (Explicit Algebraic Reynolds Stress Models) and full-Reynolds-stress turbulence models for Reynolds-averaged Navier-Stokes codes.

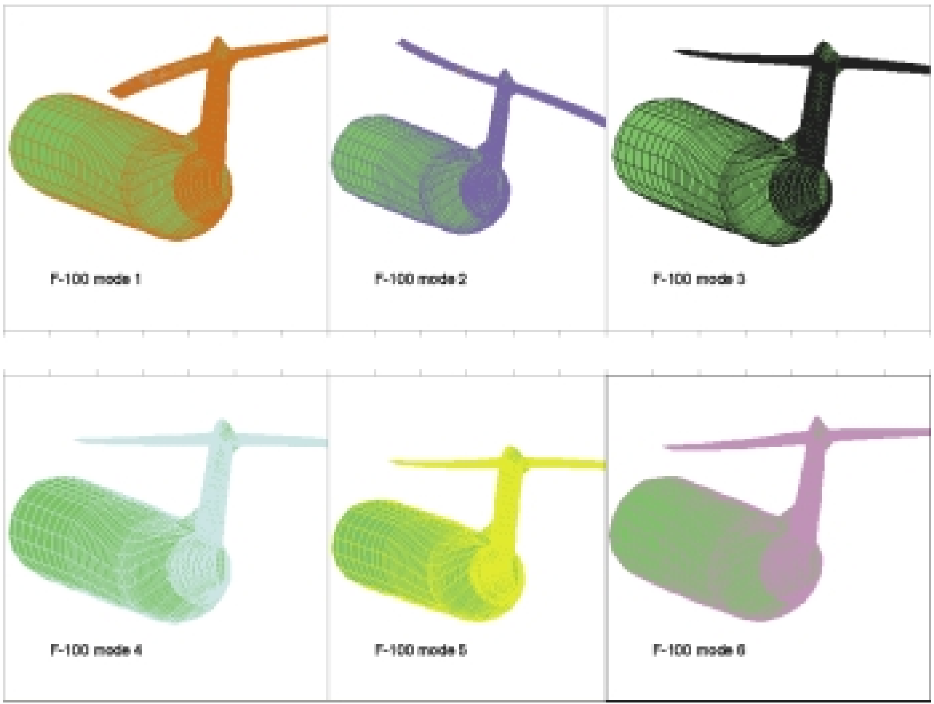
A notorious problem of the standard k-omega turbulence model for Reynolds-Averaged Navier-Stokes computations is that the flow solution may depend in an unphysical manner on the free-stream values of the turbulence variables. This problem has been overcome by deriving a set of new, TNT transport coefficients that represent the physical propagation characteristics of the turbulence near turbulent/non-turbulent interfaces.

Euler Methods
The development of the time-accurate Euler solver HEXADAP, based on discontinuous Galerkin finite element discretization, was continued. Emphasis was placed on the accurate and efficient simulation of time-accurate vortex flow. The unified space-time discretization of the Euler equations is aimed at the simulation of helicopter rotors in forward flight. The space-time formulation was tested on simple cases with solid body motion, and results were compared with those of the standard time-marching version of HEXADAP and with results obtained by the ENFLOW system. The agreement was good.
A major improvement of the algorithm enabled highly accurate results to be obtained on relatively coarse meshes with non-uniform local grid refinement, while comparing favourably with conventional methods using, globally, much finer meshes.

CFD Code Validation Experiments
Work in the GARTEUR Action Group (AD) AG-28 continued, albeit at a low pace. The objective of this Action Group is to execute comparative, complementary wind tunnel tests on a semi-span model of the AS28G wing-body configuration in the ONERA S1 wind tunnel and a full-span model of the same configuration in the ETW and the DNW-HST wind tunnels.

Scale Effects
NLR contributed to the analysis of the results of a joint wind tunnel test, with EREA partners, in the European Transonic Wind tunnel (ETW) to study the effect of Reynolds number variations on the aerodynamics of a subsonic transport aircraft model. The contribution of NLR consisted of wind tunnel wall interference assessment, CFD analysis using the MATRICS-V code and analysis of the experimental results. The results confirm the capability of the MATRICS-V system to correctly model scale effects on drag for the type of aircraft configuration considered.

Radar Cross Section (RCS) Prediction Methods
NLR continued the development of RCS prediction techniques in collaboration with the Physics and Electronics Laboratory TNO-FEL. This work relies heavily on the CFD infrastructure at NLR.
A new prediction technique based on a hybrid algorithm for combining a high-frequency approximation, as in physical optics, with the exact Electrical Field Integral Equation (EFIE) was implemented. The EFIE method was applied to a cylindrical wave guide for validation.
Results of the computations were compared with measured data produced by TNO-FEL. The work was partly funded by the Ministry of Defence.



Visualization of calculated aeroelastic phenomena with a Fokker 100 T-tail

Aeroelasticity and Vibration Research

Air Vehicle Operations Aeroelastic Support

Support was given to the RNLAF, the RNLN and Fokker Services in investigating operational problems with aeroelastic and vibration aspects. A semi-empirical method for the prediction of non-linear flutter phenomena of combat aircraft, including Limit Cycle Oscillations (LCO) has been improved and applied successfully for the RNLAF.

Computational Aeroelastics

AESIM-Basic is a Computational Aero Elastic (CAE) system, based on a full-potential flow aerodynamic model, for the prediction of dynamic loads, flutter and other unsteady aeroelastic phenomena by time-accurate simulation of the interaction between the aircraft structure and the unsteady airflow.
As part of the NIVR Basic Research Programme, the system was extended with two novel time-integration algorithms that offer improved computational efficiency. In order to facilitate the use by external customers, a tutorial for flutter analysis applications of AESIM-Basic was written. The system was implemented on a workstation of a customer under a leasing contract.

Because the AESIM-Basic system is based on a full-potential flow model, application to fighter type aircraft exhibiting limit-cycle oscillations is beyond its possibilities. In order to remove this limitation, the development of a new capability was started. In this AESIM-Mil project, the full-potential flow model of AESIM-Basic will be supplemented with a flow model based on the unsteady Euler/Reynolds-averaged Navier Stokes equations. The modelling of aircraft control systems is also envisaged. This work is partly financed by the Ministry of Defence through NIVR.

Interest of the Netherlands aerospace industry in prediction methods for the steady aeroelastic distortion of aircraft components has triggered research into the applicability of CFD methodology for the prediction of aerodynamic loads on the tail surfaces of transport aircraft. As a first step, aerodynamic computations have been performed with the ENFLOW CFD system for a rigid model of the Fokker 100, with a T-tail. The results have been validated against experimental data obtained earlier in the DNW-HST wind tunnel. Coupling with a finite element structures model is envisaged. The work is part of the NIVR Basic Research Programme.

Aeroelastic Investigations for Space Vehicles

Under contract to ESA/Aerospatiale, a wind tunnel test programme was executed to investigate unsteady pressure load phenomena in the base-flow and on the nozzle of the Ariane 5 launch vehicle under transonic and supersonic flight conditions. An existing wind tunnel model was fitted with a new nozzle, which was instrumented with a large number of Kulite pressure transducers. An intensive test campaign was run in the DNW-HST and in the DNW-SST.

Non-aerospace Aeroelastics Investigations

Under contract to the Ministry of Transport, experiments have been performed to investigate the aeroelastic characteristics and vibration risks of mutually interfering road traffic sign gantries. For this purpose gantry shapes of different cross-sections at several in-between distances were tested in the DNW-LST wind tunnel.

Aeroacoustics

Air Vehicle Operations-related Acoustic Investigations

In support of an acquisition project of the Royal Netherlands Army for a remotely piloted vehicle, the compliance of the noise emission of a vehicle with the applicable regulatory limits has been checked. Noise emissions, maximum sound pressure levels during fly-over, for take-off and under various level flight conditions, have been measured according to methods described in the International Civil Aviation Organization (ICAO) standards. In addition the directional characteristics of the acoustic power emission in four directions have been determined according to a national standard for the measurement of industrial noise.

Turbofan Engine Source Noise and Duct Acoustics

In the EU project RESOUND (Reduction of Engine Source Noise through Understanding and Novel Design), NLR is involved in the design of a rotor/stator combination optimized with respect to noise generation. NLR's computer model for rotor/stator interaction noise was extended by the incorporation of active noise control through controlled oscillation of stator vanes. By means of this model the effect of optimizing design parameters, such as the position of the axis of rotation of the stator vanes and the amplitude and phase angle of the oscillation, was investigated. The results indicate that the application of stator vanes with controlled oscillation may reduce the rotor/stator interaction noise by as much as 11 dB.

A computational model for rotor-stator interaction noise was extended successfully by incorporating the effect of vane leading edge suction. This higher order effect appears to model a realistic base level for rotor-stator interaction noise under conditions where, according to linear theory, the noise would vanish. At other, more realistic conditions the incorporation of the leading-edge suction effect may increase the predicted interaction noise by as much as 10 dB.

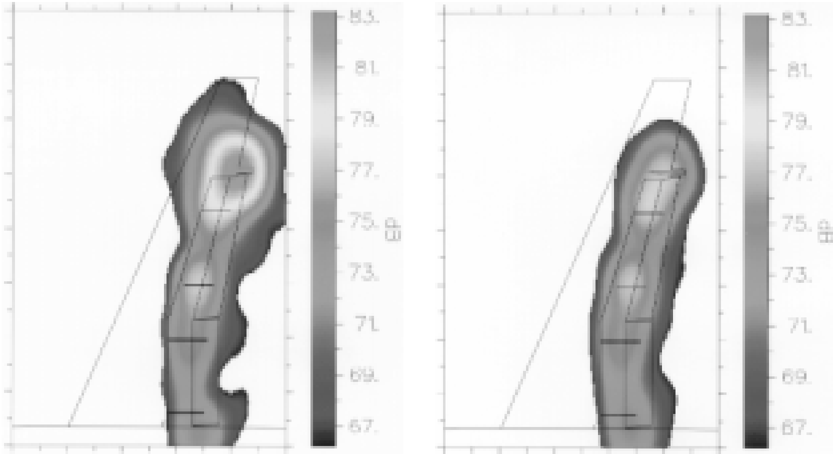
NLR's participation in the EU project RANNTAC (Reduction of Aircraft Noise by Nacelle Treatment and Active Control) consisted mainly of the analysis of two innovative, non-locally reacting acoustic liner concepts, based on transmission loss measurements carried out on liner barrels in NLR's aeroacoustic facilities. Measurements of insertion loss and impedance were carried out on liner samples. The results provided valuable information for the assessment of the novel liner concepts.

The EU project DUCAT (Basic Research on Duct Acoustics and Radiation), co-ordinated by NLR, focuses on the development and validation of computational tools for the determination of the propagation of sound in engine ducts. In the anechoic configuration of the DNW-LLF wind tunnel, the radiated acoustic field from NLR's model turbofan was determined. The results will be used for the validation of computational models.

Airframe Noise

As part of the Netherlands JSF Preparation Programme (NVJSF), research on the weapons bay acoustics of combat aircraft is carried out in collaboration with TNO-TPD and Lockheed-Martin Tactical Aircraft Systems (LMTAS). A combined CFD-CAA method is applied in order to investigate the influence of the geometry of the interior of the weapons bay and of exterior

Wing model with flap tip device, used in airframe noise measurements

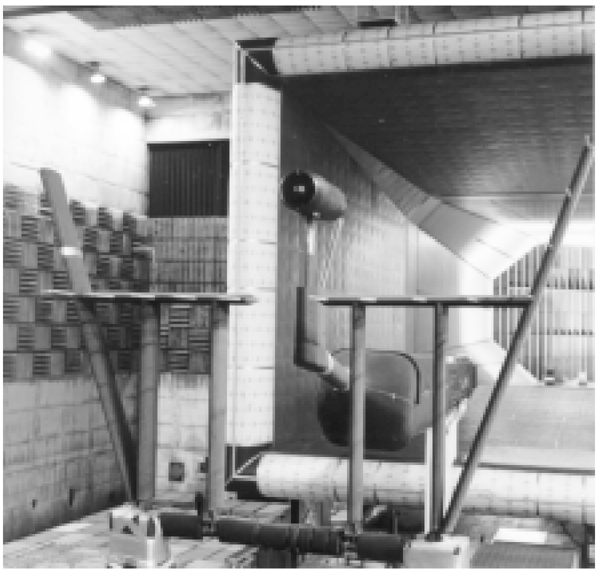


Airframe noise maps of a wing with extended flap: (left) without flap tip device, (right) with flap tip device

parts of the aircraft on the acoustic loads on parts of the aircraft structure. As a first step the flow field in and around the weapons bay of a JSF aircraft configuration is being computed by means of the ENFLOW and FASTFLO CFD systems. Validation through wind tunnel tests in the DNW-HST is envisaged.

In support of the NVJSF weapons bay acoustics project, and in collaboration with Lockheed Martin, a pilot test was carried out in the DNW-HST with the objective to investigate the unsteady pressure levels on a low-fidelity model, at both subsonic and supersonic flow conditions. Unsteady surface pressure data and PIV data have been obtained.

The flow-induced noise of the extended trailing-edge flaps of a civil aircraft model was investigated experimentally in the DNW-LST. As part of the NIVR Basic Research Programme, the effect of thickening the trailing edge of the flap on airframe noise was determined. The effect of the application of so-called flap tip devices on noise was also investigated. The results of these tests indicate that the effect on airframe noise of thickening the flap trailing edge is hardly measurable, but that the application of a fence-like device at the outboard tip of the flap yields a reduction of the noise source at the flap tip of 2 to 6 dB over the relevant range of frequencies.



NLR's model turbofan in the anechoic open jet configuration of the DNW Large Low-speed Facility

For this test a new acoustic data acquisition system was used enabling high-quality acoustic scans to be made even in an acoustically hard-walled wind tunnel.

Propeller Noise

Research on propeller noise in the context of the EU project APIAN (Advanced Propulsion Integration Aerodynamics and Noise) was continued. The contribution to this project mainly consisted of an extension of the computer program DIFREF for the calculation of the scattering of propeller noise by an aircraft fuselage. The extension makes possible the computation of the scattering of noise by a cylinder of a non-circular cross-section representing the fuselage, with incorporation of the boundary layer.

The acoustic lifting surface theory for propellers was applied to advanced propellers in pusher mode. The unfavourable reputation of pusher propellers with respect to noise was confirmed unambiguously. Interaction with the wing wake was found to cause a dramatic noise increase, especially for the higher harmonics.

Noise Propagation

In the EU project RAIN (Reduction of Airframe and Installation Noise), NLR is responsible for the sub-task Fan Noise Installation Effects. An experiment was carried out, in the Small Anechoic Wind Tunnel (KAT) of NLR, for the validation of computational models for the refraction of sound by vortical flow. In this experiment a tip vortex was generated by placing an airfoil in the open jet of the KAT. Both the sound propagation and the flow characteristics were measured in great detail, providing a comprehensive database.
As part of the NIVR Basic Research Programme, the shielding of noise radiated from aft-mounted turbofan engines by the wing of an aircraft was modelled on the basis of the wave equation solved by the Wiener-Hopf method and implemented in NLR's LINDA system of computer programs. The results of an application indicated that the effect of wing shielding on the noise perceived at ground level can be quite substantial.

Non-aerospace Acoustic Research

NLR continued its contribution to the EU project DATA (Design and Testing of Acoustically Optimised Airfoils for Wind Turbines) with the testing of a number of new wind turbine airfoils in the NLR Small Anechoic Wind Tunnel (KAT). From these tests some marked conclusions could be drawn with respect to the sound generation by these airfoils, providing valuable guidelines for the design of a complete wind turbine model, to be tested in the DNW-LLF in 2000.

Facilities and Equipment

Wind Tunnels

Several, relatively minor, improvements in and extensions of the equipment of the transonic wind tunnel DNW-HST were realized, including new sting supports and adapters for civil aircraft testing.

With the objective to improve the control of vibrations of sting-supported models in the DNW-HST, possibilities of applying dissipating elements for increasing the damping of model vibrations in pitch/heave were investigated. Various types of elements, to be inserted in the interface between the model support and the cone-adapter, were analysed and tested. The results indicate that excellent damping characteristics can be realized by applying stacks of spring-washer type elements. Further experiments and validation of this novel technique are in progress.

For establishing the background noise level of the DNW-HST in its current configuration, noise measurements were performed over the full Mach number range with a 10-degree cone model equipped with acoustic pressure transducers. The results are being processed and analysed.

The supersonic wind tunnel DNW-SST was subjected to a major overhaul, which included replacement of a number of critical parts and obsolete subsystems. The valve for controlling the pressure in the settling chamber as well as all hydraulic cylinders and actuators were completely dismounted for inspection and either

AerMacchi AEM/YAK 130 model in the DNW-HST wind tunnel

replaced or fitted with new, redesigned and improved seals. A new pressure reference system with new pressure transducers was installed. Installation of a modern man-machine interface in the tunnel control room is in progress.

The so-called alpha-shifter part of the model support system of the DNW-SST was modified in order to increase the maximum admissible load levels and to improve the compatibility with the model support system of the DNW-HST.

Wind Tunnel Testing Techniques

Possibilities for improvement of the Pressure Sensitive Paint (PSP) pressure measurement technique were studied in the framework of the GARTEUR Action Group (AD) AG-40 and in collaboration with the Central Institute for Nutrition and Food Research of TNO. The collaboration with TNO involves the development of a new type of dually, pressure- and temperature-sensitive, ‘paint’, offering prospects of improved accuracy.

As part of the DNW Research Support Programme a computational study has been made of the flow disturbances induced by the wind tunnel walls in wind tunnel testing of helicopter rotors. For this purpose use was made of the WIN3D computer program for wind tunnel wall assessment. The results indicated the need for an extension of this program in order to cope with the strong asymmetry of such flow fields. Programming of this extension was initiated.
It was also found that at low forward speed, the basic assumptions of the method are violated to the extent that reliable results cannot be expected.

Another activity in the area of wind tunnel wall interference consisted of the improvement and extension of the WINMIR code for the theoretical determination of wall interference and wall pressures in wing-body configuration testing. Results of the WINMIR code can be used for the verification of wall interference correction methods that make use of measured wall pressures.

For the purpose of investigating a possibility for improving ground effect simulation in the DNW-LST, tests were performed with a simple wing model above a ground board with active boundary layer control, through blowing, on the ground board. The results indicate that this technique is not feasible in the case of close proximity and high lift coefficients.

Instrumentation and Measurement Systems

Developments in the instrumentation and measurement systems of the DNW-HST wind tunnel included the completion of the manufacturing, calibration, validation and documentation of a new strain gauge balance for combat aircraft model testing, and the manufacturing of new electronic signal generators for the (daily) calibration of data acquisition systems and new inclinometer conditioning units with automatic compensation for vibration.

Calibration procedures for strain gauge balances for the DNW-HST and DNW-SST wind tunnels were studied in greater depth, including the analysis of results of new calibration software based on the concept of transfinite interpolation of calibration data.

A special procedure was developed to compensate NTC (Negative Temperature Coefficient) type anemometry probes for ambient temperature effects. The procedure was checked in the DNW-LST. Also, alternatives have been studied for the future replacement of the temperature sensitive NTC probes.

The equipment for unsteady aerodynamic and vibration measurements was improved by the purchase of a new, 128-channel, data acquisition system. After a brief period of familiarization the system was implemented for operational use.

The microphone array system for aeroacoustic measurements was improved further with the introduction of another 128-channel data-acquisition system. The new system allows simultaneous, multi-channel data to be sampled with long measuring times at high sample frequencies. The new acquisition system was implemented and validated through acoustic array measurements in the DNW-LST. The array configuration for the DNW-LST consists of 96 microphones, flush-mounted in a sidewall of the tunnel. The tests showed that the new system is capable of producing high-quality acoustic data without ‘acoustic pollution’ by aerodynamic background noise, even in wind tunnels without acoustic wall treatment such as the LST.

Infrastructure for Computational Fluid Dynamics

In preparation of the installation at NLR of the NEC SX-5/8 supercomputer, replacing the NEC SX-4/16, benchmark tests were performed with the ENFLOW, FASTFLO and HEXADAP flow solvers. For CFD applications the main advantage of the SX-5 is the large size of the shared memory, which allows CFD simulations to be carried out on finer grids. This is particularly important for drag prediction and for the fidelity of geometry representation of complex aircraft configurations. The SX-5 also allows faster turnaround of time-accurate simulations for aeroelastic analysis.

The increase in demands and requirements for the visualization of results of CFD simulations has led to the purchase and implementation of additional visualization software and state-of-the-art hardware for high-quality reproductions. The developments in CFD technology and the arrival of the NEC SX-5 supercomputer are also driving a gradual shift towards time-dependent flow visualizations. The collaboration between NLR and Computer Engineering International (CEI) Inc. on concurrent visualization utilizing a supercomputer was therefore continued.

3.2 Flight

Summary

In the area of aircraft systems design, studies and experiments were performed to improve the operability and safety of aircraft operations. New concepts for integrated cockpit systems controls and flight management system configurations were designed, to accommodate more efficient and environmentally friendly operations. Aircraft operations more sustainable under adverse weather conditions were pursued by projects on synthetic and fused imagery displays and on improved flight control systems. The prevention of accidents of the type Controlled Flight Into Terrain (CFIT) was pursued by participating in projects such as Increasing Safety through Collision Avoidance Warning Integration (ISAWARE).
The collaborative research with NASA into airborne-based separation assurance concepts for Free Flight applications was continued.

In the military field, support was provided to the industry aiming at participation in the design phase of the Joint Strike Fighter and the development of maritime helicopters. Research into laser threat, self-protection and airborne reconnaissance was continued.

In the area of aircraft procurement and assessment, work was focused on providing policy and technical information for national programmes for the replacement of aircraft such as the F-16 fighter and Lynx helicopter. The application in fighters of technologies such as helmet-mounted display systems, aircraft self-protection measures and dogfight missiles were assessed, as were implications of thrust vectoring.
Work on the application of uninhabitated aerial vehicles (UAVs) was continued intensively.

In the area of aircraft simulation, work on the Research Flight Simulator (RFS) was continued with the design of a new re-configurable cockpit. This design allows several aircraft types including Fokker, Boeing and Airbus types to be simulated. Work on the context simulation concept, addressing detailed simulation of both operational and environmental factors, was continued, for the accurate prediction of crew behaviour and of the vulnerabilities of future flight deck and flight control systems. The helicopter pilot station was equipped with a Fokker-developed control loading system. Work on the 'family concept' of modular simulator software was continued.

The networking of simulators with different levels of fidelity is actively pursued by users, at the risk of creating a mix of simulator-dependent skills that negatively transfer to the real world. Experiments that address these issues were prepared in the national Air Warfare demonstrator and the NLR/NASA Free Flight Internet project.

In the area of aircraft operations, work on interactions of aircraft characteristics with environmental disturbances was continued. Interactions of autopilot systems with strong and varying crosswinds were studied. Similarly, threats imposed by aircraft-induced wake vortices were analysed and studied for both fixed-wing and rotary wing aircraft. New approach and landing procedures were investigated for noise and fuel optimization when followed by airliners with different levels of equipage. In the helicopter domain, advanced approach trajectories were investigated for safety, noise and efficiency. Aircraft power plant models were updated to assist national research in this area. Work on the Advanced Continuous Descent Approach (ACDA), reducing noise footprints on the ground, progressed with the development and demonstration of a specific flight management system module.

A considerable effort was spent in improving the self-protection capabilities of military aircraft and helicopters participating in the operation Allied Force. National and international trials on electronic warfare were supported, and the evaluation of Allied Force operations required a great deal of work. The regular support for the RNLAF was continued with the analysis of tactical performance and limitations of weapon systems, the preparation of tactical manuals, and stock planning.

In the area of certification, work in support of the RNLAF and RNLN (Royal Netherlands Navy) was continued. Updated navigation and targeting

pods for the F-16 were tested and certified. The airworthiness of the Sperwer in particular and operational impacts of Uninhabitated Aerial Vehicles in general were investigated. Support was provided to the RNLN for the extension of the Westland Lynx operational life and in NH90 flight testing.

In support of international military operations, several national and international helicopter-ship combinations were investigated by means of flight tests and modelling tools to determine safe operating limits. Work on international aviation rulemaking was continued by NLR participating in European harmonization efforts on crew resource management and other non-technical skills.

In the area of human factors aspects of aircraft certification, NLR was invited to participate in an FAA/JAA (Federal Aviation Administration/Joint Aviation Authorities) harmonization working group that develops new rule making.

In the area of maintenance, work was continued on Health Usage Monitoring Systems (HUMS) and their application in the monitoring of aircraft and helicopters systems, and on the development of conditional aircraft maintenance procedures. Human maintenance errors and the efficiencies of existing and alternative procedures and tools were addressed. New tools for assisting the mechanics and preventing errors were developed and tested, in close collaboration with airlines and military operators.
Maintenance lessons learnt by incidents and on-site reviews were analysed and translated into requirements to more safe and endurable systems to be developed.

In the area of manning, work on human factors issues associated with flying under both routine and high-stress working conditions and with equipment design, training and selection was intensified. Objective and quantifiable measurements on crew performance and error management are crucial in this area. The application of point-of-gaze eye tracker equipment was therefore extended, and tested in routine flight deck applications, whereas the processing of measured data was accelerated by the development of dedicated analysis software. NLR's unique capability was applied in many areas, such as Free Flight development, flight deck system optimization, military training, and the assessments of workload and awareness issues for both flight crew and air traffic controllers.
Human centred design and evaluation methods for user interfaces were addressed in close collaboration with aircraft manufacturers, equipment suppliers and users. Applications were implemented in future user interfaces for aircraft and Air Traffic Control.

Training and selection work was continued with the evaluation of pilot debriefing tools based on skill-orientated human performance measurements. Aircraft embedded training concepts and other pilot training tools, such as FMS (Flight Management System) training devices, were prototyped. Transition training of pilots because of aircraft changes was investigated with emphasis on various glass cockpit transitions.
In response to the growing need for pilot training candidates, selection methods based on Divided Attention capabilities were updated, and tested by national type rating training organizations.

Knowledge that NLR has developed for aeronautics has proved to be useful in other domains. Expertise in aircraft maintenance and human factors was applied in national projects on building underground transport means. Concepts such as mid-life updates and conditional maintenance of life support systems were transferred and applied.

The analysis methods for 'human data' were transferred to the national industry, for application in generic software packages for the assessment of overall human behaviour.
The experience on human-machine interaction could be re-used in the development of co-operative means for interacting with computers. The Ministry of Economic Affairs supported the development of a so-called companion user supportive interface based on NLR concepts. National industries found technologies used for airborne-based separation to be applicable with innovative concepts for road traffic safety.

Testing a Chinook helicopter equipped with flares for the RNLAF

Aircraft Systems Design

Autopilot Control Laws Design

In the EU project 'Robust and Efficient Autopilot control Laws design', a software environment, REALCAM (REAL Civil Aircraft Model benchmark), was set up. It contains assessment tools for validating the robustness and performance characteristics of autoland controllers in relation to design requirements. SIMPA Light Edition (SIMPALE) is one of these tools. It was developed by the *Office National d'Etudes et de Recherches Aérospatiales* (ONERA) and essentially is a simplified Matlab/Simulink version of the Monte Carlo simulation tool used by Aerospatiale-Matra Airbus. The Delft University of Technology (DUT) and NLR have set up a preliminary controller using conventional design methods. With this controller, the REALCAM benchmark was evaluated. Design teams from the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) and ONERA proceeded with the actual autoland controller design using Multi-Input Multi-Output (MIMO) methods. ONERA made use of a robust eigenvalue/eigenvector design and synthesis method. DLR made use of various methods. For the aircraft-dependent inner loop, DLR used the non-linear dynamic inversion method. For the aircraft-independent outer loops, Total Energy Control System (TECS) and Total Heading Control System (THCS) were applied. Tuning of free parameters in the control structure was performed by means of the Multi-Objective Parameter Optimization (MOPS) method. To assess the robustness, controls developed and connected to the SIMPALE tool could be tested on pre-defined CAT-III autoland requirements. The full design and synthesis set up has a potential to improve the efficiency of the design process by reducing the number of design cycles, while delivering autoland controllers with profound robust characteristics.

Development activities of DLR and DUT resulted in the second aircraft benchmark, labelled REALATTAS, which relates to DLR's ATTAS flight test aircraft. DUT and NLR started preliminary controller design activities.

Pilot-in-the-Loop Oscillations

The advent of fly-by-wire technology has caused Airplane-Pilot Coupling (APC), more commonly known as Pilot Induced Oscillations or Pilot-In-the loop Oscillations (PIO), to become a research area with increasing importance in both civil and military operations. NLR participated in the

GARTEUR Exploratory Group (FM) EG 18, ‘Aircraft-Pilot Coupling’, for the definition of the terms of reference for a future Action Group. The Executive Committee decided to establish Action Group (FM) AG 12 on Pilot-in-the-Loop Oscillations – Analysis and Test Techniques for their Prevention. The detailed definition of the work to be carried out in five work packages and the division of the tasks and responsibilities among the AG members were begun. Prominent susceptibility criteria have been evaluated, and simulator experiments have been planned.

Affordable Digital Fly By Wire Flight Control System

The EU project ADFCS (Affordable Digital Fly By Wire Flight Control System for Small Commercial Aircraft) focuses on advanced technologies in Fly By Wire (FBW) flight control system design. The goal of this project is to develop an architecture for an affordable FBW digital flight control system (DFCS) for small commercial aircraft, utilising advanced technologies such as Fuzzy/Neural and robust control algorithms 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 affordability and cost effectiveness of incorporating these technologies in small civil aircraft will be evaluated. The main emphasis of NLR is on the evaluation of a developed affordable FBW system by means of a flight simulation programme on the RFS.

Pilot Workload

In collaboration with Defence Evaluation and Research Agency (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. This programme aims at the incorporation of Advanced Information Processing (AIP) and decision support techniques into the modern cockpit. For this purpose several Human Machine Interfaces (HMIs) were developed for various applications, using AIP.

Eye Point of Gaze Feedback (IMPACT)

For the Netherlands Ministry of Defence, a Small National Technology Project supervised by the Royal Netherlands Navy was started. The applicability of Eye Point Of Gaze measurements of up to three operators using a Large Wall Display in a Control Centre environment will be studied. This project is performed in collaboration with *Hollandse Signaal Apparaten*, and seeks to demonstrate a working prototype system that enables the team members to see where the other members are focussing their attention, such that the team effectiveness is enhanced.

NH90 Design and Development

In co-operation with Fokker Aerostructures and SP Aerospace and Vehicle Systems, NLR has continued its participation in the design and development phase activities of the NH90 programme. One wind tunnel test campaign with a 1:10-scale fuselage model of the NH90 was conducted in the Low Speed wind Tunnel (DNW-LST).

One employee was posted at the Eurocopter flight test centre at Marignane, France, as a member of the NH90 integrated flight test team.

A show model (scale 1:25) of the NH90 helicopter, manufactured by NLR employees, was handed over by the Royal Netherlands Navy to Madurodam, the Hague.

NH90 Project Office Support

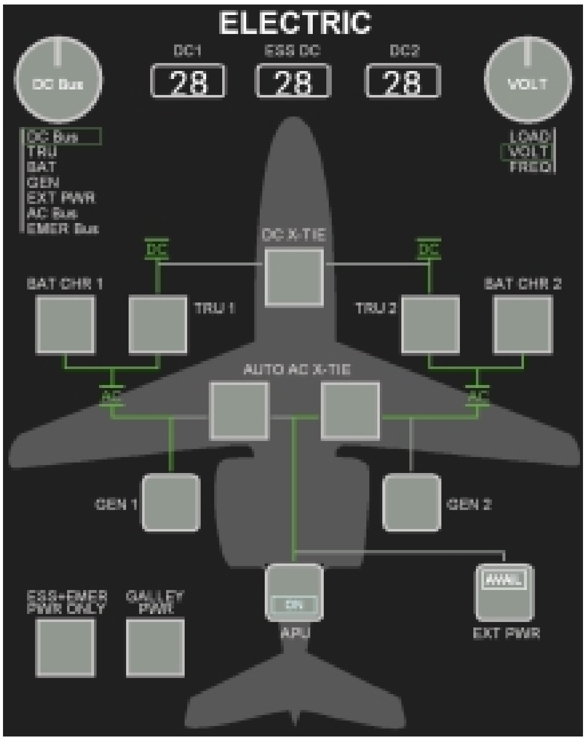
The support provided to the NH90 project office of the Royal Netherlands Navy (RNLN) was continued. Since the start of the project, NLR has provided technical expertise to assist in monitoring the NH90 design and development activities, and has provided the required contribution to the international qualification process on behalf of the RNLN. In particular, work was done with respect to prototype flight clearance.

Gas Turbine Simulation Program

The Gas Turbine Simulation Program (GSP) is gaining international interest. DERA has purchased a license and support contract, and has received support in a marine gas turbine propulsion feasibility project. The GSP was also used by DERA and NLR for the calculation of emissions in the AEROCERT project. For the F-16 successor project of the RNLAF, propulsion aspects have been assessed using GSP models of generic state-of-the-art fighter aircraft engines. For the Low Observability Project, generic state-of-the-art engine exhaust conditions were calculated using the GSP for the assessment of infra-red signature calculations.

New Analysis Techniques for Clearance of Flight Control Laws

Upon recommendation of the GARTEUR Exploratory Group (FM) EG-17 'Robust Flight Control II', the Action Group (FM) AG-11 on 'New Analysis Techniques for clearance of flight control laws (NEAT)' has been established. This Action Group is a follow-up of (FM) AG-08 'Robust Flight Control'. AG-11 focuses on advanced analysis techniques that more efficiently detect weaknesses of a flight control law design throughout the entire flight envelope. Three models have been prepared for the group's research and the current industrial clearance process has been described.



Human Machine Interface for overhead panel

The main contribution of NLR will be the development of a restricted network for GARTEUR, which will enhance collaboration and communication within projects and between projects. The network will contain a database for technical knowledge and software as well as management information of active projects. Functional requirements have been specified and a first version has been developed.

Collision Avoidance

The objective of the EU project 'Increasing Safety through collision Avoidance WARning intEgration' (ISAWARE) is to develop an Integrated Situational Awareness System (ISAS) by integrating the functionality of various subsystems such as Ground Proximity Warning Systems (GPWS), Traffic Alert and Collision Avoidance System (TCAS), Airborne Collision Avoidance System (ACAS), weather/windshear radar, wake vortex detector, and by using advanced technologies such as Automatic Dependent Surveillance-Broadcast (ADS-B), Surface Movement Guidance and Control System (SMGCS) and controller pilot data link (CPDL). The requirements to the ISAS system concept definition were set up. They included the definition of the Integrated Warning Function (IWF) and the Man Machine Interface (MMI) aspects related to the new displays. A subset of these requirements, which constitutes the ISAS demonstrator, was derived. This demonstrator will be modelled in software and connected to NLR's RFS for a piloted evaluation. NLR contributed to the MMI evaluation of the ISAS displays, specified the weather radar model and started the definition of the environments that all ISAS sensors require.

Future Utility Systems

In the FOCUS (Future Operations Concepts for Utility Systems) project (see also Chapter 3.7), aimed at the development and evaluation of new technology for system control, an initial Human Machine Interface has been designed and implemented. The project is being carried out under contract to the NIVR and supports technology development at Fokker Elmo. The main driver for the Human Machine Interface is the application of flat panel display technology. This technology for system control may reduce

electrical wiring and panels, simplify the aircraft production process, and, finally, reduce aircraft weight.
In the first phase of FOCUS, the overhead panel of the Fokker 100 is used as a baseline of which five different system control functions were selected. These functions are covered in five ‘pages’ on a touch screen LCD (liquid Crystal Display) that can be selected by the pilot. In the second phase of the project, two design versions will be evaluated with a pilot in the loop. A cockpit mock-up will be used in which pilots will perform tasks that include dealing with several system malfunctions.

Free Flight FMS
In the Free-Flight Flight Management System (3FMS), seven engineer-pilots evaluated prototypes of a Free Flight Human Machine Interface (HMI) in a civil cockpit mock-up. The HMI was fitted to a Free Flight concept that was based on literature and ongoing research into human factors of airborne separation assurance. The concept definition task was led by NLR. In the initial design evaluation, pilots were confronted with a high traffic density situation in which the FMS detected traffic conflicts and proposed two alternative routes to solve a conflict. Three different HMI versions were used and two levels of automation were applied. Data included both subjective and objective measures.

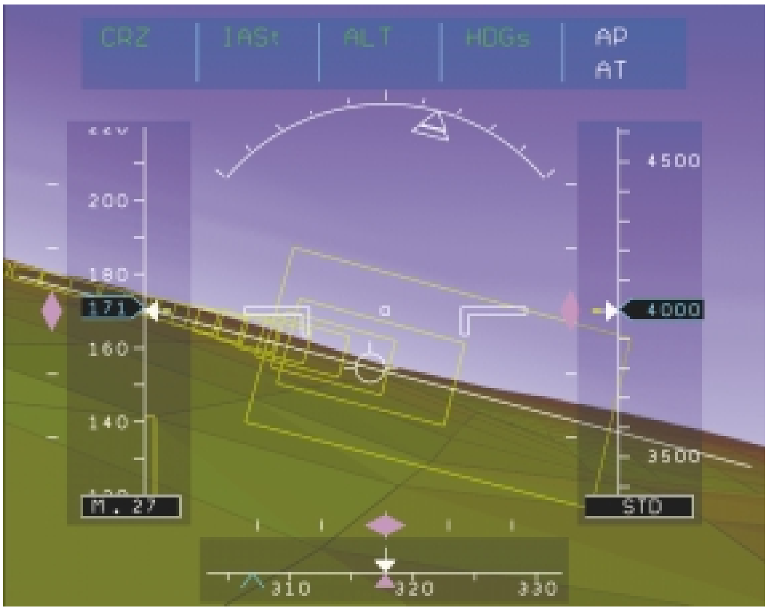
All Weather Arrival and Departure
In the scope of the EU project All Weather Arrival and Departure (AWARD), human factors orientated flight simulator trials with the AWARD Synthetic Vision System (SVS) were performed in NLR’s Research Flight Simulator. The main objective of the trials was to evaluate the feasibility of an SVS as a means for approach and landing under Cat III conditions.
Two versions of SVS were tested, one containing predictive information with respect to the aircraft flight path, and one with a depiction of the current aircraft flight path combined with a situational target. Dedicated manual crew co-ordination procedures for Cat III operations were used for these display formats. A contemporary primary flight display with flight director information was used as the reference condition.
This display format was also flown with manual crew co-ordination procedures, but under Cat II weather conditions. The trials were completed.

Free Flight Research
The feasibility of Free Flight concepts was explored using integrated air-ground simulations, with pilots and controllers in the loop. The goals of this research were to explore possible 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:
– testing the conflict resolution method for robustness, on critical conflict geometries;
– investigating whether the performance of contemporary avionics technology for navigation and ADS-B is sufficient for the Free Flight concept;
– developing and testing prototype HMIs for both pilots and controllers.

Integrated Self-Protection Electronic Warfare
The National Technology Project ‘Self Protection Electronic Warfare manager concept demonstration’ neared completion. The manager employs information about the threat situation from various sources, such as Intel, on-board sensors, datalink etc. to build and maintain threat situation awareness. It determines the best countermeasure for the situation including active threats, the flight situation, the available on-board countermeasure assets, taking into account any restrictions imposed by the operator, for example if the tactical situation prohibits certain countermeasures, and acts accordingly. The project is carried out in co-operation with the TNO Physics and Electronics Laboratory.

Laser Threat and Protection
The National Technology project ‘Laser threat and protection for air crew’ was started. This project aims at the determination of the future threat of lasers for aircrew and the identification



Synthetic Vision System tested in the Research Flight Simulator

of the required protection measures for aircrew. The project is carried out in co-operation with the TNO Physics and Electronics Laboratory and the TNO Human Factors Research Institute. Phase 1 of the project has been completed.

Tactical Recce System

The RNLAF will replace its conventional F-16 wet film Recce system, ORPHEUS, with an all-digital system. Demonstration flight tests and other programmes in the recent past have resulted in a detailed requirements list for the new system. Digital sensors are still under development but a number of potential candidates have reached sufficient maturity to be included in the rugged environment of a pod-mounted tactical Recce system. Support was provided in the definition of the technical and operational requirements in the request for quotation. As more NATO partners are upgrading their systems, new interoperability standards, for example on image exchange and data links, have been developed. NLR has participated in a number of the working groups on these Recce-related standards.

Conversion and Updates of ORPHEUS Recce System

As the new tactical Recce system will not be available until 2002, an interim solution was required to enable the current ORPHEUS Recce system to operate on the F-16 MLU. NLR has designed and produced an interface unit for a flight test demonstration of this capability. This unit, located in the ORPHEUS pylon, translates the conventional controls of the ORPHEUS to the all-digital controls of the F-16 MLU so that the ORPHEUS system can be controlled through the Multi Function Displays. After the successful completion of the flight tests, NLR received an order for the production of eight units. Furthermore, one infrared line scanner system will be modified to a digital system to continue the support of special missions.

Bird Catcher

For the Bird Catcher project of the RNLAF, in which bird migration patterns are investigated using a Flycatcher radar system, new data acquisition hardware and data processing software were provided.

Aircraft Procurement and Assessment

F-16 Replacement

A great deal of effort was spent to support the RNLAF with the determination of the likely successor of the F-16. The work included the drafting of Requests For Information and the definition of the evaluation process. The main effort of NLR in the evaluation process is directed towards the assessment of the operational performance of the candidates. The project is carried out in co-operation with TNO.

Uninhabitated Aerial Vehicles

The National technology project 'UAV Technology' was continued. The project aims to assess the state of the art with respect to UAV technology and to identify developments that could soon result in operational capabilities.

Aircraft Simulation

Work on the upgrading of the Research Flight Simulator (RFS) was continued with the design and development of a generic side-by-side flight deck and cockpit. This flight deck can be configured to represent several aircraft types including Fokker, Boeing and Airbus types.
The NLR simulation facilities provide detailed simulation of both the operational and environmental context. Such realism has proved essential for acquiring accurate predictions of future crew behaviour and for the prevention of future vulnerabilities in error management and safety.
The simulation facilities were used in several projects, one example being the implementation of a flight deck fully equipped with avionics suited for Free Flight and other types of Air Traffic Management operations. Combined with the NLR Air Traffic Control Simulator, the RFS enables full-scale demonstrations and evaluations of possible solutions for traffic congestion to be carried out.
The NLR simulation facilities were selected by the EU as a unique facility with European relevance, and contracts were awarded that enable it to be used for fundamental research by European universities.

The simulator software was modified in order to allow the creation of additional modular simulations with varying levels of fidelity, to be used in different stages of training and /or industrial product development. This 'family concept' was tested by connecting several desktop variants with fixed-based and full-fidelity variants in order to study effects on learning and human performance strategies. Connecting or networking simulations can improve the acquisition of a wide range of skills, but at the risk of creating multiple simulator dependent skills with negative transfer to the real world. National experiments were prepared that connect several types of simulators and operators in a common air warfare simulation cluster.

In the helicopter area, NLR participated in the activities of the GARTEUR Group of Responsables for Helicopters. Contributions were made to Action Group (HC) AG-09, 'Mathematical Modelling for the Prediction of Helicopter Flying Qualities' which delivered their final report. Contributions were also made to the activities of Exploratory Group 16, 'Dynamic Stall', Exploratory Group 17, 'Tilt Rotor External Noise' and Exploratory Group 18, 'Aero-elasticity & Dynamics of Tilt Rotor Aircraft'.

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

An important milestone in the upgrade of the RFS was reached by the procurement of a generic transport aircraft cockpit. This cockpit will be developed, manufactured and installed by a consortium of Dutch industries headed by Siemens Nederland N.V. Initially, the cockpit 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 on the replacement of seven large graphical workstations that provide 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 required for the harmonization of the NSF and RFS simulation software environments has been finished. 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 has changed the software of the EWMS to comply with the simulation requirements of the NSF.

Generic Pilot Station

The computer systems and the software for generating the out-of-the-window view 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 visualization software package 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, a three-dimensional modeller tool and an OpenFlight file converter. These tools will also provide support in database generation for other simulation facilities of NLR, for example the Tower Research Simulator (TRS).

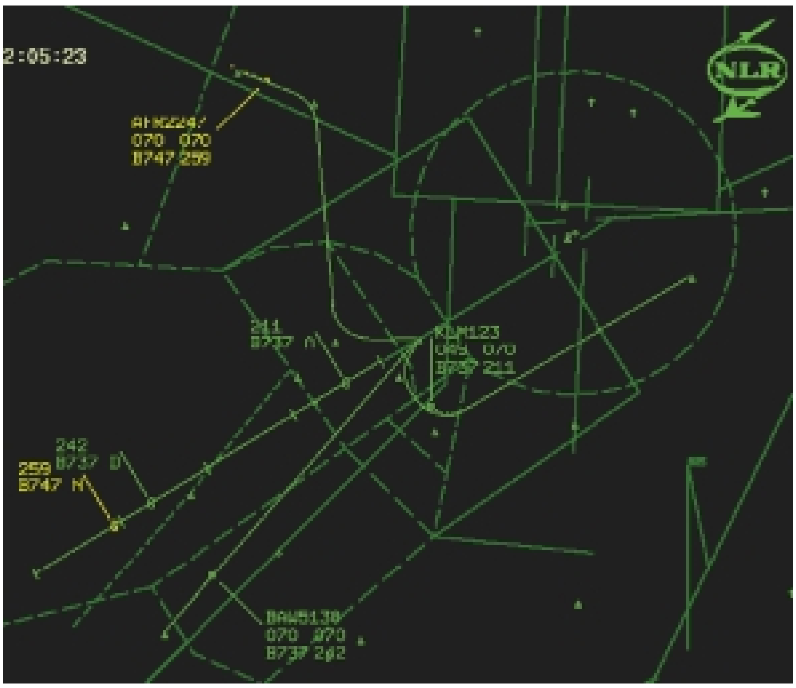
Helicopter Pilot Station

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

Aircraft Operations

Noise Abatement Research

New environmentally friendly procedures are becoming feasible with the introduction of new approach, navigation and flight management systems. A recent example is the current Continuous Descent Approach (CDA) procedure 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 separation is increased because ATC has to release the aircraft in an early phase of the approach, which reduces the predictability of its arrival time over the runway threshold. The large separation intervals of the current CDA limits the application of this procedure to the night-time period, when traffic densities are low.



Preliminary ATC display tool that depicts on the extended centre line of the runway the positions of aircraft on Continuous Descent Approach paths

NLR is now developing a new approach concept, the Advanced Continuous Descent Approach (ACDA). The idea behind the ACDA concept is to maximise the utilization of the potential noise benefits of the CDA procedure by developing tools that provide the cockpit crew and the air traffic controller with more accurate control of the arrival time over the runway threshold. The ACDA separation intervals can then be restored to the level of conventional approaches, which makes ACDA applicable during more busy periods of an airport. The ultimate goal is to end up with an ACDA procedure that can be used even during peak hours.
Software has been developed for a first version of an ACDA mode in the Research Flight management System (RFMS) of the Boeing 747-400 flight simulator model. Successful operation of this ACDA FMS mode was demonstrated on the RFS. A preliminary ATC display tool that depicts all positions of aircraft flying different CDAs on the extended centreline of the runway for the air traffic controller was developed.

Procedures for Decreasing the Impact of Noise
In the EU project Study of Optimization Procedures for Decreasing the Impact of Noise (SOURDINE), new flight procedures that lead to the reduction of noise in the vicinity of airports and requirements for supporting tools are defined. The consortium that carries out SOURDINE includes ATC system providers, research centres, an airframe manufacturer, an airline, civil aviation authorities (including RLD) and airport authorities, with support of ATC agencies. NLR is a major contributor 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 being considered. The effects of some short-term procedures have been evaluated for several airports: Amsterdam Airport Schiphol, Napoli Capodichino and Madrid Barajas.

Schiphol Approach
Research on three Technical Operational Measures at Schiphol (TOMS) was carried out under contract to the RLD. These measures concerned reduced-flaps approach, 3.2-degree 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 on the reduced-flaps approach and the 3000-ft final approach altitude show that modest noise benefits can be achieved by these measures. KLM has already implemented the reduced-flaps approach.

A supplementary study carried out in consultation with RLD and LVNL into possible adverse effects of the 3000-ft approach on airport capacity showed that no serious capacity reductions have to be expected. The implementation process of this measure will start after the results of a safety assessment study will be available.

The 3.2-degree 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-degree standard ILS Glide Slope value, political problems are foreseen if this measure were introduced.

Rotorcraft Procedures
NLR participated in the EU Fourth Framework project RESPECT (Rotorcraft Efficient and Safe Procedures for Critical Trajectories). The objective of the RESPECT project is to develop improved take-off and landing operations for helicopters. A common, validated performance simulation code has been established, which has been used to optimize the trajectories analytically. The practical feasibility and repeatability of new procedures will be substantiated by means of piloted simulations and flight tests.

Helicopter Aeromechanic and Aeroacoustic Interactions
NLR participated in the EU Fourth Framework project HELIFLOW (Improved Experimental and Theoretical Tools for Helicopter Aeromechanic and Aeroacoustic Interactions). Ground vortex predictions were performed for a wind tunnel model test set-up of the BO-105 in the DNW Large Low-speed Facility (LLF).

Flare trials with a Lockheed C-130 Hercules of the RNLAF

Wake Vortex
The WAVENC (WAke Vortex evolution in the far wake region and wake vortex ENCounter) project was almost finished. 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 enable the wake effects of heavy aircraft on the safety and separation distances of following aircraft to be investigated.

Work NLR performed together with Aerospatiale Matra Airbus has included the implementation and validation of simulator set-ups at both companies, as well as the execution of encounter simulations. NLR made wake encounter simulations to assess worst-case scenarios, which supported pilot-in-the-loop simulations performed at Aerospatiale Matra Airbus.

Military Crew Station Design
The RNLAF was supported by studies aimed at identifying the state of the art of the use of Night Vision Displays. Information from technical, physiological and pilot's points of view was gathered.

Self-Protection Electronic Warfare
The Chinook and Cougar helicopters were provided with self-protection means for operations in Kosovo. Support was provided in determining the best installation positions and in determining the best countermeasure program settings.

In on-going series of field trials, the results of an international trial on flare effectiveness for fighter aircraft, carried out at Sardinia in 1998, and a national trial on flare effectiveness for helicopter and transport aircraft were assembled. One national trial was carried out to determine chaff performance and countermeasure effectiveness. In this trial, helicopters and fixed wing aircraft of the RNLAF and RNLN participated. Preparations were made for trials on flare effectiveness for helicopters and for participation in an international trial on Electronic Counter Measures (ECM) effectiveness.

Military Operations
The RNLAF was supported with the analysis of the tactical performance of weapon systems, fighters, helicopters and ground-based air defence systems, and the production of Tactical

Allied Force action

Manuals. The introduction of the RNLAF Flycatcher as a ground-based threat in the Low Flying Training Area in Goose Bay, Canada, was supported. Instruction material and lessons were provided to the Tactical Evaluation and Standardization Squadron, and a new set of lectures for an intelligence personnel course was developed. Also lessons on fighter performance and weaponeering were given at the NATO Tactical Leadership Programme and at the NATO school in Oberammergau.
The air-to-ground part of the F-16 participation in the operation Allied Force was evaluated, with a focus on weapon employment effectiveness.

Furthermore the RNLAF was supported in a number of activities with regard to possible improvement of the present operational capabilities, weapon stock planning, and the provision of threat and own weapon system data for training support equipment.

Aircraft Certification

Helicopter-Ship Qualification Testing

Under contract to the Royal Netherlands Navy, NLR was tasked to organize a test campaign to determine the Ship Helicopter Operational Limitations (SHOLs) for the Sea King helicopter on board the Landing Platform Dock (LPD) Hr. Ms. Rotterdam.
Flight trials to be carried out in a co-operative programme, involving DERA Boscombe Down, the Royal Navy, the RNLN and NLR were prepared.

F-16 MLU with navigation and targeting pods, in certification programme

A study was carried out in order to support the selection of wind measuring systems for RNLN ships so as to be optimal functional during shipborne helicopter qualification and operation.

Certification of F-16 Equipment.

The certification programme for the navigation and targeting pods for the F-16 was continued. To enable the targeting pod to be used during the Operation Allied Force, part of the certification process was accelerated, which resulted in a provisional airworthiness certificate. Most of the flight tests have been carried out.
Work was started to extend the separation envelope for external fuel tanks of the F-16.

Helicopter Support to the Royal Netherlands Air Force

Support to the Royal Netherlands Air Force (RNLAF) in the area of the CH-47D Chinook Avionics Control & Management System (ACMS) improvement, including the integration of a new radio, was continued.

Support was given in the certification process of the Netherlands AH-64D Apache helicopter. A mathematical model of the AH-64D Apache helicopter is under development This flying qualities simulation model is being implemented in the FLIGHTLAB engineering software environment. Static validation has provided satisfactory results.

NLR supported the RNLAF with the integration and certification of a new Electronic Warfare system on the Chinook CH-47D and Cougar AS-532U2 helicopters. The activities included structural verification, EMC/EMI tests and in-flight evaluations of handling qualities and operational aspects.
A plan was drafted for a certification programme for operating RNLAF Cougar helicopters onboard the Landing Platform Dock (LPD) Hr.Ms. Rotterdam of the RNLN.

Certification of UAVs

The work on the airworthiness certification of the Sperwer Uninhabitated Aerial Vehicle (UAV) for the Royal Netherlands Army continued. Also support was provided with the preparations for operational use.

Sperwer Uninhabitated Aerial Vehicle taking off, in certification programme

The Belgian Army, in concert with the Netherlands, was supported in the certification of the Hunter UAV.

Aircraft Maintenance

Automatic In-flight Data Acquisition

In the framework of the Lynx helicopter life extension programme, the RNLN was supported in certifying and introducing in service one of the new maintenance applications foreseen with the use of the AIDA (Automatic In-flight Data Acquisition) system.

HUMS Cougar

The Health and Usage Monitoring Systems (HUMS) technology project was completed. One of the work packages concerned setting up a Cougar HUMS ground station. The station, including computer and software is operational at NLR for scientific HUMS support to the RNLAF. In co-operation with the RNLAF, HUMS and maintenance-related problem areas were identified and transformed into a list of applications for this new facility.

HUMS F-16

One of the work packages of a national HUMS project concerned the development of a series of models for improving F-16 engine component life prediction as based on monitored real flight data. A thermodynamical engine model, which provides information required on engine component operating conditions such as turbine inlet temperatures and pressures, was developed in the Gas Turbine Simulation Program (GSP) environment.

Prognostic Health Monitoring

For the Prognostic Health Monitoring (PHM) project, knowledge in the domain of gas turbines was maintained, and supplied in a number of presentations. A number of gas turbine PHM technology projects were defined and assessed in co-operation with the JSF prime contractors. A proposed GSP simulation of a Short Take Off and Vertical Landing (STOVL) lift-fan propulsion system has come to an advanced stage. Projects to demonstrate data-mining technology with gas turbine engine operations were defined.

Human Factors in Aircraft Maintenance

In previous and ongoing European (EU) and national (RLD) research projects, a large number of human factors issues in aircraft maintenance were identified, leading to insight in specific areas that need further attention in order to improve the efficiency and safety of task execution in maintenance.

The Aircraft Maintenance Procedure Optimization System (AMPOS) project carried out under the EU ESPRIT programme focuses on organizational learning. It has the objective to develop a prototype Information Technology system for sharing information about maintenance processes and determining the effectiveness of adapted measures. The system will establish communication links between different departments of the maintenance organization and between the maintenance organization and the manufacturer, with respect to issues that are possibly related to human factors problems, as opposed to technical issues for which communication is currently in place. Smart data mining tools will be incorporated in the system that will operate on the systems database and external maintenance databases in order to identify problems and recognize related cases. NLR is responsible for the system development phase.

In the area of design for maintainability, research is undertaken in the DESMAIN project funded by the NIVR. The objective of DESMAIN is to improve the error tolerance of aircraft design and system design by ensuring cognitive consistency of the maintenance task. The project is a logical extension of the ergonomic checks the aircraft industry has already adopted, which, for example, have ensured better accessibility of aircraft systems in modern aircraft than in their forerunners of the 1970s.

The ongoing EU Leonardo da Vinci project Safety Training in the Aircraft Maintenance Industry (STAMINA) covers the training area in aircraft maintenance. A training set consisting of five modules that cover the individual, task, team and organizational aspects of aircraft maintenance was developed. Each module includes separate training for different categories of maintenance personnel. NLR designed and developed the task module that addresses the task-related human factors issues. This module teaches the maintenance engineer to recognize human factors aspects in specific tasks and then to select and execute an appropriate error-reduction or recovery strategy. For this module NLR used its own training development methodology that had demonstrated its usefulness in the EU project Consequences of future ATM on Selection and Training (CAST). The resulting training is scenario-based, highly interactive and easily re-usable when changes to the training are required because of future system changes.

A study was started into ways of integrating Human Factors and technical training. The resulting integrated training will be in compliance with Joint Airworthiness Requirements JAR-66 and will reduce the training time required per employee. Thereby it will reduce training planning problems and cut associated costs while improving training effectiveness. The study addresses both maintenance continuation training and vocational education.

Work on procedural non-compliance was continued by means of research in base maintenance contracted by the RLD. Results of this national study were analysed and compared with the European situation. In a related NLR study, the development of a new concept for personalized and portable maintenance documentation continued. A physical demonstrator of a portable maintenance aid showing a possible Human Machine Interface (HMI) using the functionality of the proposed concept was realized. The concept shows potential to increase procedural compliance, to reduce the required turn-around and aircraft repair times, and hence is expected to lower the costs of maintenance.

Aircraft and Manning Issues

Operational Military Training

The RNLAF was supported in the identification of the availability of training services for the transport helicopter aircrews. On the basis of specific operational tasks, training and related simulator requirements were defined and incorporated in a Request For Quotation (RFQ). Industry responses to the RFQ were evaluated and reported.

Pilot Feedback and Debriefing Tools

For the Netherlands Ministry of Defence, the effects of feedback on pilot's performance and safety are studied in a multi-year project. This project is carried out in collaboration with the Polish Air Force Institute of Aviation Medicine and the Netherlands Aeromedical Institute. The main goal of 1999 was the preparation of an experimental flight environment using the Slingsby aircraft in which flight data, pilot input data and pilot physiological data are combined and fed back to a student pilot using computer-aided multi-media devices. For this purpose a Slingsby aircraft has been prepared with an inertial platform and differential GPS capability as well as the capability to record physiological data of the student pilot.

Effort has been put in realizing a feedback tool based on a computer simulation of the last flown flight combined with a feedback provider to enhance overall training effectiveness.

Aircrew Mission Training via Distributed Simulation

NLR participates in the Military Application Study SAS-013 'Aircrew Mission Training via Distributed Simulation' of NATO RTO aimed at the assessment of the potential of advanced distributed simulation to complement live flying training in order to enhance NATO capability to conduct combined air operations. The study team, comprising operational members, researchers of pilot performance and training, and simulation engineers from eight NATO nations, will recommend that NATO should pursue the concept of Aircrew Mission Training via Distributed Simulation (MTDS), as it holds promise as a method for substantially improving NATO's effectiveness in air operations. The Netherlands is represented by both NLR and TNO-FEL. NLR's contribution has focused on suggesting a method for implementation of a MTDS concept, and on the specification of training needs associated to inter-team skills.

Airport Movement Management

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

The EU project CAST, Consequences of future ATM systems for air traffic controller Selection and Training, has been conducted by an international consortium, led by NLR, which has presented its results.

Stress in Air Traffic Management (ATM)

Stress in ATM (SRATM), an EU project on tonic, i.e. long lasting, changes in stress levels as a consequence of changes in working conditions for air traffic controllers, is carried out jointly by a consortium of German, Hungarian, Greek, Spanish and Dutch partners. Traditional and advanced ATC systems, or versions with electronic flight stripes, are monitored during actual or simulated operations, and measurements are taken concerning heart rate, blood pressure, etc.

ATC/ATM Controller Human Machine Interface

In collaboration with Eurocontrol, National Air Traffic Services Ltd (NATS), CENA and LVNL, the PHARE Ground Human Machine Interface (GHMI) project was finished. The PHARE system is an experimental controller working position designed for the period 2010-2020. A comprehensive evaluation of the project, including participation in workshops, was done.

Free Routing

Free Routing is one of the future ATM concepts being explored as a means to accommodate the air traffic growth and reduce the congestion over northern Europe. Under likely Free Routing scenarios, the air traffic controller would continue to play an important, albeit new, role. This role would raise a number of potential human performance problems. Under Eurocontrol's Eight States Free Route Airspace Project (FRAP), NLR has been assessing human performance and workload implications of Free Route operations. Real-time, controller-in-the-loop simulations were used to explore how free routing impacts the performance of the controller under normal and error mode conditions. Performance was assessed through a comprehensive battery of physiological, subjective, and system performance parameters.

Education

The Delft University of Technology was supported in educational tasks. Lectures and workshops on gas turbine performance were given, and further developed. MSc graduates were coached.

3.3 Air Transport

Summary

National and international aerospace clusters, including authorities, airport operators, airlines and air traffic control providers received support on technological developments, and on the design and modification of airport and airspace layout, to increase airport capacity and efficiency. Studies on airport capacity and controller workload have been carried out using the fast-time simulation tool Total Airspace and Airport Modeller (TAAM). To extend the activities in this area, NLR is developing a Tower Research Simulator. While under development, this simulator has been used to support activities such as the development of runway incursion alert systems and taxiway conflict monitoring systems.

NLR won a contract to build a highly representative fast-time simulation model of Amsterdam Airport Schiphol and the Netherlands airspace, called Dynamic Capacity Model Schiphol. This project is funded by Amsterdam Airport Schiphol (AAS), Air Traffic Control the Netherlands (LVNL) and the home carriers of the Netherlands. The Dynamic Capacity Model Schiphol will be used for studies on capacity and other issues on and around Schiphol. Studies concerning new ATC sector layout and additional holding locations were carried out.

NLR was also involved in airport technology projects on Surface Movement Guidance and Control Systems (SGMC), such as 'SMGCS Airport Movement Simulator' and 'A-SMGCS Testing of Operational Procedures by Simulation', partly funded by the European Union. In both projects, benefits of new airport automation tools were demonstrated in complex and multisite simulations.

Several projects in the field of Communication, Navigation, Surveillance (CNS) and policy have been conducted to support the Netherlands Department of Civil Aviation (RLD) in Air Traffic Management safety and concept validation. In some of these projects NLR made use of the NLR ATC Research Simulator (NARSIM) and the Traffic Organization and Perturbation AnalyZer (TOPAZ). For the EU projects 'European pre-Operational DataLink Applications' (EOLIA) and 'Prototype Aeronautical Telecommunications Network' (ProATN), successful in-flight datalink demonstrations over the Aeronautical Telecommunications Network (ATN) were performed at the Paris Air Show. These demonstrations were followed by in-flight evaluations addressing Human Machine Interface aspects and datalink procedure acceptance as well as flight plan consistency checks.

Work regarding air transport and the environment focused on air pollution, noise exposure and the monitoring of environmental aspects.

The AERO (Aviation emissions and Evaluation of Reduction Options) consortium, consisting of Resource Analysis of the Netherlands, MVA of the UK, and NLR, applied the AERO model in a study for the analysis of European fuel taxation. Taxation would lead to tankering, heavier loaded aircraft and therefore more emissions. The competitiveness of the airports and airlines involved would be affected.

In the re-design of the methodology of noise regulation around Amsterdam Airport Schiphol, NLR assisted the RLD by providing noise exposure characteristics for transport scenarios for 2003 and 2010. Also a comparison was made between the currently used Dutch Kosten unit and the day-evening-night-equivalent noise level (L_{DEN}) which is expected to become the standard in the European Union.

In a consortium with TNO (Netherlands Organization for Applied Scientific Research), DUT (Delft University of Technology) and NLR, an extensive research programme was started on determining aircraft noise exposure based on measured noise levels rather than calculated noise levels. This programme focuses on guidelines for measuring noise exposure in urban areas and guidelines for noise measurements to validate the Dutch calculation method. Also the applicability of acoustical microphone arrays is under investigation.


Testing an Air-Ground Digital Datalink in the Cessna Citation II research aircraft of NLR, in a European collaboration

The functionality of the Flight track and Aircraft Noise Monitoring System (FANOMOS) was extended with a fully centralized input processor system, enabling flight data of Amsterdam Airport Schiphol, Rotterdam Airport and Maastricht-Aachen Airport to be processed continuously (see also section 3.6).

Many calculations for third party risk analysis around airfields were carried out, most notably for Schiphol. A model update and associated risk exposure calculations were completed to provide the government with data required for a decision on the future of Amsterdam Airport Schiphol. The Metro II research aircraft was used to perform in-flight testing of navigation and landing aids in the Netherlands.

Air Traffic Management

In December the Netherlands government has decided that the national airport Schiphol is allowed to grow while remaining within the boundaries of specific environmental and safety requirements that protect the surroundings of the airport. Accomodating the growing number of movements within the restrictions requires the development of special operational techniques and technology. NLR conducts several projects to support these developments, under contract various customers.

Communications

NLR took part in the European projects 'pre-Operational DataLink Applications' (EOLIA) and 'Prototype Aeronautical Telecommunica-tions Network' (ProATN) projects, co-funded by the European Commission (DG-13), EUROCONTROL and the consortium members, with NLR performing successful in-flight datalink demonstrations over the Aeronautical Telecommunications Network (ATN). The Cessna Citation II research aircraft of NLR has been equipped with an Aérospatiale Air Traffic Services Unit (ATSU) data communications computer, hosting ATN software compliant to Standard and Recommended Practices (SARPs) set by ICAO, a Rockwell-Collins Multifunction Display Unit, Smiths Industries Datalink Control Display Unit and a Racal/Honeywell Satellite Data Unit. This equipment was supplemented by the NLR proprietary avionics, most notably the NLR Research Flight Management System (RFMS). At the 1999 Paris Air Show, NLR aircraft performed daily in-flight demonstrations exchanging Air Traffic Control (ATC) data communication messages and navigation data with the EOLIA/ProATN ground station of Airsys-ATM.

In December, NLR performed in-flight datalink evaluations with the Citation II and two ground stations, the NLR ATC Research Simulator (NARSIM) and the Airsys ATM ground station in Paris. The evaluations addressed datalink HMI and datalink procedure acceptance in general with a focus on the ATC Communications Management (ACM) service. ACM allows 'silent handovers', a semi-automated aircraft handover from one ATC centre to another. In addition, NLR demonstrated the Flight Plan Consistency check (FLIPCY), which allows the ground system to make a comparison between the filed ATC flight plan and the airborne flight plan.

Early 1999, NLR performed the 'DAP Reduced R/T Experiment' under contract to EUROCONTROL. The experiment results have been used by EUROCONTROL for a Cost-Benefit Analysis for Mode S enhanced surveillance radar system. Enhanced surveillance is an additional functionality of Mode S that enables airborne parameters such as airspeed and heading to be downlinked. The objective of the analysis was to find out whether the downlinked parameters could contribute to the Air Traffic Management process in terms of increased capacity and flight efficiency.

The experiment, at the NLR ATC Research Simulator (NARSIM), comprised several test runs with four operational air traffic controllers. The objectives of the simulations were to investigate whether the presentation of the downlinked indicated airspeed and heading would reduce the controller Radio Telephony (R/T) taskload, and would influence the capacity and flight efficiency. The results indicated a significant decrease in R/T taskload while the other effects remained rather small. One remark from the controllers was that in order to benefit from the additional information maximally, specific working procedures should be developed.

Navigation

Under contract to the Netherlands Department of Civil Aviation (RLD), NLR assisted in a campaign for the implementation of GPS-based approach procedures at airports in the Netherlands. Trials were conducted at runways 04 and 22 of Maastricht Aachen Airport and at runway 06 of Amsterdam Airport Schiphol. In close co-operation with the airlines KLM-Exel and Transavia, NLR collected radar data and workload evaluation forms from pilots of selected scheduled flights. Using these data, the pilot workload and the spread of tracks in the final approach segment were compared in order to analyse economic benefits and safety and environmental aspects (see also section 3.6). Complementary to this study NLR has carried out a qualitative safety evaluation of the use of GPS for non-precision approach operations in Germany for the German ATC organization *Deutsche Flugsicherung* (DFS).

A risk identification study has been performed for the potential reduction of longitudinal separation on final approach with the application of the Microwave Landing System (MLS).

In a study on the potential use of a Local Area Augmentation System (LAAS) at Amsterdam Airport Schiphol, specific attention was given to four operational concepts: 4D area navigation, advanced surface movement guidance and control operations, runway segregation, low visibility operations and advanced operations. This study was performed under contract to the RLD and in collaboration with the US research organization MITRE.

Surveillance

The project Datalinking of Aircraft-Derived Information (DADI), partly funded by the European Commission, was conducted by a consortium of European research establishments and industrial partners. The consortium was led by NLR, and the project explored the general concept of datalinking of aircraft-derived information to ensure it meets the requirements of ATC providers, airlines and other airspace users. DADI was first concentrating on determining the type of information needed to be exchanged between the ground and air systems. Subsequently a comparative analysis has been made in order to demonstrate the capability of the pre-operational technologies and data link services to provide the information.

The ultimate objective of DADI was to contribute to the enhancement of airspace capacity and safety, by evaluating the use on the ground of various types of information available from aircraft. The project's approach was to explore, in various near-operational scenarios, how to provide aircraft-derived information for the highest priority requirements of various types of ground-based users. Three complementary evaluation sites were set up to investigate concepts, to evaluate implementation options and to assess user benefits in various operational scenarios. These evaluation sites were set up in France, Norway and the Netherlands.

The evaluation in the Netherlands by NLR was based on real-time simulations with use of NARSIM, and was designed to qualify and quantify the benefits of aircraft data in surveillance and medium-term trajectory prediction in high air-traffic density airspace. Attention was paid to Human Machine Interface aspects on the ground and direct benefits to reduce controllers' workload. To supplement these practical evaluations, the 'TOPAZ' (Traffic Organization and Perturbation AnalyZer) tool has been used to assess analytically the capacity and safety benefits of DADI concepts.

Initial, complementary, pre-operational trials were undertaken to demonstrate and verify the user benefits of Downlink of Aircraft Parameters (DAP) in remote and en-route areas.

ATM Policy Support and Consultancy

The Netherlands Department of Civil Aviation (RLD) took the initiative to contribute to the design and development of ATM in order to support parties involved in ATM in the Netherlands in enhancement activities. An advanced and enhanced ATM system will ensure that ATM service providers LVNL, Maastricht UAC and MilATCC obtain increased capacity to cope with increasing demand and other critical elements such as safety, economy, punctuality and environmental issues. In a structured top-down approach, a concept was developed for the future development of ATM in the Netherlands, taking into account the present status of ATM and ongoing research in the Netherlands, in Europe and in the world. It was recommended to establish a framework for ATM developments on the basis of this concept, and to investigate on a case-by-case basis the possibility to link present ATM projects or programmes to this framework.

NLR continued its participation, partly funded by RLD, in ARDEP (Analysis of Research & Development in EUROCONTROL Programmes), where a group of organizations from several European countries provide information regarding their R&D activities in order to support the policy and decision makers at national as well as European level.

In 1998 EUROCONTROL published a strategy to streamline the validation of the European Air Traffic Management Programme (EATMP), the programme to improve Air Traffic Management (ATM) in Europe. One of the recommendations was to develop a Validation Data Repository (VDR), which would contain easily accessible information on projects related to ATM validation. The first VDR development steps were to demonstrate its need and benefits, and to obtain a well-founded set of user requirements. These were the goals of the VALERY project (Study for the Development of a prototype Validation Data Repository), performed for EUROCONTROL by a consortium of NLR and two Italian partners. Using a Prototype VDR that was distributed among potential users, two main groups of users with specific interests were identified. Managers and planners, responsible for the validation of the EATMP, would use the VDR to generate overviews to support decision making. Engineers, setting up and conducting ATM validation exercises, would use the VDR to select the most suitable options for their own ATM validation exercise, and to obtain qualified validation input data. The results of the VALERY study, the consolidated user requirements in particular, are used by EUROCONTROL to make a business case for the further development of the VDR.

A study was conducted to examine the feasibility of curved approaches and the technology needed. The study was carried out under contract to the RLD and in close co-operation with the American research institute The MITRE Corporation. The results of the study were based on the assessment of prior work involving curved approaches and the considered opinion of specialists from NLR and MITRE. Both the noise and the economic impact of utilizing curved approaches were considered, for Amsterdam Airport Schiphol and for a new offshore airport in the Netherlands. It was determined how curved approaches could reduce the distance that a new island airport would have to be from the coast of the Netherlands, minimize noise and reduce airport construction costs. Operational benefits of the use of curved approaches at both Schiphol and the new island airport were also identified.

A conclusion from this study was that curved approaches have the potential to reduce the noise load on the ground significantly, especially if they are combined with noise abatement procedures in the vertical plane, for example Continuous Descent Approaches. However, more detailed research remains necessary to assess the feasibility and benefits of curved approaches.

NLR continued to participate with research and technological development activities in various ICAO Panels, thereby representing the LVNL and RLD. These panels are the Secondary Surveillance Radar (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 each panel are reported to the LVNL and RLD, and serve as input for their policy in the specific technical areas, while the technical details can be further used by NLR to maintain its knowledge.

Air Trafic Control

NLR participated in the project Capacity Increase through Computer Assistance Tools (CINCAT) of the EU, carried out by a consortium consisting of European research establishments and industrial partners. The main objective of the project was to produce, up to a pre-operational standard, a set of computer tools for assistance in air traffic management, in order to increase the European airspace capacity. The tools were derived from PHARE (Programme for Harmonized Air traffic management Research in EUROCONTROL), and national programmes, and comprised: Trajectory Predictor, Conflict Probe, Flight Path Monitor and Co-operative Tools. The Trajectory Predictor calculates an aircraft's predicted future trajectory, including uncertainty data. The Conflict Probe compares trajectories and identifies potential infringements. The Flight Path Monitor, whose architecture was designed by NLR, monitors the actual progress of aircraft and identifies those deviating from their predicted trajectories. The Co-operative Tools provide the controller among other things with the capability to display only those aircraft relevant to the solution of a conflict, and with an activity predictor displaying the controller's future activities on an agenda.

These CINCAT tools have been integrated on the Platform for ATM Tools Integration up to Pre-Operation (PATIO), based on a Client/Server model and relying on standardized interfaces for communication. PATIO has also been developed within the European Commission's Fourth Framework Programme. Some of the CINCAT tools, such as the Flight Path Monitor, will be re-used in the EU project AVENUE (ATM Validation Environment for Use towards EATMS).

Modelling and ATM Concept Validation

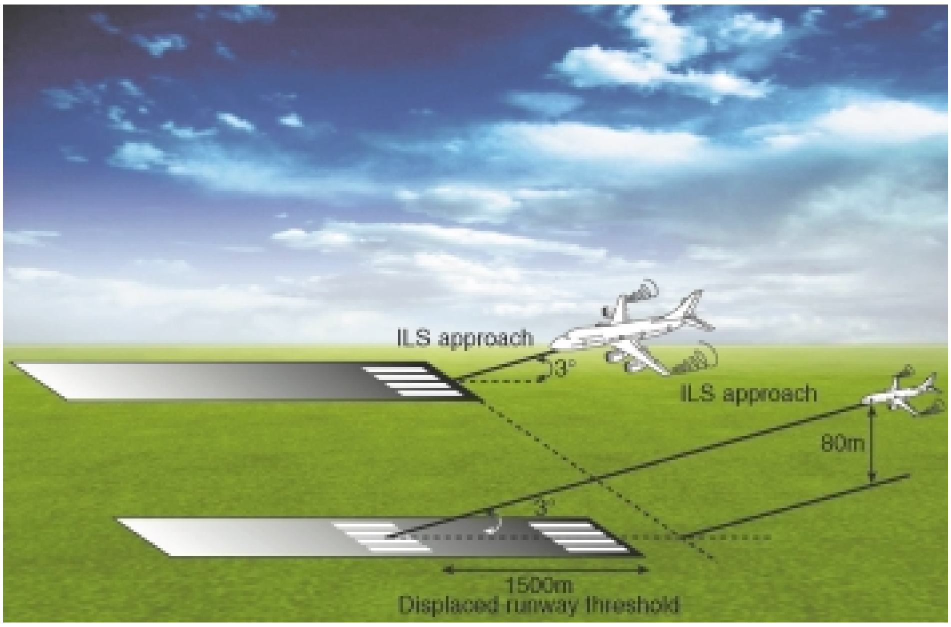
Projects in the field of modelling and ATM concept validation concerned the development and demonstration of model-based validation of concepts, in combination with a consistent description of the validation methodology. ATM safety responsibilities end up with the human elements in the responsibility chain, air traffic controllers and pilots. Understandably, ATM service providers and airlines therefore have difficulties accepting any new system, procedure or operation that potentially reduces the controllability of various non-nominally evolving traffic situations, while their responsibility increases with traffic volume. A systematic way to manage these paradoxical developments that lead to lower controllability and higher responsibility is required.

The EU project ARIBA (ATM system safety criticality Raises Issues in Balancing Actors responsibility) has been co-ordinated by NLR. Several certification issues in ATM have been addressed. A cost-effective methodology for ATM safety validation throughout all life-cycles has been identified through a comparison of the results of earlier ATM validation studies and of

studies on other domains including nuclear, finance and ground transport.
The applicability of Safety Management, Safety Cases and safety assessment methodologies, which are supported by tools such as TOPAZ (Traffic Organization and Perturbation AnalyZer) and SAM (Safety Argument Manager) has been evaluated. A harmonization approach towards responsibility issues that are related to system safety criticality has been developed. This approach includes the development of a framework for the operational introduction of ATM enhancements.

Using its Traffic Organization and Perturbation AnalyZer (TOPAZ) methodology, NLR has executed a safety assessment study for *Deutsche Flugsicherung* (DFS) for a new approach procedure, High Approach Landing System (HALS), at Frankfurt Airport. HALS will be introduced to increase capacity by reducing unnecessary wake-vortex separation distances for aircraft on final approach using two parallel dependent runways. Since wake vortices very rarely rise above their originating point, the idea of HALS is to separate the traffic flow such that all medium weight aircraft fly approximately 80 metres above the glideslope of the right-hand runway, which is used by all heavy aircraft. The threshold of the left-hand runway is displaced by 1500 metres. For this new procedure, TOPAZ was used for a collision risk assessment for simultaneous missed approaches on the two parallel runways and for missed approaches interacting with aircraft waiting on another runway nearby. TOPAZ has been extended with a probabilistic wake vortex model to assess the wake vortex induced risk for staggered aircraft approaching the two parallel runways. Safety feedback and recommendations have been produced to support the developers in their further optimization of the HALS operation (see also section 3.6).

The inclusion of manually entered EFL (Executive Flight Level) inputs in the STCA (Short Term Conflict Alert) algorithm has been evaluated under contract to the LVNL. A set-up consisting of two synchronized ATC simulations, using NLR's Air Traffic Control Research Simulator, NARSIM, running the same scenario was used. One simulation displayed the current day practice of STCA as it is used by the LVNL in the AAA (Amsterdam Advanced ATC) system, and the other one displayed an identical simulation with the controller's EFL input included in the STCA algorithm. The simulations were presented to several LVNL controllers and showed that manual EFL information can be used in the STCA algorithm to reduce the number of nuisance alerts.



High Approach Landing System (HALS), assessed for Frankfurt Airport

Airspace

The LVNL contracted NLR to study the effects on air traffic controller workload and airspace sector capacity of a changed utilization of Sector East due to changes in the German airspace structure. The LVNL also asked NLR to study the impact of two additional holding areas within the Dutch FIR on air traffic controller workload and sector capacity.

For the Spanish ATC organization AENA, studies were carried out on re-sectoring of parts of the Spanish airspace, as well as improved ATC operational usage of the Barcelona Terminal Manoeuvring Area (TMA) to increase the capacity of Barcelona airport. Also a study was carried out to study the impact of new flight routes and sector configurations for the air shuttle between Madrid and Barcelona.

Multi Sector Planning

Under contract to the EUROCONTROL Experimental Centre, NLR evaluated through its TAAM® facility numerous operational ATC scenarios and their effects on delay, punctuality and capacity, in the project TOSCA (Testing Operational Scenarios for ATM). NLR has led the task to identify a limited set of variables (dimensions) that can be used to describe concepts of Multi Sector Planning (MSP). In this task MSP refers to any operational approach which applies Air Traffic Management (ATM) to an area which has more traffic than a typical current (1999) sector. Through a human factors approach the set of dimensions was extended further.

Airports

Airport and TMA Operations

Under contract to Amsterdam Airport Schiphol, assistance was given to the Project Optimization Schiphol, an initiative from several Netherlands airlines, LVNL and Amsterdam Airport Schiphol. NLR's contribution consisted of advice on runway and airspace utilization issues.

NLR was asked by the *Mediationsgruppe Erweiterung Flughafen Frankfurt* to provide an independent expert opinion on capacity calculations carried out by the U.S. FAA Technical Centre of possible future Frankfurt airport configurations. The *Mediationsgruppe* occasionally asked NLR also to participate in public hearings to provide its opinion on airport and related ATC issues.

Airport Automation

Together with the Holland Institute for Traffic Technology (HITT), NLR developed and implemented an operational Taxiway Collision Monitoring (TCM) system, an operational subsystem to support tower controllers in runway monitoring and conflict detection tasks, for the Manchester, UK, airport. Assistance was provided to the LVNL in the project Implementation Schiphol Advanced Airport Surveillance (ISAAS). Also research work was started for a demonstration and concept evaluation facility for the development of a Runway Incursion Alert System, dubbed MORIASS. MORIASS features will be implemented on the NLR Tower Research Simulator (TRS) under development.

Along with several European partners, NLR participated in the EU project Surface Airport Movement Simulator (SAMS). This simulator platform was used for demonstration on the Tower Visual Simulator at DLR Braunschweig integrated with the Boeing 747 cockpit simulator of DERA Bedford and NLR's TRS computer system. SAMS will be used by the European Commission to test operational procedures of Advanced Surface Movement Guidance and Control Systems (A-SMGCS) (see also section 3.6).

Safety

Contaminated Runway Performance

NLR participated in the working group on contaminated runway performance of the Joint Aviation Authorities. The objective of this working group is to improve the current advisory material for contaminated runway certification. NLR has developed a new method for predicting the rolling resistance of aircraft tires on snow covered runways. The method was validated against full-scale experimental data obtained with NLR's Citation II research aircraft and other aircraft.

Crosswind Operations

NLR conducted a study on the safety aspects of crosswind operations under contract to TNLI (Future Netherlands Air Transport Infrastructure). The study gives insight into certification, operational use, and safety statistics of crosswind operations. The study has attracted international attention and has been quoted in internal safety magazines of a number of airlines worldwide.

Bird Strikes

An offshore island in the North Sea has been considered as a location of a new main airport for the Netherlands to accommodate the projected traffic growth. In general, islands are attractive habitats for birds, in particular sea gulls. Birds in the vicinity of airports are a potential hazard to the safety of aircraft, since bird strikes can lead to fatal aircraft accidents. NLR was therefore contracted by the Ministry of Transport to develop an empirical method for the prediction of fatal bird strike rates for an airport located on an offshore island. The method was used for risk assessment of bird hazards to civil aircraft for a proposed offshore island.

Development of Causal Models for Aviation Safety

NLR continued its efforts in the development of causal models for aviation safety analysis. A consortium of NEI, SAVE, Delft University of Technology and NLR, co-ordinated by NLR, has investigated the feasibility of the development of a causal model for the analysis of third party risk around airports. The investigation addressed static and probabilistic models and analysed the possibilities for dynamic modelling, and the modelling of management systems. Feasibility criteria included technical feasibility, relevance for policy development and possibility for linkage with existing national and international research projects.

The EU project Air Transport Safety Improvement through Quantitative Risk Analysis (DESIRE), co-ordinated by NLR, on the development of a methodology for risk assessment which includes cost/benefit analysis, was continued by linking causal factors of aviation accidents to associated cost factors. Using data from more than 1000 accidents, a model was developed for calculating the costs associated with accident consequences. These accident consequences provide the link between causal events on the one side of the model and the cost arising from the accident on the other. Generic event trees were developed to model the causal events that lead to accidents.

Safety of Air Cargo Operations

In co-operation with the RLD, the level of safety of air cargo operations was investigated and compared with the level of safety of passenger operations. Flight cycle data was combined with aircraft ownership information to establish utilization data for different types of operations. Accident rates were subsequently calculated for scheduled and non-scheduled passenger and cargo operations. This information was compared with results from platform inspections performed by RLD teams under the Safety Assessment of Foreign Aircraft (SAFA) programme. Recommendations were given to improve the safety level of cargo operations in developing countries.

Military support

Accident Investigations

NLR supports the Royal Netherlands Air Force (RNLAF) in the investigation of aircraft accidents. NLR staff forms an integral part of investigation teams, in particular to investigate technical and operational factors.

Two F-16 accidents were investigated, one of which involved a collision with a light general aviation aircraft. NLR also supported the Dutch Transportation Safety Board with the civil part of the investigation of this accident.

NLR also further 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 F-16 MLU.

A number of new aircraft and helicopter types have become operational with the RNLAF in recent years. The collection of type-specific information on these platforms was initiated.

NLR assisted the Royal Netherlands Navy in the investigation of a helicopter accident. The assistance mainly concerned wreckage analysis and the investigation of a main rotorhead fracture.

Aircraft Operations

Research Aircraft

Fairchild Metro II

The use of the Fairchild Metro II research aircraft continued to be intensive due to the carrying out of flight inspection of the radio navigation aids in the Netherlands. This activity, started in 1997, is performed under contract to Air Traffic Control the Netherlands (LVNL). In 1999 some 300 hours have been flown.
The aircraft was further used to fly instrumented GPS approaches for the EU project ECUREV (Definition of User Requirements and EGNOS Validation Tool Development), and for the EU project MAGNET-B (Multimodal Approach for GNSS-1 in European Transport).

Cessna Citation II

A number of flights have been made with the Phased Array Universal Synthetic Aperture Radar (PHARUS) for various purposes including further testing of interferometric use of the radar for research into two-dimensional deformation of objects on the ground, and in support of the analysis of data from the ERS satellite.
The aircraft was also used for currency training of RLD pilots, and for Air Traffic Management datalink research in the context of the EU EOLIA and ADS-B projects (see also section 3.7).

Transport and Environmental Studies

Air Pollution

The Intergovernmental Panel on Climate Change produced a report on ‘Aviation emissions and the global atmosphere’. Supported by the Netherlands government, NLR as Co-ordinating Lead Author was responsible for the chapter on Air Transport Operations and the Relation to Emissions. NLR co-organized an EREA/NASA symposium, for dissemination and discussion of the IPCC report in the European Union.

Under contract to the International Air Transport Association (IATA), NLR continued a study into operational measures for reducing aviation emissions, such as ATM improvements and optimization of flight performance. Information and views were obtained from airlines, EUROCONTROL, and global organizations such as IATA and ICAO.
NLR contributed to the thematic network on Identification of Aircraft Emissions Relevant for Reduction Technologies (AERONET) funded by the EU. AERONET’s expert group on Operations and Forecast of Air Traffic Development is co-ordinated by NLR.

For the RLD, a consortium consisting of Resource Analysis of the Netherlands, MVA of the UK, and NLR continued the development of the computer model for ‘Aviation emissions and Evaluation of Reduction Options’ (AERO).
Under contract to the European Commission, the AERO Consortium applied the model in a study for the analysis of European fuel taxation, showing that such taxation would lead to tankering, which would cause aircraft to be loaded heavier and therefore produce more emissions. In addition, the competitiveness of the airports and airlines involved would be affected.
Under contract to the European Commission, the study Aircraft Environmental Impacts and Certification Criteria (AEROCERT) into options for possible improvement of the existing certification procedures for emission of noise and exhaust gases was continued. The study is being carried out by several partners in Europe; NLR is project co-ordinator.
On behalf of the Netherlands Ministry of the Environment, NLR presented to the ICAO-CAEP Emissions Group a paper concerning the NO_x emissions around Amsterdam Airport Schiphol in the context of both national and international regulations. The paper showed the need for continued concern for the development of technology for reducing NO_x, to cope with more stringent European emission policy.

For Amsterdam Airport Schiphol, NLR in co-operation with TNO started a comparison of models for the calculation of local emissions in the surroundings of Schiphol.

In the framework of NLR's basic research programme, among other things a study into models for the dispersion of local emissions around airports was performed.

Noise Exposure

As in earlier years, NLR calculated aircraft noise exposure for several civil, military and regional airports throughout Europe. Not only the actual noise exposure was calculated and compared with legal noise limits, but also predictions were made for future scenarios.

The aircraft noise and performance database, which is part of Dutch noise exposure calculation guidelines was updated. The underlying categorization of civil aircraft uses both the aircraft maximum take-off weight and the aircraft noise performance. Several flight procedures were changed or added, for example ICAO-A procedures, Continuous Descent Approaches and reduced-flaps procedures. Noise and performance data were updated or added for several aircraft types and data for new aircraft types were added.

Future noise contours calculated for the region around Amsterdam Airport Schiphol

Under contract to Amsterdam Airport Schiphol, noise exposure calculations were performed for the Environmental Impact Studies for the configuration to be used until 2003. The Environmental Impact Studies serve to provide information for establishing new noise zones around Amsterdam Airport Schiphol to accommodate the growth in air traffic in the near future. Similar studies into the environmental consequences of additional or changed air transport infrastructure were performed for other airports.

A major subject was the re-design of the methodology of noise regulation around Amsterdam Airport Schiphol. NLR assisted the RLD by providing noise exposure characteristics for transport scenarios for 2003 and 2010 and by making a comparison between the currently used Kosten unit and the day-evening-night-equivalent noise level (L_{DEN}) which is expected to become the standard in the European Union.

A consortium of TNO, the Delft University of Technology and NLR started a research programme on determining aircraft noise exposure based on measured noise levels. This programme focuses on guidelines for measuring noise exposure in urban areas and guidelines for noise measurements to validate the Dutch calculation method. The applicability of acoustical arrays is also under investigation.

NLR performed research into the basic information required for noise exposure calculations, such as noise and performance characteristics and dispersion in flight tracks.

Monitoring of Environmental Aspects

Under contract to the Netherlands Ministry of Housing, Physical Planning, and the Environment, NLR has analysed the 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 LVNL, NLR worked on extensions of the functionality of the Flight track and Aircraft Noise Monitoring System (FANOMOS). A new, fully centralized, input processor system was realized, enabling flight data of Amsterdam Airport Schiphol, Rotterdam Airport and Maastricht-Aachen Airport to be processed continuously.

The quality of flight track reconstruction by FANOMOS was investigated by comparing flight tracks to high precision position data obtained from NLR research aircraft.

Under contract to the National Institute of Public Health and the Environment (RIVM), FANOMOS information was used to support studies on health impact studies related to aircraft noise.

Third Party Risk Analysis for Airports

A considerable effort was spent on the reassessment of parameters and the implementation of new insights in the third party risk model. A number of risk calculations were carried out with an adjusted model to aid the government in its decisions on the future of the Netherlands air transport. In the ongoing project under contract to the Ministry of Defence on the development of third party risk calculation methods and models for military airbases, new input data was collected from the archives of the United States Air Force.

Third party risk calculations were performed under contract to Amsterdam Airport Schiphol as part of an environmental impact analysis. Under contract to the RIVM, other third party risk calculations were carried out for Amsterdam Airport Schiphol. This work was part of the annual national review by the RIVM of the state and development of the environment. Third party risk calculations for Rotterdam Airport were performed, these are used in the decision making process regarding the future development of this airport. The third party risk model has been used for the first time in calculations for a small airfield, Zeeland Airport. A study on third party risk was performed as part of the capacity planning for Eindhoven Airport.

Facilities and Equipment

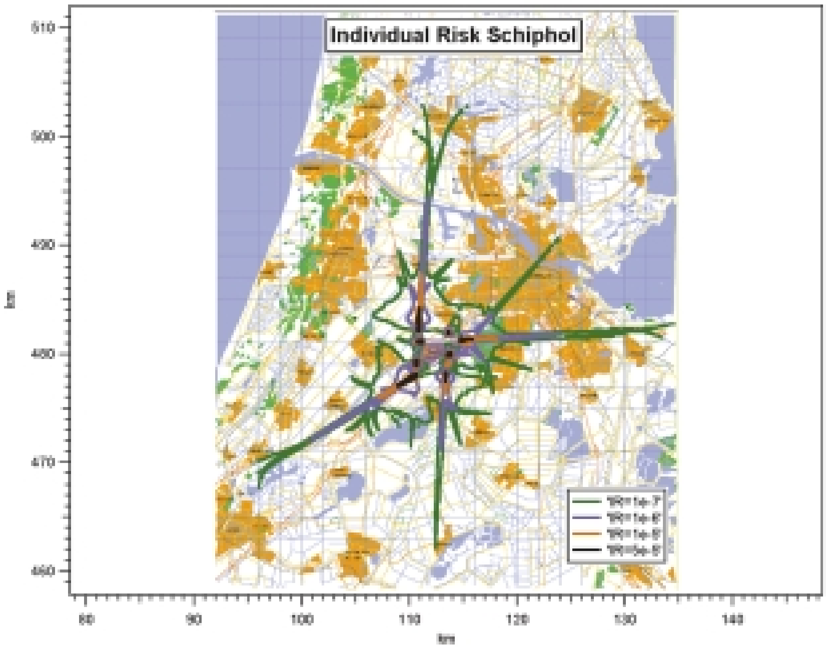
NLR Air Traffic Control Research Simulator

In a continuous effort, software has been developed to enhance the capabilities of the NLR Air Traffic Control Research Simulator (NARSIM) and to keep it up-to-date. Work on a new radar display interface was started. The scope of the activities includes the specification and implementation of a generic platform for the development of user interfaces, be they radar displays, pseudo pilot interfaces, ground traffic displays or any other type. Another software development consists of integrating the PHARE Demonstration 3 (PD/3) software into the NARSIM baseline software. NARSIM software has been used as a starting point for the Tower Research Simulator (TRS) NLR is building.

NARSIM has been used in several projects, some of which required expanding its capabilities. In the EU project DADI (Downlinking of Aircraft Derived Information), extensive Datalink simulation capabilities were developed, as well as a new Trajectory Predictor and an improved Human Machine Interface for displaying downlinked aircraft-derived information. The EU project Free Flight Flight Management System (3FMS) necessitated contributions to the development of extensive capabilities of simulation of datalink. In the course of the AVENUE (An ATM Validation ENvironment for Use towards EATMS) project of the European Union, a robust ASAS (Airborne Separation Assurance System) module was developed for simulation platforms.

Traffic Organization and Perturbation AnalyZer (TOPAZ)

The Traffic Organization and Perturbation AnalyZer facility (TOPAZ) assists safety assessment and model-based ATM concept validation studies. TOPAZ emphasizes an overall validation approach that views safety as the result of complex interactions between all ATM elements and supports effective feedback to an ATM design team. TOPAZ was used in several projects.



Calculated external risk around Amsterdam Airport Schiphol

Application results, know-how and an exhaustive explanation of the validation methodology were prepared for inclusion in a newly developed TOPAZ Information Management System.

Total Airspace and Airport Modeller (TAAM)
For the Netherlands air transport sector and under contract to Amsterdam Airport Schiphol, NLR developed a highly realistic fast-time simulation model of Schiphol airport using its Total Airspace and Airport Modeller (TAAM®) facility. With this model the sector uses a reference scenario to develop improvements in the operational use of Schiphol with respect to ATC procedures, airline timetables, airport maintenance and airport layout changes.

Future Aircraft Systems Testbed (FAST)
A new real-time computer system for the Cessna Citation as Future Aircraft Systems Testbed (FAST) was delivered.
The Research Flight Management System (RFMS), an internal NLR development for advanced FMS research) has been adapted for real flight applications within FAST. Care has been taken to ensure that the RFMS remains fully compatible with flight simulator applications, such that flight simulator research can be carried over to real flight experiments with minimum effort. At the end of the year the first version of RFMS was successfully deployed in the EU EOLIA/ProATN flight trials. A flightworthy, and generic, datalink functionality was developed. The FLAAS (Flexible Airborne ATN System) project provided a solid base for this development. Dedicated airborne datalink computer equipment has been ordered in order to realize this functionality for FAST, and to support the FLAAS project.

3.4 Structures and Materials

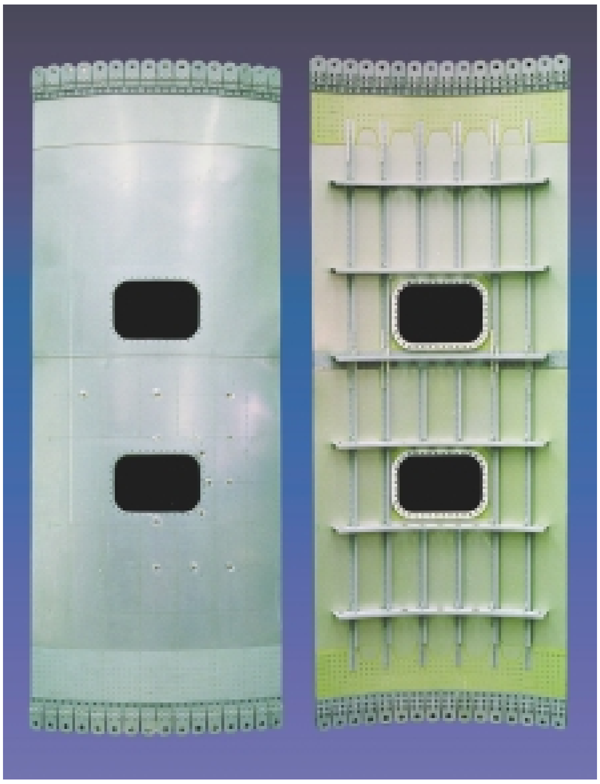
Summary

The start up of technology readiness projects, such as projects aimed at Dutch participation in the US Joint Strike Fighter (JSF) programme and new projects under the Fifth Framework Programme of the European Union, has significantly affected the activities in the area of structures and materials. Increased efforts of NLR in the GLARE® development and in the JSF projects nearly doubled the volume of technology projects under contract to the Netherlands Agency for Aerospace Programmes (NIVR), compared to 1998. A significant amount of contract research has been carried out also for the Royal Netherlands Air Force (RNLAF), the Royal Netherlands Navy (RNLN) and the Dutch aerospace industry.

Loads and Fatigue

Aircraft Loads and Certification

The one-dimensional modelling of atmospheric turbulence for gust load analysis prescribed in the current airworthiness requirements may not be adequate for future very large aircraft. In view of the broad interest in the possibilities of more realistic modelling, in which also spanwise variation of gust velocities is accounted for, various investigations have been carried out to judge the effects of two-dimensional modelling of vertical turbulence on gust loads on large aircraft. In continuation of research on this subject in the early nineties, work was carried out under contracts to the Netherlands Department of Civil Aviation (RLD) and DaimlerChrysler Aerospace Airbus.
The RLD was also supported with information about loads prediction methods and tools that may be used to judge certification procedures of aircraft according to Federal Aviation Regulation/Joint Airworthiness Requirements (FAR/JAR) 23 and 25.
In support of Fokker Aerostructures, a project for the development of a computer program for the generation of load sequences for fatigue testing and analysis was started. In this project, use is made of experience with the Fokker 100 fatigue tests carried out in the mid-eighties.
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.



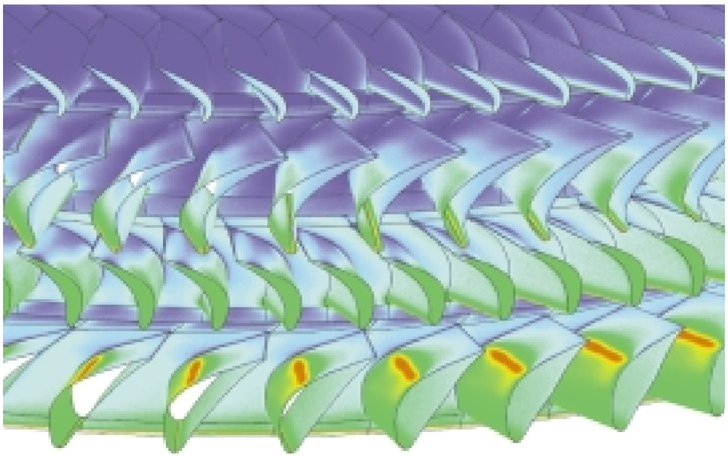
Fuselage panels made of GLARE by Shorts, before testing in the Fuselage Panel Test Rig of NLR

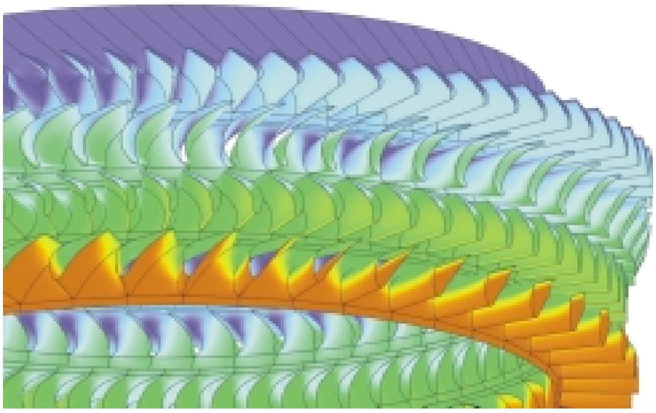
Under contract to the FAA, through RLD, NLR participates in the FAA's Flight Loads Programme. NLR participates in the analysis of flight loads data supplied by NASA, to determine required sampling rates for on-board aircraft loads/flight data recorders.

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 new, advanced fatigue load monitoring equipment for the F-16s, based on specifications made by NLR, was installed in nearly all RNLAF F-16 aircraft. The Central Logistic Ground Station is located at NLR.

Engine cycles are recorded on a sample of the fleet of Westland Helicopters Limited Lynx helicopters of the RNLN. Work has been done for the development and certification of new





Application of computational mechanics for gas turbine components: heat transfer calculations

instrumentation, in close co-operation with the manufacturer. This equipment will be installed fleetwide.

For the RNLAF, the preparations of a load measuring programme for the Lockheed Martin C-130 Hercules fleet were continued.

For the RNLN and the Portuguese and Spanish armed forces, load monitoring on Lockheed P3 Orion aircraft was being continued.

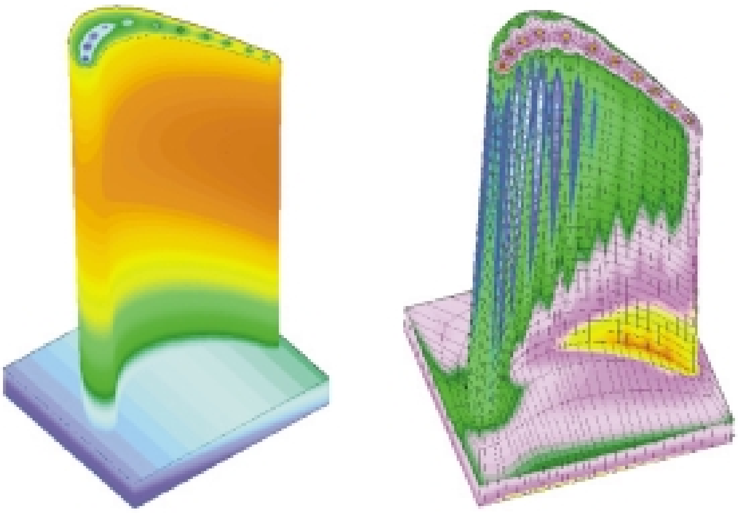
On behalf of the RNLN, NLR participates in the Service Life Assessment Programme (SLAP) and Service Life Extension Programme (SLEP) for the Orion aircraft. SLAP/SLEP is a collaborative programme between the US Navy, the Canadian Forces, the Australian Forces and the RNLN. As part of this programme, a full-scale fatigue test on an Orion aircraft will be performed in the USA. NLR is responsible for the comparison of the flight load spectra of the four participants in terms of fatigue life and damage tolerance behaviour.

To reduce maintenance costs, the Joint Strike Fighter (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 system. PHM technologies are to be demonstrated in collaboration with the US manufacturers to the JSF Programme Office using F-16 data collected with the monitoring system FACE.

Gas Turbines

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

A multidisciplinary project under contract to the NIVR for the determination of 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 presence of cooling channels is taken into account. In



Application of computational mechanics for gas turbine components:
Temperature and thermal stress distributions calculated for a gas turbine blade with cooling channels

another NIVR project, a method for the determination of the blade metal temperature experienced in service was developed and applied. This method is based on a non-destructive replication technique that reveals micro-structural degradation. It is applied to in-service exposed blades originating from industrial gas turbines. The method and data obtained were used to estimate residual lives.

For the engine to be used in the JSF, technology maturation programmes have been defined in co-operation with the industry. Four programmes, dealing with improved production methods of specific engine parts, were started.

NLR continued participating in a national programme for investigating the necessity of coating internal cooling channels in turbine blades and vanes, conducted by the Dutch Gas Turbine Association (VGT).

To investigate the influence of layer thickness and material properties, a computer program for the calculation of the temperature and stress distribution in a multi-layered tube subjected to external heating and internal coating was written.

To improve the efficiency of gas turbines, new materials are developed and evaluated. NLR is involved in a European programme on the characterization and evaluation of TiAl and single crystal materials.

Failure Analysis

Several service failures were examined. As examples, two case histories are discussed below.

During a phase inspection, a coupling clamp was found fractured. Fractographic and metallographic examination indicated stress corrosion cracking as the crack mechanism. The clamp specification had been subjected to a revision in 1993. One of the changes involved was a change in clamp material. The current specification specifies the material to be made of 301 steel in the annealed condition. The microstructure indicated a 1/2H condition instead of an annealed condition. This was confirmed by hardness measurements. Chemical analysis showed that the clamp material conforms to 301 steel. These results suggest that the clamp was manufactured before the 1993 revision and that the revision refers to a change in material condition (from 1/2H to anneal). In view of the results it was recommended to inspect other coupling clamps. As a result, six more clamps were rejected from service.

Investigation after an oil leakage revealed a cracked hydraulic tube. A similar hydraulic tube failure was examined in 1998. The crack in the hydraulic tube was forcibly broken open. Fractography revealed striations indicative of fatigue. The striations were characteristic for low-stress, high-cycle fatigue, indicating vibration of the tube as the most probable cause of the

alternating stress necessary for fatigue. No anomalies or initial defects were found that were related to the fracture.
The fracture location was identical to that of the hydraulic tube failure of 1998, when assembly stresses contributed to the failure. In the present investigation, neither the contribution nor the absence of an assembly stress could be shown. It therefore may be possible that vibration stresses solely are sufficient to initiate and grow a fatigue crack. This means that other assemblies may be prone to fatigue. It was recommended to add and/or adjust the tubing supports. Since the contribution of assembly stresses can not be excluded, it was also recommended to inspect other hydraulic tubes for correct installation, i.e. absence of misalignment.

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 was analysed.

Statistical methods have been evaluated to review their applicabilities to risk assessment of cracked structures. An efficient method was implemented and used to predict the probability of failure of an engine mount support fitting.

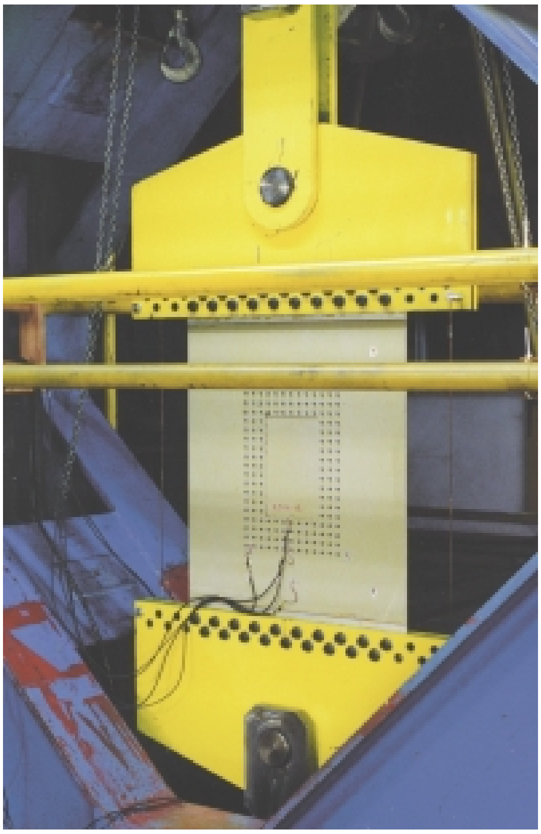
A collaborative programme with the Portuguese Air Force, for the assessment of the severity of their aircraft usage using advanced load monitoring and damage tolerance analysis methods, was continued.

The expertise of NLR in the area of fatigue and damage tolerance has been further developed and applied within the framework of various contracts, including with ESA. A fatigue crack growth model was developed for GLARE, and consultancy was provided to the Polish Air Force regarding the use of the NASGRO computer code.

Structures Technology

Materials Engineering

Materials and processes are being evaluated at NLR for their mechanical properties or the effect that certain processes may have on these properties. Under contract to the NIVR, the corrosion and fatigue properties of new, high strength steel brands are investigated, as well as the feasibility to use the phosphoric-sulphuric anodising process, which is more environmentally friendly than the traditional chromium-based anodising process. For the same contractor, Friction Stir Welding, a promising fabrication technology for welding aluminium alloys that cannot otherwise be welded, is evaluated. 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 stretching aluminium alloy 2024 on the fatigue properties was investigated. Stretch forming may lead to reduced fabrication costs because it allows the elimination of several heat treatment cycles, but it must be demonstrated that the effect on fatigue properties is minor.



Tension test on repaired GLARE panel

Under contract to the NIVR, several projects are being carried out for the GLARE Technology Development Programme in co-operation with Fokker Aerostructures, Structural Laminates Industries and Delft University of Technology. The technical and economical feasibility of GLARE as a skin material for the Airbus A3XX fuselage was demonstrated. Research for achieving technological readiness, was started in co-operation with DCAA (DaimlerChrysler Aerospace Airbus) and Aerospatiale/Matra. In the field of materials engineering, NLR contributed with an investigation into the environmental durability of GLARE, the effect of fatigue loading on riveted joints, and the mechanical properties and stresses in splices (integrated joints between sheets of GLARE). Also, a complete materials test programme was carried out, to support the certification of a GLARE demonstrator panel that was built into an Airbus A310 of the German Air Force. In addition, the development of maintenance concepts was supported with studies to determine the corrosion behaviour of GLARE, the effect of paint strippers on mechanical properties and the performance of repair configurations. The effect of alternating temperature on the fatigue behaviour of GLARE, and the feasibility of in-service inspection techniques were also studied.

Composites Fabrication Technology

The development of fabrication technology for structures made of composite materials was continued in co-operation with Fokker Special Products and SP Aerospace and Vehicle Systems. New matrix materials for thermoplastics were evaluated, to find solutions that can withstand temperatures up to 200°C, and new consolidation techniques were developed. The Resin Transfer Moulding (RTM) technique has been used to make complex parts with concentrated load introductions, such as landing gear components. A major component for a helicopter landing gear for SP Aerospace and Vehicle Systems was built using braided forms made by Eurocarbon, and successfully tested up to the design ultimate load. A modified RTM process was developed to fabricate two cargo doors in the EU project APRICOS (Advanced Primary Composite Structures), in which dry fibre preforms and prepreg materials were used simultaneously. The doors, one of them with applied damage, were tested by applying a 0.12 MPa pressure difference, and sustained the load without failure. Under contract to the NIVR, stiffened panels were made with preforms fabricated by stitching stacks of several layers of fabric, while other options to make preforms, using binding powder, were evaluated. A contribution was made to the design of a mast with a length of 44 metres for the yacht Pamina. The mast was subsequently fabricated in one piece by Royal Huisman Shipyard on the basis of a low cost prepreg/oven technique. Masts developed in previous years were in full operation and behaved satisfactorily. A programme, funded by the Ministry of Economic Affairs, was started to support a regional industry cluster, Composites Cluster Flevoland, with consultancy for the design and fabrication of composite structures and materials.

Structural Design

The development of design methods continued to be a major research activity. A co-operation with Fokker Aerostructures was set up, whereby NLR has upgraded Fokker's software to the UNIX standard, and will supply support in maintenance and quality control. The development of a range of new design methods was initiated. These methods are focused on the composite and metallic technologies in use by Fokker Aerostructures, and include the design of mechanical joints, sandwich panels and shear webs with holes or corrugations; fatigue and certification methodology for composites; the simulation of metal plate forming; and the optimization of stiffened panels. Part of the work is carried out in international co-operation, such as the EU project EDAVCOS (Efficient Design and Certification of Composite Aircraft Structures) and a new project, BOJCAS (Bolted Joints in Composite Aircraft Structures). The trinational military project DAMOCLES (Damage Management of Composite Structures for Cost Effective Life Extensive Service), carried out with DERA of the UK and FFA of Sweden, was successfully concluded by the demonstration of an optimization routine for the design of damage resistant panels, which has potential for cost savings related to inspection and repair. Within the framework of a national technology programme, a composite drag brace for the landing gear of the F-16 was designed for SP Aerospace and Vehicle Systems.

Final evaluation of structural designs and of newly developed design methodology requires full-scale component testing. In a technology project for URENCO Aerospace, for the development of a composite helicopter drive shaft, full-scale components were tested in torsion under environmental conditions, and also with ballistic impact damage. The design was supported with finite element analysis. In the EU project ADPRIMAS (Advanced Concepts for Primary Metallic Aircraft Structures), fuselage panels with window cut-outs, made of GLARE by Shorts, were tested to demonstrate the technological feasibility of GLARE for this application. The panels were tested in a specially developed fuselage panel test set-up, in which panels are subjected to circumferential loads, transverse pressure and axial loads, representative of cabin pressure and fuselage bending (due to taxiing and gust loading).

Computational Mechanics

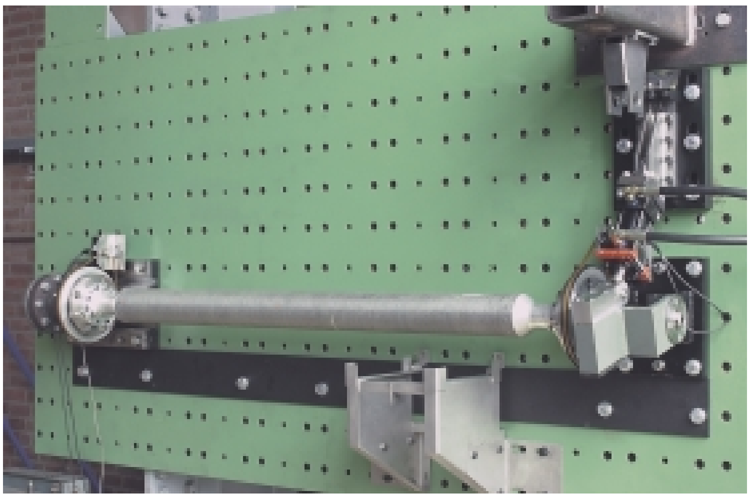
All new developments in the area of computational mechanics were carried out within the B2000 finite element code, a highly modular code with an accessible database structure. New algorithms, finite elements, material models, and optimization strategies can be implemented very easily, which is demonstrated by the fact that the Delft University of Technology and Twente University both operate and contribute to the code. Aeronautical institutes DLR of Germany and CIRA of Italy also use the code, which accommodates the exchange of software developments.

Vibration Analysis

Within the framework of the NIVR space technology programme (NRT), “piezo” finite elements were used to simulate active damping of vibrating structures, and optimization routines were used to tune the model to the measured values. This topic is of interest for space applications and for equipment isolation in military aircraft and helicopters, and was addressed in co-operation with international partners in GARTEUR Action Group (SM) AG-23. The interest of the Ministry of Defence in the subject has also resulted in NLR’s participation in EUCLID programme VIBRANT (Vibration Reduction by Active Control Technology), together with Fokker Space. For the USAF and DWA, a manufacturer of metal matrix composites, stress analyses were carried out of the F-16 engine access cover with ventral fins, based on dynamic loading conditions that were measured in-flight. This programme has resulted in a proposal for design modifications.

Optimization

Several designs for structural components made of composite materials were optimized, including landing gear components and masts. A new damage initiation constraint was developed, in



Torsion test of a composite drive shaft for Urenco Aerospace order to design composite components with a specified degree of damage resistance for the DAMOCLES programme. Four divisions of NLR started co-operative work in a new EU project, Multi-disciplinary Optimisation of Blended Wing Bodies (MOB).

Impact Dynamics

Crash and impact are load cases for which structural concepts are developed to achieve improved safety of aircraft and operations. EU projects CRASURV (Crash Survivability of Composite Aircraft Structures) and HICAS (High Velocity Impacts of Composite Aircraft Structures) are focused on the development of structural concepts and computer codes for structures made of composite materials, allowing for the case of bird strike. NLR's contribution to EU project CAST (Crashworthiness of Helicopters on Water, Design of Structures using Advanced Simulation Tools) is the development of a fuselage panel concept, aimed to resist the water pressure upon a forced landing, in order to extend the time for evacuation.
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 approach light structures at 140 km/h. The test data were made available by manufacturers in Finland and Canada.

Thermal Analysis

Thermo-mechanical analysis tools were developed for the determination of thermal stresses in, and the creep behaviour of rotating gas turbine blades with cooling channels. Within the framework of the National Space Technology programme of NIVR, a new design concept for the hot structure of a rudder for the X38 re-entry vehicle has been developed.

Plasticity

A model for the simulation of the high rate plastic deformation of aluminium in the friction stir welding ion process was developed, based on momentum and energy conservation considerations. Stress and temperature distributions were computed and compared to experimental data.

Also, a simulation method for computing plastic deformations was developed, related to Fokker's plate forming technology.

Certification Tests

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

Certification tests were carried out for the Fokker 60. This work, done under supervision of Fokker Services, consisted of fatigue tests on a main wing spar and on wing panels.

In the framework of a national technology programme for re-usable launchers, Aeolus, static tests on the X-38 rudder were performed.

Facilities and Equipment

NLR Test House Schiphol

With the installation of a Windows NT network with new workstations and personal computers, the NLR Test House Schiphol was fully integrated in the computer infrastructure of NLR. Facilities for structures and systems tests were modernized.

Structures Testing and Instrumentation Equipment

The creep test capabilities were improved and extended. In conjunction with research projects on high-temperature components, a thermal shock system and new measurement techniques were being developed.

Materials Research Equipment

A Field Emission Scanning Electron Microscope and an X-ray dispersive material analysis system were purchased. This new system will be used to carry out work for the JSF research programmes. New techniques for environmental tests on electronic and aviation systems were introduced.

Manufacturing of Fibre Reinforced Materials

Tests with hybrid production techniques combining prepreg with dry weavings were performed. A new control system for the autoclave and the Resin Transfer Moulding system was being developed.

3.5 Space

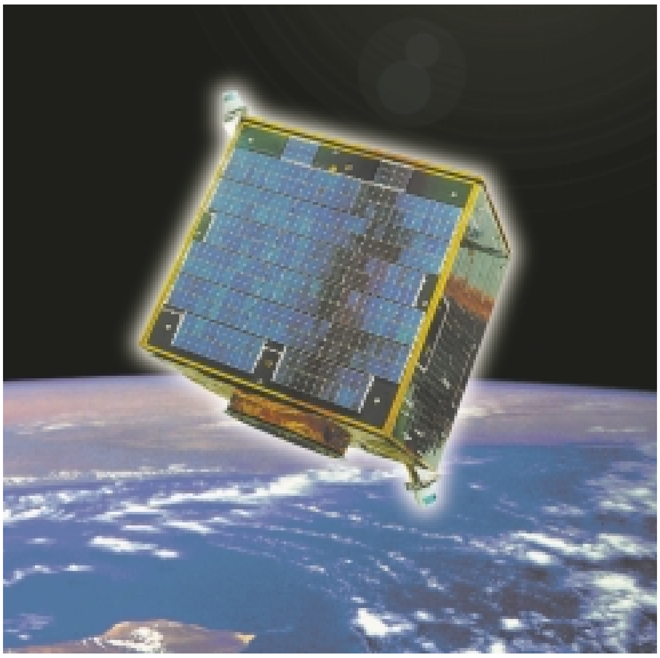
Summary

1999 has been an exciting year for space. The turnover of NLR in space-related activities has increased compared to previous years. New challenges were coming up in the space market, offering new opportunities for Dutch industries, user communities and NLR. An important event was the Conference of Ministers of ESA (European Space Agency) in May, where positive decisions were taken on important ESA programmes.

Europe has decided to start up a feasibility study for the European satellite navigation programme Galileo. NLR prepared for effective participation in Galileo by setting up a navigation cluster of staff embracing all relevant expertise and by initiating extensive communication with ministries and user communities. NLR has participated in programmes related to EGNOS (European Geostationary Navigation Overlay Service), such as the European Union's ECUREV (Definition of user requirements and EGNOS validation tool development) study, as well as in the Galileosat and Galileo Satellite Navigation architecture and definition studies.

Not only in the area of navigation but also in the area of remote sensing there is a trend to a more user-oriented and service-oriented approach in the global market. This approach has been adopted by NLR both in its participation in the Galileo project and in the remote sensing projects.

The mobile remote sensing system RAPIDS has been brought into action on several locations in the world, for example in Bangladesh where NLR completed a successful flood prediction project in co-operation with a value adding industry of the Netherlands. NLR has actively supported the value adding industry by playing a major role in the setting up in the Noordoostpolder of the Geomatica Park, a location for new value adding industries that has been opened in 1999. Another project in the remote sensing area was the continuation of the implementation of the Netherlands Earth Observation Network, a structured and organized infrastructure for the



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

Dutch users of earth observation data. Increased interest in remote sensing applications for defence was shown in European satellite surveillance programmes where NLR participated, and in the demonstration of remote sensing applications NLR held for the RNLAF. These projects focused on the application of current and future remote sensing systems for Netherlands defence operations.

A major part of the construction of Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit), a small satellite for fluid dynamic research, has been completed. Activities were focused on the production of the experiment tank and its measurement system and on integration. Potential new activities in the area of small satellites have also been investigated; possibilities are foreseen both in remote sensing and in re-entry vehicles.

In the area of manned space, NLR has continued the development of the Mission Preparation and Training Equipment for the European Robot Arm. The design has been finished and the implementation has been completed up to unit testing. Related to space station utilization, NLR has supported the set-up of a user support environment in the new Erasmus building of

ESTEC, the European Space Research and Technology Centre at Noordwijk. A proposal has been made to ESA for the definition and development of a Facility Responsible Centre for the European Drawer rack. Close co-operation with ESTEC in future user support activities is foreseen.

The Lidar Performance Analysis Simulator developed in co-operation with the Royal Netherlands Meteorological Institute, was delivered to ESA.

Alenia and Dornier were supported in the use of the Test and Verification Equipment NLR developed, in the XMM (X-ray Multi-mirror Mission) and INTEGRAL (International Gamma-Ray Astrophysics Laboratory) programmes. The Assembly Integration and Test activities for INTEGRAL are on schedule, and the Special Checkout Equipment for the Attitude and Orbit Control System delivered by NLR has been extensively used. The XMM satellite was successfully launched.

In preparation of the next science missions and the earth observation mission Gravity and Ocean Explorer, several technology studies on new bus environments were executed.

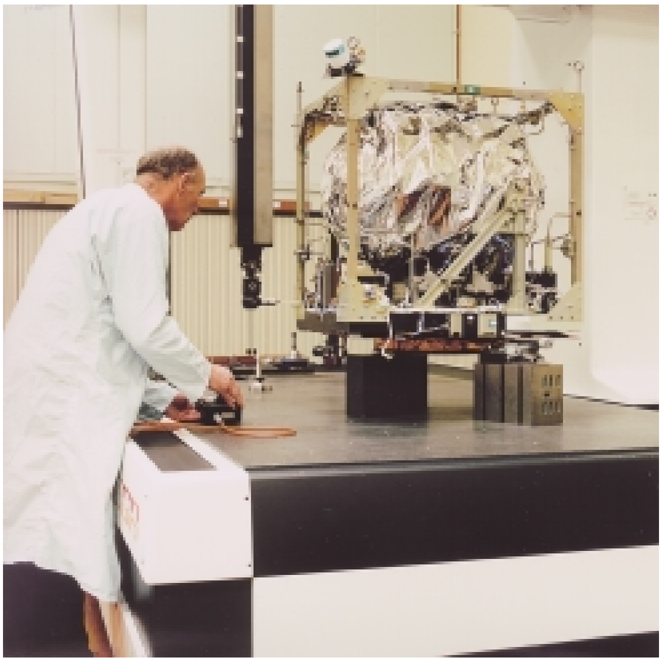
A proposal for a reflight of the Two Phase Flow Experiment was prepared. In close co-operation with the Dutch industry, the Meteosat Second Generation Gauging Sensor Unit has been successfully qualified. This unit is a very accurate measuring device for estimating the remaining fuel in satellites.
As a spin-off of the research in two-phase cooling, a passive cooling device based on this technology has been proposed, and approved, in the Joint Strike Fighter programme.

Sloshsat FLEVO
Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit), a small satellite for fluid dynamics research, to be launched from a Space Shuttle, is being developed by a team headed by NLR and including Fokker Space of the Netherlands, Verhaert and Newtec of Belgium and Rafael of Israel, under contract to ESA and the Netherlands Agency for Aerospace Programmes (NIVR). National and international partners delivered most satellite subsystems. The On-Board Software was integrated with the Data Handling Subsystem and tested. The test support and ground operations software was also finished. Supporting subsystems such as the Customer Ground Support Equipment and the Mechanical Ground Support Equipment were accepted. The installation of the Reaction Control Subsystem was successfully executed at Rafael in Israel. The solar arrays became available and were integrated with the satellite structure. The performance of the radio communication system was tested. Activities included the modelling of the Coarse Sensor Array (CSA), which measures the fluid distribution over the tank, and the calibration of the measurement signals. Special attention was paid to the preparation of the experiment tank with respect to the water quality.

An important aspect in the second safety review with NASA was the possible recontact hazard, meaning that Sloshsat FLEVO would be able to generate a speed increase which could result in a collision with the Shuttle. Preparatory meetings were held with the NASA Hitchhiker group to discuss activities in the project.

ERA Mission Preparation and Training Equipment
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 ERA 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 ERA MPTE is developed by a team headed by NLR, and including Spacebell and Trasys of Belgium and Fokker Space. The design of the ERA MPTE has been completed and the development and integration activities were started. A new hardware platform for the MPTE was



Preparation of Sloshsat FLEVO at ESTEC

defined, enabling better visualization of the cosmonaut environment and sufficient growth capabilities to be obtained. System capabilities have been demonstrated to experts and end users, who gave comments that led to further improved system performance. Most development activities for the pre-flight delivery were completed and subsystem and system integration were started.

Modular Payload Systems

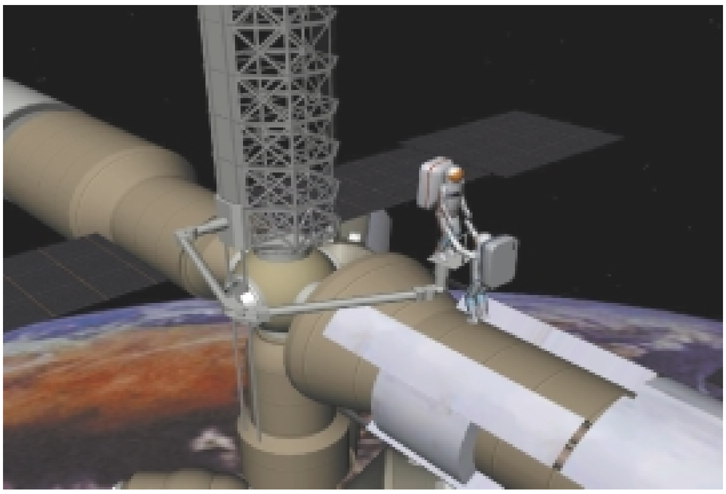
NLR developed two breadboard versions of a miniature microscope. The microscopes are planned to be used in cell biology research in micro-gravity during space flights in the International Space Station. They are being developed for use in the standard containers of the Biolab and the Modular Cultivation System. The Dutch-Belgian industrial team consists of prime contractor Fokker Space, NLR, Delft Sensor Systems, and Logica.

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.

Technical research for a demonstration version of a scientific microscope for the EDR-FRC was executed. In close co-operation with Dutch industries 3-T BV, SPE and Bioclear, the feasibility of a Biomass sensor based on turbidity measurements has been proven. This type of sensor can be useful for biological experiments on board the ISS. An application could be the BIOKIN-3 experiment of Bioclear.

Utilization

In co-operation with Origin, NLR has developed a demonstration model for an Advanced Crew Terminal (ACT) in support of Sloshsat FLEVO. This model has been presented to NASA-JSC, of Houston. The positive response of NASA led to a proposal to NASA, ESA and NIVR for such an ACT.



Artist's view of astronauts operating European Robot Arm on the International Space Station (courtesy ESA)

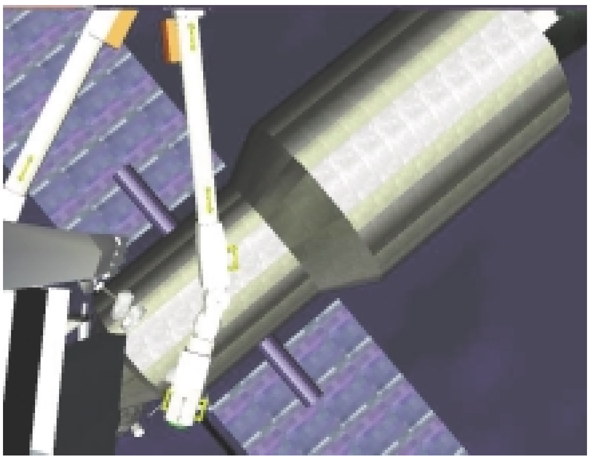
Phase 2 of the Advanced Crew Terminal (ACT) Follow On project was started. After a change in the consortium, a reorientation has been undertaken. A drawer payload will be selected for the demonstration project.

Possibilities to establish a Facility Responsible Centre at ESTEC for the European Drawer Rack using the Dutch Utilisation Centre (DUC) together with the Belgian USOC were investigated. An integrated NLR-DUC/B-USOC proposal for the EDR-FRC has been submitted, resulting in a first contract for the definition phase. Contributions from Dutch industries Origin, Bradford, Fokker Space and SPE have been incorporated in the proposal.

NLR together with the Royal Netherlands Meteorological Institute completed the development of the Lidar Performance Analysis Simulator (LIPAS). LIPAS enables meterologists to analyse the operational use of Doppler Wind Lidar at ISS.

Global Navigation Satellite System

Europe has decided to start-up the feasibility study for the European satellite navigation programme Galileo. By setting up a navigation cluster within NLR involving all relevant expertise and by communicating extensively with ministries, industries and user communities, NLR prepared for effective participation in this programme.



The European Robot Arm on the future International Space Station

NLR participates in the EU ECUREV project aimed at demonstrating the applicability of EGNOS Europe. In the EGNOS-ASQF project, NLR is expected to be contracted the simulation prediction module. NLR will perform static and dynamic verification measurements in the EGNOS-AIV project. NLR is involved in Galileosat focusing on availability and safety aspects of the total system. Furthermore NLR will contribute to the GALA project of the EU, focusing on Galileo validation tools.

Thermal Control

A proposal for a reflight of the Two-Phase Flow Experiment was prepared, aiming to demonstrate the behaviour of two phase flow cooling in space and to investigate the behaviour of different components in a two-phase flow loop.

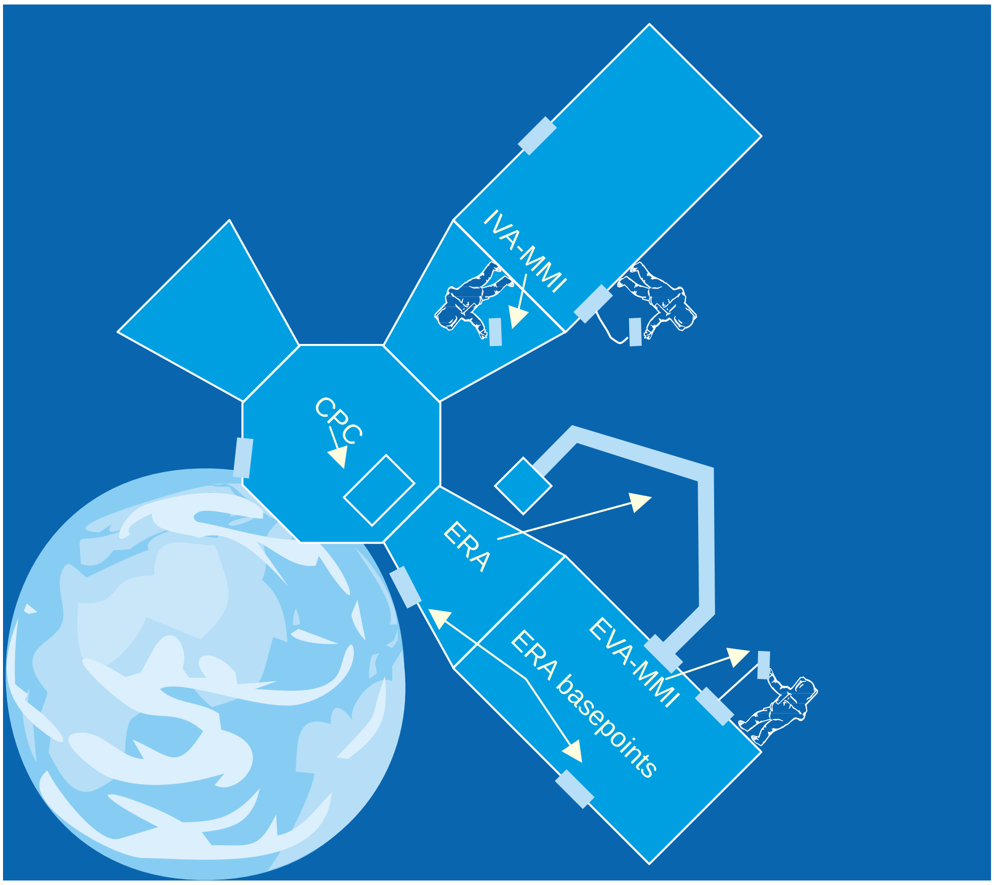
In close co-operation with the Netherlands industry, the Meteosat Second Generation Gauging Sensor Unit has been successfully qualified. This unit is a very accurate measuring unit for the estimation of the remaining fuel in satellites, which is of importance for their life and operational use.

As a spin off of the research in the area of two-phase cooling technology, a passive-cooling device based on this technology has been proposed and approved in the Joint Strike Fighter programme.
In close co-operation with Bradford Engineering, NLR has worked on the development of an Ultrasonic Flow meter.

Test and Simulation

The Test and Verification Equipment (TVE) delivered by NLR for the XMM and Integral projects was operational, and has been used by Dornier and Alenia in the integration phase of these two satellites. This contributed to a successful launch of the XMM satellite at the end of 1999.

In preparation of coming science and earth observation missions such as the First/Planck and the GOCE (Gravity Field and Steady-State Ocean Circulation) missions, NLR has worked on improvements to the TVE concept. This work



Schematic of ERA on the International Space Station, for the Mission Preparation and Training Equipment project, with man-machine interfaces (MMI) for internal and external control

included activities for the Central Node simulator project and the development of an IEEE-1355 bus interface.

Remote Sensing Operational Ground Systems
The RAPIDS ground station has been demonstrated and upgraded in several projects. A campaign for the reception and distribution of ERS and SPOT data for the agribusiness sector has been executed. Agreements with SPOT Image were made to exploit RAPIDS within and outside the Netherlands for projects based on SPOT products. NLR together with Geoserve BV participates in a consortium with SPOTImage that has been selected by ESA for the commercial distribution of Envisat data.

A campaign with RAPIDS in Indonesia, conducted in co-operation with a Netherlands value adding industry, was finished. The system was demonstrated and operated by LAPAN, the Indonesian counterpart, supported by NLR, NRI and BURS Ltd. The data acquired will be used in a number of Indonesian projects, to assess bathymetry conditions in the coastal zone, to monitor forests and to estimate the rice production. After this demonstration, RAPIDS has been exploited for a period of nine months in Dhaka, Bangladesh. A project within the ESA Data User Programme has been executed to demonstrate near real time delivery of ERS data for flood monitoring. This project was executed in close co-operation with Synoptics BV and Resource Analysis.

As part of the EUCLID RTP 9.8 project, Rapids has been demonstrated at Volkel Airbase.

NEONET
The realization of the Netherlands Earth Observation Network (NEONET), an infrastructure for the Dutch users of earth observation data, was continued. It will provide facilities for searching and retrieving earth observation data and information via the Internet. NEONET is being realized by several consortia under contract to the Netherlands Remote Sensing Board (BCRS) and the Space Research Organization Nether-

lands (SRON). A pivotal role in NEONET is played by the Core Facility, comprising a collection of technically identical Topical Nodes, each of them tasked with the gathering of information on a certain topic. The hierarchical tree structure in which the Topical Nodes are grouped enables users addressing the top node or NEONET Apex to have access to the complete information set. This NEONET Apex will also provide the interface to the international infrastructure that is provided by the Centre for Earth Observation (CEO).

With respect to the remote sensing data infrastructure, NLR finished two projects within the Fourth Framework Programme of the EU: Remote Sensing for Analysis of Coasts (RESSAC) and Computer Aided System for Teleinteractive Learning in Environmental Monitoring (CASTLE). The results of both projects have been used in the further development of NEONET.

Satellite Remote Sensing

In view of the increasing importance of small earth observation missions and constellations, NLR has signed an MOU with Surrey Space Centre Ltd. for further development of the ground segment. An evaluation of Surrey's TMSAT images for different application has been executed.

NLR also contributed to the EU concerted action COCONUDS (Co-ordinated Constellation of User Defined Satellites). Within COCONUDS a feasibility study has been executed for a constellation of small earth observation satellites including a distributed ground segment for natural resource management.

NLR has participated in several ESA studies on future earth explorer missions, particularly in the field of modelling hyperspectral and directional earth observation data.

3.6 Information and Communication Technology

Summary

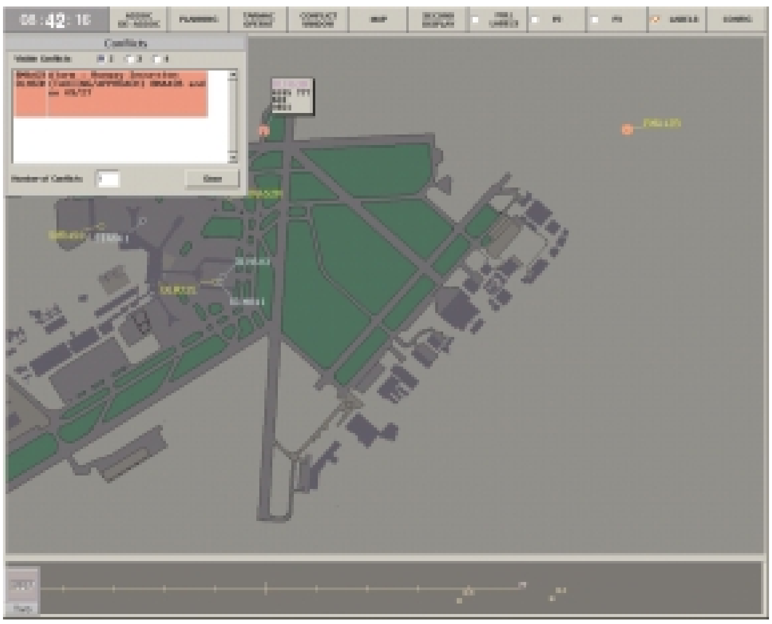
Activities in the area of information and communication technology have included the development, production and life cycle support of information systems for a variety of application areas. Major areas were: air traffic management; consultation, command and control in military environments; process 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. Operational systems for runway allocation, monitoring, conflict detection and usage analysis were developed or upgraded. A large distributed real-time man-in-the-loop simulation environment was set up, connecting research and technology development tools and facilities for airport support at DERA, DLR and NLR.

In the area of surveillance, NLR continued the development of sensor data processing systems for civil and military use. The ARTAS tracker was enhanced to improve performance in situations with many closely separated targets and situations involving steeply climbing or descending military aircraft. Work on a more extensive, upgrade of the tracker was started: the incorporation of mode-S elementary surveillance. An ARTAS2 prototype tracker, an enhanced ARTAS system that can handle aircraft-derived data, delivered by means of SSR Mode-S and Automatic Dependent Surveillance, was installed at the Eurocontrol Experimental Centre in Bretigny for use in the SurVITE testbed. In co-operation with Holland Institute of Traffic Technology (HITT); the Military ARTAS tracker evaluation system was made available at the NATO Consultation, Command and Control Agency (NC3A) premises at the Hague for evaluation tests.

In the area of consultation, command and control, NLR has continued to support several national and international customers. In co-operation with DERA, the Pilot-oriented Workload Evaluation and Redistribution project was continued. NLR supported by RNLAF by the fielding of the modernised Operations Management Information System (OMIS) at Volkel Air Force base.

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. Databases were developed for storage and



Traffic display made with a simulator for Advanced Surface Movement Guidance and Control Systems analysis of health and usage data. Under contract to the RLD, an investigation into the relation between the software development process and certifiability of systems containing software was continued. For European customers, various software certification support activities were carried out. Work was started to update certifiable safety-critical avionics software.

Various process and product improvement activities related to aircraft development and maintainability and logistics support were carried out. A framework for generic design optimization was realised in the NICE (Netherlands Initiative for CFD in Engineering with HPCN) project.

The development of SPINEware, a facility that provides and combines tools and middleware software to support the construction and usage of working environments on top of possibly heterogeneous computer networks containing UNIX, Windows, and Linux systems was continued. A SPINEware-based working environment turns a local or wide-area computer network into a single computer, a so-called metacomputer. The graphical desktop enables its users to operate the metacomputer in PC style, via point-and-click and drag-and-drop operations on icons in windows. The CORBA (Common Object Request Broker Architecture) standard is applied to facilitate the integration of commercial and other third-party software.

The EU ENHANCE project (ENHanced AeroNautical Concurrent Engineering) by a consortium of 14 contractors, was started. The ENHANCE project is aiming at improving the European Aeronautical industry's competitiveness by streamlining and defining best practices through the whole supply chain. NLR is leader of two of the nine workpackages: Information Technology and Support.

Facilities were set up and maintained at NLR for software engineering support, for decision support engineering and application, for control engineering, for statistical and risk analysis, and for multi-sensor data processing software development and evaluation of tracker behaviour.

In the area of simulation, training, visualization and virtual environments, NLR continued the development of the Mission Preparation and Training Environment (MPTE). NLR co-founded the Eurosim consortium. The Eurosim simulation products can be used for a wide variety of real-time simulations, ranging from simple to complex. Tools were completed to control real-time geographically distributed simulations.
The acquired capabilities of the SIMULTAAN project have been demonstrated successfully by demonstrating how in a very short period of time a complete distributed simulator could be built and run.
In the area of robotics NLR continued participating in the development of the European Robot Arm (ERA) at Fokker Space. The participation concerned the ERA Exception Handling system, ERA Operations, and ERA Evolution.

NLR continued the extension and improvement of its Information and Communication Infrastructure. To make state-of-the-art supercomputer power available to NLR and its customers, the SX-4 supercomputer has been replaced by an SX-5. This replacement provides a four-fold increase in processing speed and processing capacity.

NLR was leading the effort to increase the accessibility and promote the use of the facilities of the four High Power Computing and Networking (HPCN) sites (NLR and three universities) in the Netherlands by integrating the facilities into one uniform infrastructure with standard web browsers as main user interface.

Air Traffic Decision Support Systems

Information and communication technology and mathematics support to operators, regulatory authorities and policy makers on airport environmental monitoring, analysis and decision support was continued. New versions of information systems for noise abatement, environmental monitoring, runway planning and runway usage analysis were delivered and installed at a variety of customer sites. In addition, applied research was carried out in co-operation with European research institutes and major airports to develop methods, techniques and tools for future airport support systems.

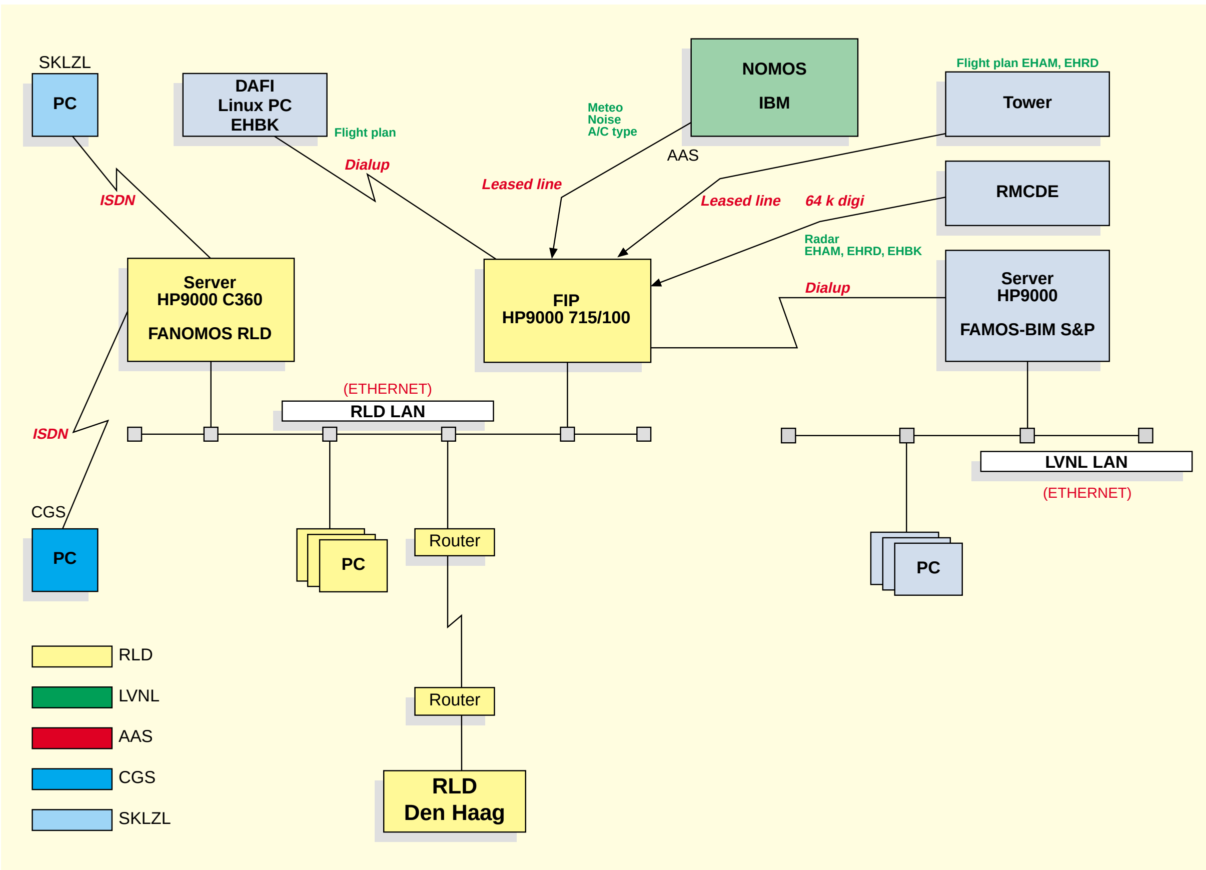
Recording and Analysis
On many airports, the Flight track and Aircraft Noise Monitoring System (FANOMOS) provides operators and authorities with the following functions: track and noise monitoring, calculation of noise exposure and matching of noise information to recordings of actual flight tracks, complaints and flight plan information.

On request of the Netherlands Department of Civil Aviation (RLD), NLR has developed a new FANOMOS acquisition system, FIP (FANOMOS Input Processor) that fulfils:

– Central processing for Amsterdam Airport Schiphol, Rotterdam Airport and Maastricht-Aachen Airport;
– Numerous data acquisition (radar data, flight plan, noise, meteo etc.) and processing tasks, in such a way that the FANOMOS server systems are relieved from them;
– Flight track reconstruction based on the new surveillance standard ASTERIX.

The FIP system was installed at RLD, parallel to the existing system. It was then successfully tuned and evaluated. The effects of the new data and improved algorithms were investigated within the overall FANOMOS functioning; the results showing further improvement of the trustworthiness of the FANOMOS results.

Monitoring
A preferential runway use system is used at Amsterdam Airport Schiphol to keep noise exposure for the environment as low as possible. If weather conditions and traffic density permit, the runways that cause the least noise exposure are used for take-off and landing. Under contract to Air Traffic Control the Netherlands, NLR has developed and installed two systems: The Runway Allocation Assistant System (*Baangebruiks Advies Systeem*, BGAS) and the Runway Use Inspection System (*Baangebruiks Controle Systeem*, BGCS). BGAS provides advice to the Executive Air Traffic Controller for



Schematic of Flight Track and Aircraft Noise Monitoring System connected to RLD, LVNL, AAS, and noise complaint offices the best runway combination for take-off and landing, based on the preferential system, runway availability, traffic density and weather conditions. It is in use at Schiphol Approach and Schiphol Tower. The Graphical User Interface of BGAS was upgraded, in close co-operation with Schiphol Executive Air Traffic Controllers. BGCS provides information to ATC authorities on the actual allocation of runways in comparison to preferential runway use.

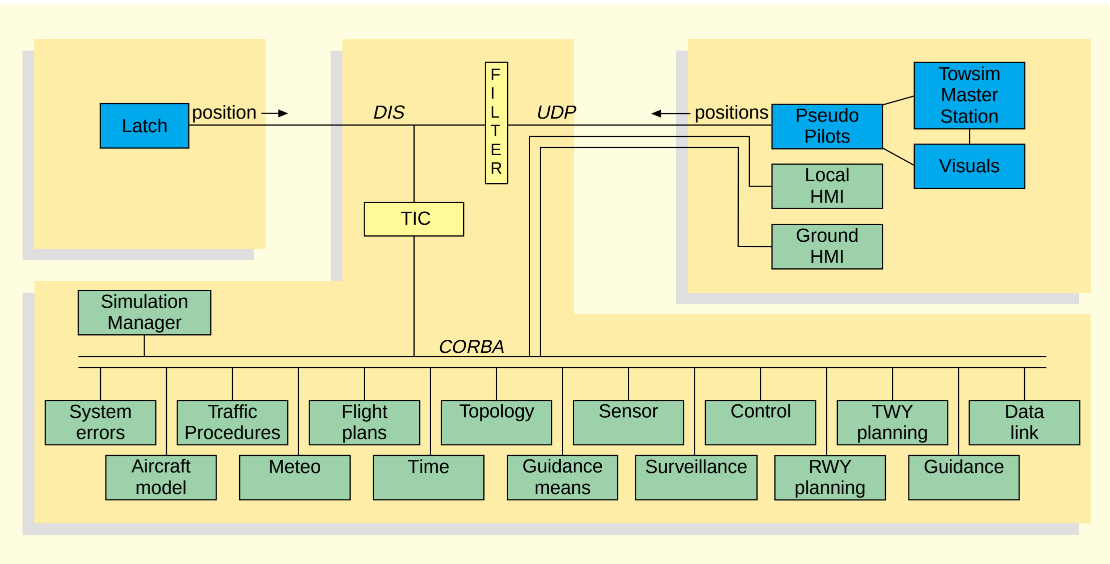
After a demonstration of the Runway Incursion Alert (RIA) research and concept demonstration tool, NLR received a contract for the development of a Taxiway Conflict Monitor based on tower controller expertise represented in software via artificial intelligence and bounding-box algorithms. It was prepared for incorporation in the larger Manchester airport support environment.

Airport Planning and Decision Support

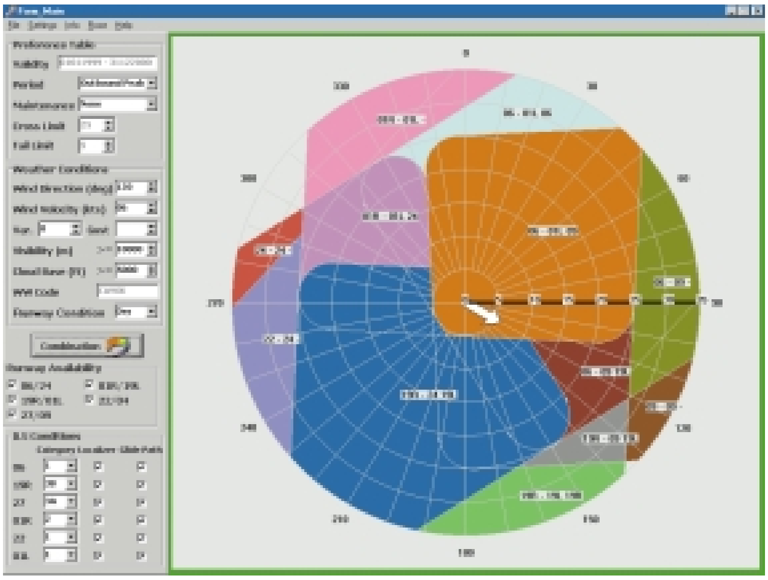
Within the EU project MANTEA (MANagement of surface Traffic in European Airports), NLR has designed and developed a tool for assisting controllers in the assignment of plans and sequences for departure traffic. The departure-sequencing tool proposes optimal runway usage and Standard Instrument Departure (SID) allocations under nominal and bad weather conditions. Constraint satisfaction methods were used to model airport regulations, such as wake vortex separation and overlaps in SIDs. A distributed open architecture based on the Common Object Request Broker Architecture (CORBA) was designed to facilitate a novel way of co-operative planning by controllers.

NLR has concluded its contribution in the EU project DAVINCI (Departure and ArriVal INtegrated management system for Co-operative Improvement of airport traffic flow). The aim of this project was to investigate architectures that promote co-operation between airport controllers in achieving more efficient use of taxiways and runways. NLR has contributed to modelling planning and collaborative decision making, and to architectures for communication between users controlling arrival management, departure management, ground movement planning, start up and pushback planning. NLR has established a simulator architecture based on these models, and partners have built the simulator. The start-up planner module and the pushback planner module have been made available to NLR for incorporation into its facilities.

NLR has participated in the EU project SAMS (SMGCS Airport Movement Simulator). NLR provided the basic simulation functionality for



Configuration of the A-SMGCS (Advanced Surface Movement Guidance and Control System) simulator developed in the EU SAMS project



Graphical User Interface showng runway preferences based on Air Traffic Controller input, using runway use advisory system (BGAS)

the A-SMGCS (Advanced Surface Movement Guidance and Control System) simulator using NLR's SmartFED tool for simulation management. In addition, NLR was responsible for the integration of all hardware and software components of SAMS partners in the advanced surface movement, guidance and control system (A-SMGCS) simulator, and for execution and evaluation of tests and simulations. The complete SAMS platform comprises three simulators, one realistic 3D outside view simulator (TOWSIM from DLR), a flight simulator (LATCH from DERA) also equipped with outside view, and the A-SMGCS simulator at NLR, Amsterdam.

The platform is client-server-based, with CORBA (Common Object Request Broker Architecture) as object-oriented middle-ware architecture. Real-time inter-site communications were set up using the DIS (Distributed Interactive Simulation) protocol over an ISDN connection. Distributed man-in-the-loop simulations took place simultaneously in Amsterdam, Braunschweig (D), and Bedford (GB). Controllers were supported through an A-SMGCS working environment, connected to the A-SMGCS simulator at NLR. Pilots were connected via a simulated data link function. The results of this work are used to test the next generation of advanced surface movement, guidance and control tools and procedures under different weather conditions.

Collaborative Decision Making

Collaborative Decision Making (CDM) is seen as one of the key concepts for the ATM2000+ strategy as defined by EUROCONTROL. EUROCONTROL aims with CDM at a better information exchange between the actors in air traffic – air traffic service providers, airspace users and airports – to improve the way they work together at the operational level. An improved information exchange will provide the basis for more efficient decision making. For instance it will allow aircraft operators more flexibility to maximise their own efficiency in meeting their schedules.

Two potential applications for CDM have been formulated for air traffic flow management, namely slot swapping and slot shifting. NLR is investigating different scenarios for these applications in the context of OPTISLOT, an application that has been developed with DLR for optimal slot allocation.

Surveillance and Aeronautical Telecommunication Network

NLR continued the development and installation of sensor data processing systems, for EUROCONTROL, for national aviation authorities, and for military organizations.

ARTAS (ATM suRveillance Tracker And Server)

The ARTAS tracker was enhanced to improve performance in situations with many closely separated targets and situations involving steeply

climbing or descending military aircraft. Work on an extensive upgrade of the tracker, for the incorporation of mode-S elementary surveillance, i.e. the use of a unique aircraft address, selective interrogation of targets and an improved pressure altitude resolution of 25 feet, was started. The first version of the so-called ARTAS V6 tracker was delivered to AIRSYS ATM for integration testing. NLR was contracted by AIRSYS ATM to participate in the pre-CAMOS (Centralised ARTAS Maintenance and Operational Support) activities. NLR provided assistance in solving problems that were raised by the pre-operational ARTAS users.
NLR also provided tuning and evaluation support to various ARTAS users, such as NAV at Lisbon, CENA at Toulouse and CAA at Gatwick).

ARTAS2 Feasibility Study and Prototype Implementation

ARTAS2 is an enhanced ARTAS system that can handle aircraft-derived data, delivered by means of SSR Mode-S and Automatic Dependent Surveillance (ADS). In a feasibility study, algorithms to properly integrate this additional information in aircraft tracking were investigated. The study was completed and the encouraging results were presented to representatives of various administrations and industry. Moreover, NLR was invited to present these results at an ADS workshop in Malaga. An ARTAS2 prototype tracker was installed at the Eurocontrol Experimental Centre in Brétigny for use in the SurVITE testbed.

Quality of Service Requirements for ADS in Europe

The ARTAS2 tracker prototype was extended with multisensor environment assessment functions. The sensor systematic error estimator was extended and a sensor accuracy estimator was developed and implemented. Testing was started. The study is done in co-operation with DERA Malvern.

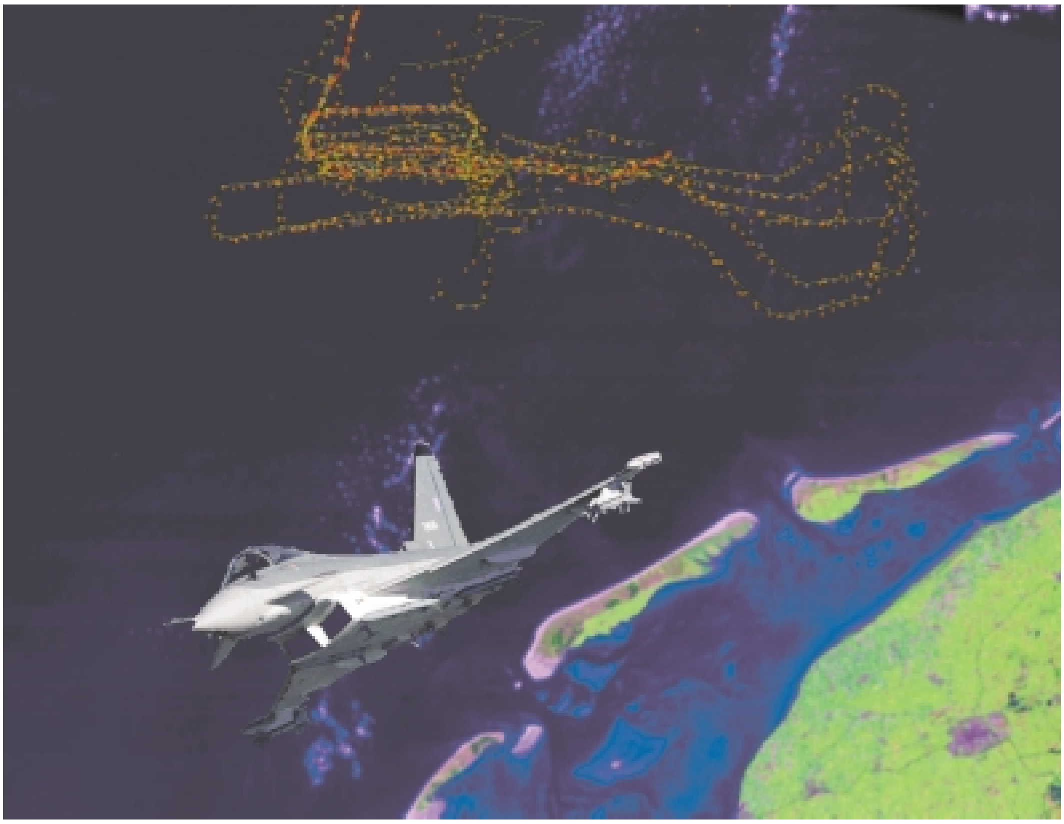
MARTAS (Military Artas)

MARTAS is a project carried out in co-operation between NLR and HITT under contract to the Royal Netherlands Air Force (RNLAF). The goals of MARTAS are to study the feasibility to use state-of-the-art-tracking algorithms in military and combined civil-military environments and use the results to draft future requirements for air surveillance systems. NLR has taken the tracker as provided to ARTAS as a starting point, and has adapted the tracker software in such a way that it could be run on the middleware Basic Components/Communications (BC/COMMS) of HITT.

The RNLAF made agreements with the NATO Consultation, Command and Control Agency (NC3A) to define and perform evaluation tests on the MARTAS tracker. To that purpose, the tracker software was put together with the existing Traffic Display (TRADIS) and the newly developed Radar Front End (RFE) of HITT to form the so-called Martas Evaluation System (MAES). The MAES system has been installed at NC3A premises in the Hague and has been demonstrated to work in that environment with live and simulated data to RNLAF and NC3A. NLR has started to support NC3A with the task to define and perform the evaluation tests of MARTAS on the basis of NLR's experience from the testing and evaluation of the tracker. NLR's Jdiff tool for the test and evaluation of trackers has been installed at the NC3A premises.

MURATREC Parameter Estimation

The Eurocontrol SASS-C (Surveillance Analysis Support System - Centre) is a set of tools for radar plot evaluation and tracker analysis. Recently, SASS-C was extensively tested and validated in the scope of the Eurocontrol CIP (Convergence and Implementation Programme) Appraisal Programme. SASS-C was selected for radar performance analysis.
During the validation, small, but relevant, discrepancies were detected between the results of the SASS-C and UK CAA versions of the MURATREC parameter estimation program. NLR was contracted to investigate the cause of these discrepancies and, if necessary, correct the SASS-C software. Changes in UK CAA version of the software with respect to the original version of the software, as delivered in 1989 by NLR, were integrated in the SASS-C version. The reported software problems were corrected and some additional software was written to automate the execution of the tests of the validation programme.



Military surveillance over the North Sea

Aeronautical Telecommunication Network

A technology transfer contract between the Institute for Information Industry (III) of Taiwan and NLR was executed. The contract concerned the Aeronautical Telecommunication Network (ATN) and comprised the exchange of theoretical knowledge and practical experience to allow III to become actively involved in the development of operational ATN systems. The technology transfer was done in three successive phases: a workshop phase, a training phase, and an evaluation phase. The theoretical knowledge provided during the workshop phase became operational in the training phase in which a training case was elaborated. NLR assisted the III participants during this phase remotely from Amsterdam, effectively by providing a tailored electronic training or e-training. The technology transfer contract resulted in a partial implementation of an ATN FIS/D-ATIS (Flight Information Services/Digital Air Traffic Information Services) application, a course handbook and a course Intranet web-site. This course material was used during the workshop held at the client's premises in Taipei, 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 on 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 incorporation of results into systems of customers.

Basic Ordering Agreement with NATO Consultancy, Command and Control Agency

The agreement with a group of Dutch companies for co-operation in projects in the area of Command, Control and Communication Information systems was renewed. The group was extended with two new partners. The group operates under the name DUCOM: 'Dutch Combination for (Multi-)national operations'. Participating companies are: Getronics Software Solutions, Holland Institute of Traffic Technology bv, Klein Poelhuis-Voltman bv, National Aerospace Laboratory NLR, Quality Center Nederland bv, M&I partners bv and TEBODIN bv.

The DUCOM partners presented their capabilities at the ICT2000 manifestation organized by the Royal Netherlands Army. NLR demonstrated the OMIS2 and MARTAS pre-operational systems. The Basic Ordering Agreement for the DUCOM partners with the NATO Consultation, Command and Control Agency (NC3A) for Engineering Services, Software and hardware was amended. The new DUCOM-partners will also enter into this Agreement.

Operations Management Information System
Under contract to the Royal Netherlands Air Force (RNLAF), NLR has finished the modernization of the software of 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. OMIS assists in the communication of all necessary information between control centres and units.

The new system (OMIS-2), redesigned using 4GL COTS (Commercial-Of-The-Shelf) software development tools from Oracle, has been implemented. The database has been designed in accordance with the Army Tactical Command & Control Information Systems standard (ATCCIS). The target hardware platform is a network of PCs running under Microsoft Windows NT. The system has a new Windows NT-like user interface and functions according to the client-server computing concept as opposed to the original OMIS, which performs centralised computing. The application of multiple replicating Oracle database servers provides failsafe operation of the system.

NLR supported the fielding of the OMIS-2 software at Volkel Air Force Base by providing training for system administrators and end users, and installation support. The installation comprised three server workstations and 109 client workstations, made available by the RNLAF. Under responsibility of the RNLAF, the completed OMIS-2 successfully went operational. Volkel AFB converted from OMIS to OMIS-2 in one day rather than running in shadow mode for a certain period. Only a few minor problems were encountered, mostly related to the scaling of the system. From mid-October OMIS-2 has been running smoothly without problems and with satisfied users. The system did not show any malfunctioning when it was intensively used during exercises.

Interoperability
NATO increasingly needs interoperability between Command and Control (C2) systems that are in use by the forces of the NATO countries, and annually holds a Joint Warrior Interoperability Demonstration (JWID) in which warfighters and ICT personnel from defence organizations and ICT suppliers perform interoperability trials against a simulated, operational war scenario as a background. In consultation with the Netherlands Ministry of Defence and the RNLAF, NLR started the preparation of a demonstrator showing aspects of interoperability between the pre-operational software of Operations Management Information System (OMIS-2), developed by NLR, and the Interim Combined Air Operations Centre Capability (ICC), developed by the NATO Command, Control and Communication Agency. NLR visited the JWID planning conferences to communicate within NATO the contents of the intended demonstration and to promote the role of the simulated Dutch forces in the operational scenario. In consultation with the Netherlands Ministry of Defence and the RNLAF, NLR prepared the participation in the NATO C3 Interoperability Environment Testing Infrastructure (NIETI) Project Team. This participation is effectuated in co-operation with TNO Physics and Electronics Laboratory (TNO-FEL).

Decision Support, Planning and Tasking
The Pilot-oriented Workload evaluation and Redistribution (PoWeR) project was continued, in co-operation with DERA. NLR’s focus is on the application of advanced information processing and human factors to support in situation awareness and decision support functions. A follow up to the EUCLID (RTP 6.5) Crew Assistant project, the PoWeR project aims at gathering knowledge and experience concerning Crew Assistant applications.

A number of small-scale experiments have been designed. In one experiment, the prediction of airborne target manoeuvres using real-time case-based reasoning is investigated. In another experiment, based on a Self-Protection Electronic Warfare manager, scheduling and execution of counter measures against threats are investigated. A theoretical experiment has been defined to investigate the feasibility of real-time Bayesian Belief networks to deal with uncertainty in on-board tasks.

Military Databases

Developments in multi-media databases appear to be promising for military information systems. Under contract to the Royal Netherlands Navy, NLR and Twente University have been carrying out research into an architecture that facilitates data storage and access to various types of media servers in an integrated manner. The main properties of this architecture are modularity and extensibility. Data may include military images, video and text.

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 Aspects of the Reduction of the Vertical Separation Minimum

As in previous years, NLR has contributed to the Mathematicians Drafting Group (MDG) of EUROCONTROL in the Reduced Vertical Separation Minimum (RVSM) programme. Several discussion papers on safety aspects of RVSM were drafted, including contributions to the mathematical supplement to the guidance material for European RVSM. NLR acted as a liaison between the EUROCONTROL 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 and contributions were made to the revision of the ICAO Manual on the implementation of a 1000-ft Vertical Separation Minimum.

Assessment of Wake Vortex Safety

Wake vortex research was directed towards the assessment of new Air Traffic Management (ATM) concepts for departure and landing at busy airports. NLR has developed a probabilistic Wake Vortex Induced Accident Risk Assessment (WAVIR) methodology and an associated software tool set to give developers feedback on the safety of new ATM concepts. The WAVIR methodology has been applied to evaluate the case of aircraft landing on a single runway. The results have been compared with the present wake vortex induced ICAO separation standards, and show the high potential of the methodology for the assessment of more appropriate and safe separation standards. The methodology has also been applied to assess the wake vortex safety related to the High Approach Landing System (HALS) procedure for simultaneous landings on the closely spaced parallel runways at Frankfurt airport. Results from this assessment show that the methodology also provides valuable feedback to ATM concept developers. The WAVIR methodology was integrated with the stochastic modelling and analysis setting of the Traffic Organizer and Perturbation Analyzer (TOPAZ), which is also used for collision risk assessment. The WAVIR methodology also includes an independent safety criteria framework for wake vortex induced accident risk, which has been developed to judge the acceptability of the obtained wake vortex safety assessment results. This framework consists of selected suitable safety measures and safety requirements based on a combination of the Target Level of Safety (TLS) and the As Low As Reasonably Practicable (ALARP) approach. The framework is consistent with existing ICAO and JAA safety requirements, and can be used to judge the acceptability of newly proposed procedures.

Causal Collision Risk Model

NLR has developed and implemented a causal model for evaluating the collision risk between aircraft during independent simultaneous departures. The model is capable of providing insight into the causes and consequences of a number of identified key hazards, and accounts for both flying characteristics and performance of the surveillance and intervention system.

Radar data has been analysed to provide probability distributions for deviations from the prescribed departure routes, describing the flying behaviour under nominal conditions. A method to quantify the effect of occurrence of a non-nominal situation on the flying characteristics has been developed and applied, using regression models and expert judgement. A number of scenarios have been numerically evaluated to obtain a first estimation of the collision risk under both nominal and non-nominal conditions.

Safety Related to GPS NPA Procedures

As part of study for the RLD on the implementation of approach procedures based on the Global Positioning System (GPS), a data collection programme to verify the accuracy of GPS Non-Precision Approach (NPA) procedures was started. Radar data on approaches to Beek runway 22 were collected using the FANOMOS flight registration system. These data is analysed and modelled by appropriate probability distributions. The obtained distributions can be used to compare the relative accuracy of GPS NPA approaches with both ILS precision approaches and conventional NPA approaches. The accuracy of GPS NPA procedures will be compared with existing accuracy criteria established by the ICAO OCP.

Health and Usage Monitoring Support

NLR continued to support the Royal Netherlands Navy in health and usage monitoring of the Lynx helicopter. The development of the AIDA (Automatic In-flight Data Acquisition) Host Station software was continued. This software provides the user with facilities to store, manage and graphically display the measurements, and compute condensed usage data.

Safety and Certification

Investigations for the RLD into the relation between the software development process and the certifiability of systems containing software were continued. Assistance was given to the Royal Belgian Air Force with regard to the software aspects of airworthiness certification of candidate uninhabitated aerial vehicles. NLR supported the RNLAF in the analysis of software systems of a successor for the F-16. Under contract to the RLD, research was continued into the innovation of current certification practices, focusing on the reuse of software and Commercial-Off-The-Shelf (COTS) software.
Certifiable avionics software work for the extension of a previously completed avionics software product was started. The extension comprises software to be certified at various Eurocae/RTCA 12B/DO-178B safety levels up to the highest level A (safety critical application). RTCA Steering Committee 182/Eurocae Working Group 48 has defined the Avionics Computer Resource (ACR) concept. ACR aims to integrate several applications onto a single platform. Independent updates of these applications lead to incremental certification. Work was started to evaluate such incremental certification processes.

Process and Product Improvement

NLR supports customers in process and product improvement, and pays attention to process and product improvement inside NLR as well. In this area, ICT plays an increasingly important role. Computer-based working environments are created that support conservation, accumulation and re-use of know-how and products.

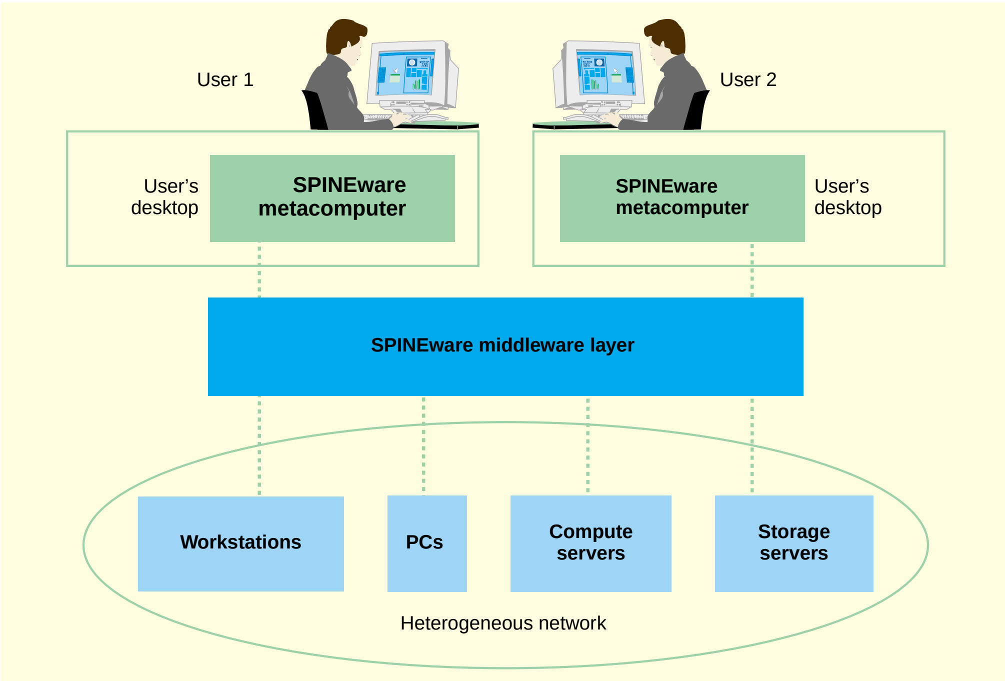
Middleware for Generation of Working Environments and Virtual Enterprises

NLR has continued the development of SPINEware, under contract to NEC, the supplier of NLR's supercomputer. SPINEware is a facility that provides and combines tools and middleware software to support the construction and usage of working environments on top of, possibly heterogeneous computer networks containing UNIX, Windows, and Linux systems. A SPINEware-based working environment turns a local or wide-area computer network into a single computer, a so-called metacomputer, providing uniform and network-transparent access to the information, applications, and other resources available from the computer network. A working environment may be tailored to particular end usage and applications areas. Its graphical desktop system enables its users to operate the metacomputer in PC style, via point-and-click and drag-and-drop operations on icons in windows. The metacomputing capability, the tailoring facilities, and the user-oriented desktop system capabilities enable powerful and easy-to-use application environments to be realized.

The development of SPINEware started in the early 1990s and emerged from experiences NLR had gained in the construction of user and application oriented information systems for more than a decade. During the past few years, SPINEware was further enhanced and extended to meet customer and user needs. For flexibility, openness, and easy extendibility of SPINEware and of SPINEware-based working environments, state-of-the-art technologies and software are applied. In particular, the CORBA (Common Object Request Broker Architecture) standard is applied to facilitate the integration of commercial and other third-party software and to reuse the object-oriented support and communication services provided by software implementations of the standard.
A SPINEware-based working environment provides a suitable basis for the realization of the computing infrastructure of so-called virtual enterprises, since the underlying network may span several enterprises, irrespective of geographical distribution and computing network size. Several advanced industries are considering integrating their networks and software into seamless, virtual environments to join their power in order to reduce the life-cycle cost of their products. Requirements emerging from these efforts applying to, for example, standardization, security, and support for execution of business processes, provide inputs for the ongoing development of SPINEware.

Optimization and Frameworks for Process and Product Improvement

In the Netherlands Initiative for CFD in Engineering with HPCN (NICE) project, a framework for generic design optimization was realized. An important aim of this framework is that it permits flexible usage of a wide range of readily available software packages, e.g. CFD solvers and FE packages for analysis calculations of the design, and state of the art optimization algorithms for the optimization. Also, the use of high-performance platforms and parallel job execution is ensured to meet the high computational requirements of the considered analysis calculations.
This optimization system has been used in several design studies involving CFD simulation, for the optimization of an industrial air heating system and hot air curtain devices.
In a recent study, several design optimization calculations of airfoil geometries have been performed successfully for different flow conditions. In these calculations, the flow domain considered is discretised by an automatic grid generation process, using a parametric representation of the airfoil geometry. The



SPINEware enables working environments to be constructed and used on heterogeneous computer networks objective functions are based on the aerodynamic quantities C_l and C_d, which are calculated from the Reynolds averaged Navier Stokes equations closed by a turbulence model.

Multidisciplinary Design Framework

In the application of the framework for generic design optimization to multidisciplinary design problems, it is desirable to deal effectively with separate design objectives that originate from different disciplines. In general, these objectives cannot be adequately compared, weighted or combined a priori, and should therefore be dealt with as separate multiple objectives in the optimization calculation. After the optimization calculation –a posteriori–, when the results of the objective functions for each evaluated design are available, the designer can choose the most suitable design. Each of the objective functions, and possibly other aspects or constraints of the design that are not included in the objective functions can be considered. A literature survey has shown that evolutionary algorithms provide suitable ways to deal with multiple objectives in multidisciplinary design optimization.

Enhanced Aeronautical Concurrent Engineering

For several decades, European aeronautics companies have recognised the benefit of multinational collaboration. New aircraft programmes are becoming increasingly complex. To succeed, European companies are investing in the re-engineering of their processes, and have started to implement Concurrent Engineering techniques accordingly. Successful implementation of Concurrent Engineering on the scale needed to run a new large aircraft programme throughout the whole supply chain is an immense challenge. To cope with this, the major European players in the aeronautics industry have decided to make use of the experience that Concurrent Engineering can now be combined with state-of-the art Information and Communication Technology to build up the capability required for enhanced design, fabrication and support processes, throughout the aeronautics industry. This has led to the definition of the EU ENHANCE project (ENHanced AeroNautical Concurrent Engineering) by a consortium of 14 contractors, including the co-ordinator. These contractors are: Aerospatiale (co-ordinator), Alenia, British Aerospace, CASA, Daimler-Benz Airbus, Dassault Aviation, Eurocopter, Liebherr, Messier-Dowty, MTU, NLR, Rolls-Royce, SNECMA and Sextant Avionique.

The ENHANCE project is aiming at improving the European Aeronautical industry competitiveness by streamlining and defining best practices through the whole supply chain. It is executed by the contractors and 39 associated contractors representing airlines, SME's, engines, equipment, helicopters, SME suppliers, Information Technology vendors and research institutes. NLR is leader of two of the nine workpackages, Information Technology and Support.

The project is funded by the EU under ESPRIT (European Strategic Programme for Research and Development in Information Technology).

ENHANCE was started with an assessment of today's aeronautical design, fabrication and support processes, and the Information and Communication Technology infrastructures currently in use by the Aeronautical industry. From that, requirements for the 'common way of working' within the desired, future European Aeronautical Extended Enterprise have been derived, including requirements for the Information and Communication Technology environment required to support the common way of working.

In ENHANCE NLR is responsible for the support of the implementation and application of concurrent engineering (CE) methodology in aeronautical industry. The support is focused on CE in aeronautical business processes and on human factors (HF) in CE The approach according to which the support is provided is as follows. First the current state of the art of CE methods and HF in aeronautical industry is assessed. Next the state-of-the-art of CE methodology and technology and HF currently available is assessed. Based on this, a reference model of CE and HF is defined for aeronautical industry together with roadmaps and guidelines for implementation of CE and HF in aeronautical industry. The first version of documents describing these models and methods have been made available to the consortium.

Facilities for Flow Simulation

In the NICE project, partially funded by the foundation HPCN (High Performance Computing and Networking) and co-ordinated by NLR, the development of parallel and distributed CFD applications was finalized. The NICE digital working environment HCS (HPCN Centre for flow Simulation), has been used to consolidate, conserve and prepare for re-use the achieved results. HCS was realized starting from the NLR ISNaS working environment for CFD based on the generic framework SPINEware. SPINEware enabled this working environment to be extended by the NICE partners, to realize their own local working environments. To this end, tools developed by the partners themselves, such as Delft Hydra of Delft Hydraulics, were added. After the conclusion of the NICE project, HCS will continue to support the collaboration between the NICE partners.
The technology tested in NICE will be applied in the HPCN Infrastructure project "Super Broker", in an IT environment supporting Stork/Fokker in "Collaborative Engineering" and in projects acquired by NLR in the context of the Fifth Framework Programme of the European Union.

Continuous Acquisition and Life-cycle Support (CALS)

NLR's participation in the Netherlands Interservice CALS Working group on Electronic Technical Manuals and the Standard for the Exchange of Product Model Data (STEP) was continued.
For the European aircraft industry, technology development and demonstration activities were carried out in the area of design modelling, using the STEP Express Language. Subsequently, a working environment was developed enabling control engineers to perform computer-aided engineering of new vehicle control systems highly efficiently, while effectively managing system complexity.

Advanced Information Processing for Process and Product Improvement

Support is being given to aircraft industry in the area of advanced information processing techniques. More specifically, constraint satisfaction techniques, combined with problem-specific and problem-independent knowledge are applied to be of help in important design decisions, reducing the weight of the resulting design.
As a member of EvoNet, the ESPRIT Network of Excellence on Evolutionary Computing, NLR is leading the Aerospace Working Group. In the group, information is exchanged of specific aerospace-related requirements for evolutionary computation, of current and future application areas, and of available tools. NLR's focus is on evolutionary multi-objective optimization.
The area of is data mining, the (nontrivial) extraction of implicit, previously unknown, and potentially useful knowledge from large data sets, has seen a surge. Domain expertise and data mining technology and tools were being used to identify new relationships, which enable improvements to design, maintenance and logistics to be made.

Facility for Control Engineering

In the framework of the GARTEUR Flight Mechanics, Systems, and Integration Group of Responsables Action Group (FM) AG-11, New Analysis Techniques for clearance of flight control laws (NEAT), NLR is developing a Wide Area Network (WAN). The Information and Communication Technology part of NLR's contribution focuses on a model and tool repository to enhance efficient co-operation between the GARTEUR partners. Preparations have been made for a demonstration of some possibilities of multidisciplinary design. Requirements have been identified prior to the development of the model and tool repository.

The ISMuS (Information System for Multi-body Systems) working environment is used to store and distribute knowledge obtained in projects centring around the field of modelling, simulation, and control on the basis of systems of ordinary differential and difference equations. It has been used in various projects. Various new versions of existing models and tools (including accompanying documentation and other relevant information) have been integrated and put under configuration management. An electronic service request handling system has been developed which allows the ISMuS users to track their requests and the ISMuS technical support team to handle the requests electronically while keeping the requestor optimally informed.

Facility for Statistical and Risk Analysis

The SPINEware-based working environment for Statistical and Risk Analysis ISTaR has been used within the safety projects described above in the 'Reliability, availability, maintainability, safety and certifiability' section. ISTaR enhances the development and re-use of models and software tools for example to assess collision risk between aircraft, wake vortex induced risk, and external safety around airports. Its graphical interface provides easy access to various models and software tools for statistical and risk analysis at NLR.

Working Environment for Software Engineering

ISEnS is an environment to support software engineers is finding and using technology and tools to produce high-quality software effectively and efficiently. Using ISEnS, software engineers can easily find information and tools for their analysis, design, production and testing work. Moreover, a combination of tools for specific project can be easily made. Both commercial-of-the-shelf and own tools, possibly on different systems, can be integrated using ISEnS integration mechanisms based on SPINEware.

Simulation, Training, Visualization and Virtual Environments

Flow Simulation and Solvers

Work was done on the further development of the NLR simulation system ENFLOW for viscous, turbulent flows around complex aerodynamic configurations using the Reynolds-averaged Navier-Stokes equations. In particular, this work was concerned with time-accurate simulations and with the modelling of turbulence. A contribution was made to the extension of the flow solver ENSOLV to a time-accurate method, enabling the unsteady flow around a fixed or manoeuvring rigid configuration to be simulated. For these time-accurate simulations, parallelization of ENSOLV on the NEC SX-5 was required. On the basis of a mathematical analysis, a modification of the k-omega turbulence model was derived which resolves the notorious problem that the flow solution depends in an unphysical manner on the free-stream values of the turbulence variables.

The flow solver Hexadap has been extended with functionality for the simulation of rotor flow for both hover and forward flight. This work is being executed for the Boeing company, which is interested in the analysis of Blade-Vortex Interaction, for which accurate resolution of the tip vortices is required. The flow solver Hexadap is based on the relatively new Discontinuous Galerkin Method, which, though accurate, is computationally intensive. For the method to compete with more conventional methods, the computational complexity must be balanced by its efficiency on irregular, non-uniform grids. A major algorithmic improvement in the numerical method made it possible to obtain highly accurate vortex resolution on highly non-uniform meshes. These non-uniform meshes are obtained by locally refining coarse meshes in the regions where the vortex is visible. This results in meshes that contain considerably fewer grid cells than conventional meshes. It has been demonstrated that the computational complexity of the method is more than balanced by its accuracy on highly irregular meshes.

Vehicle Behaviour Models

A behaviour model for dynamic vehicle simulation, based on multibody dynamics has been developed in the SIMULTAAN project. Models of planetary rovers, trucks, cars, and tractors can be obtained by tailoring the parameters of generic models. An instantiation of a model has been used in a demonstration of the SIMULTAAN project. Special attention was paid to the interaction between the vehicle and the ground, for which several terrain models can be used.

In the development of the vehicle behaviour model, the multibody simulation tool SIMPACK is used. SIMPACK has a three-dimensional design facility in which animation is possible. It has also post-processing facilities. For real-time simulation of the vehicle behaviour model the real-time simulation tool EuroSim is used. One can export a SIMPACK model and incorporate it in EuroSim. Dynamic vehicle models have also been implemented in Matlab/Simulink. For real-time simulation these models can be transferred to EuroSim with the automatic transfer tool MOSAIC.

EuroSim

On 3 December 1999, Fokker Space, Origin Nieuwegein and NLR founded the EuroSim consortium. EuroSim is a configurable simulator tool that is capable being used in all phases of space and non-space programmes through real-time simulations with a person and/or hardware-in-the-loop. EuroSim allows existing model software to be reused.
The design of EuroSim is based on the principle that every simulator can easily be broken down into an invariant tool part and a part that is specific to the subject being simulated. By means of careful design of the tool component, i.e., EuroSim, it can be used for a wide variety of simple and complex simulators. EuroSim helps to reduce the costs associated with simulation and allows simulation activities to be used more extensively and earlier in a programme.

The EuroSim consortium will further develop EuroSim to provide the international simulation community with state-of-the-art simulation support. For the first two years, EuroSim developments will be funded by NIVR. The EuroSim consortium has initiated the EuroSim Management Board, the EuroSim Product Development Team, and the Marketing & Sales Team. Together, they form the EuroSim organization that is responsible for further commercialization of the EuroSim product and for the steering of the EuroSim product developments in response to market demands.

In the EuroSim consortium NLR participates in almost all development activities. NLR is specifically responsible for developing an attractive EuroSim Simulator Development Environment (SDE). The SDE will consist of a Model Repository tool and a Simulator Composition tool. The Model Repository will provide the means to store and retrieve in a coherent manner all information that is relevant with respect to models. This information will include for example model code, design documentation, user manuals, and related information such as relevant session results, and proprietary information. The Model Repository will be based on Web and database technology. The Simulator Composition tool can be used to combine components available in the Model Repository into an executable simulator in such a way that inclusion of hardware components later is easy. In addition, after the components have been selected, the SDE will check whether the combination of components will lead to a valid EuroSim-based simulator.

Tip vortex of helicopter in hover computed with Euler method

Transfer of Simulation Models

Under contract to ESA, NLR has developed the tool MOSAIC, which automates the transfer of simulation models from Matlab™/Simulink™ to EuroSim. MOSAIC takes model source code that has been generated by the RealTime Workshop of Matlab™/Simulink™ as input, and delivers model source code that can run in EuroSim, as well as additional EuroSim specific files as output. Matlab™/Simulink™ is often used for feasibility studies and more specifically for control system design activities. EuroSim is a general purpose simulation tool that is mostly used in system simulation studies, possibly with hardware and humans in the loop. MOSAIC represents the first step in aiding model developers in automated model transfer between Commercial-Off-The-Shelf tools. In follow-on work MOSAIC will be made suitable to deliver source code that is compatible with ESA's emerging Simulation Model Portability (SMP) standard.

Simultaan Demonstration

The SIMULTAAN R&D programme was initiated by the foundation SIMNED in 1997, partly funded by the foundation HPCN (High Performance Computing and Networking), and executed by the SIMNED partners National Aerospace Laboratory NLR, TNO-FEL, Siemens Nederland NV, Fokker Space BV, Hydraudyne Systems & Engineering, and the Delft University of Technology. In SIMULTAAN, existing knowledge and products were combined with newly developed tools to arrive at a permanent infrastructure in the Netherlands for real-time simulation that involves complex high performance computing and networking. SIMULTAAN was concluded by a demonstration of acquired capabilities.

NLR has participated in almost all activities of SIMULTAAN, but the responsibilities and major contributions in the area of ICT have been the design and implementation of generic and complex behaviour models and the design and implementation of a generic scenario management tool. In addition, NLR worked with Fokker Space on the design and implementation of a repository.

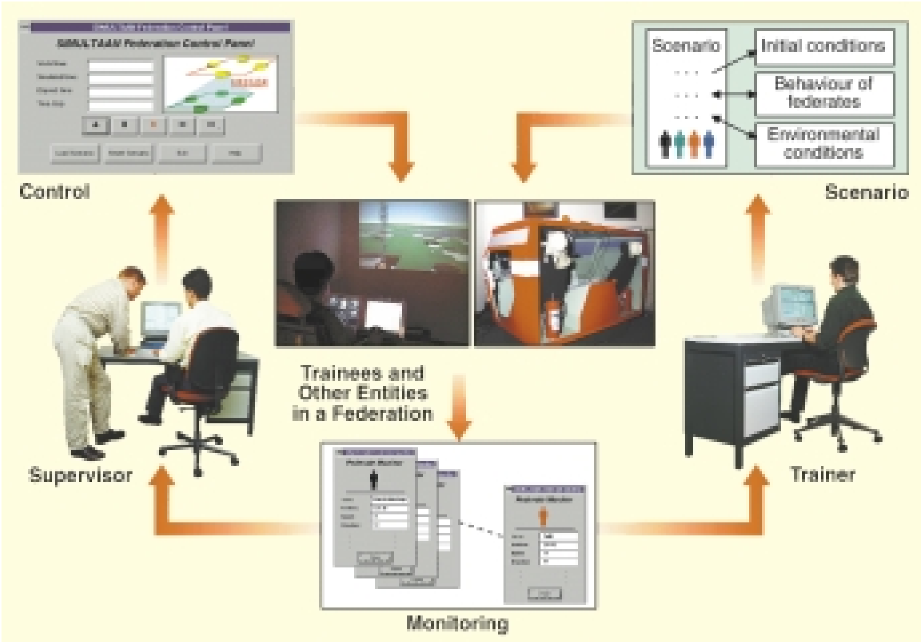
The capabilities acquired in the Simultaan project have been demonstrated successfully at the workshop 'Co-operation on Training Simulators in the Netherlands' organized by the Foundation HPCN. It was shown how a very short period of time a complete distributed simulator could be built. For this, a simulation model of a fire truck developed by NLR was downloaded from the NLR internet site in Amsterdam via restricted web-access. A motion base of Hydraudyne, located in Boxtel, was part of the simulator. Using High Level Architecture (HLA) interfacing tools, a distributed simulation was done. A large visual display allowed the participants of the workshop to follow the fire trucks and motion systems movements. In the first part of the simulation, NLR's vehicle behaviour model used EuroSim as generic simulation tool to interface with the rest of the distributed simulation. In the second part of the demonstration a real-time simulation was done of a fire extinction in a harbour area. In this simulation a helicopter simulator, physically located at the Delft University of Technology also participated. A mock-up of a fire truck was placed in the demonstration room. The behaviour model, together with the mock-up, allowed a driver to steer to the location of the fire, using a digital map of the harbour area.
The simulation was controlled by NLR's SmartFED tool, whereas two additional instantiations of NLR's vehicle dynamics behaviour model simulated the movements of additional fire trucks.

Scenario Management

A generic scenario management tool, SmartFED (Scenario MAnager for Real-Time FEderation Directing), was developed in the Simultaan project. This tool can be used for real-time monitoring and control of networked simulations. It also offers functionalities to define and execute high level scenarios. SmartFED performs scenario management for distributed simulations that are based on High Level Architecture (HLA). The part of SmartFED that controls the simulation has successfully been adapted for CORBA applications.

Automatic Debiting Systems

The Ministry of Transport is planning to introduce automatic tolling systems on the main roads leading to major cities under the name of *Rekeningrijden*. The Ministry has formulated strict requirements to the performance of the Auto Debiting Systems (ADS) systems for application in the Netherlands. A number of international consortia have offered proposals for an ADS. NLR together with the University of Amsterdam has conducted simulation studies to evaluate designs of the consortia in the development of simulation models in the design phase, under contract to the ministry. NLR has conducted evaluation studies on a framework for synchronised communication and medium access in ADSSIM, a simulation environment for ADS systems, and on a protocol evaluation tool, to assist in the performance analysis of a communication subsystem proposed by consortia. NLR has also provided the ministry with support in both the pilot test and the design evaluation.
After the conclusion of the evaluation the ministry has selected two consortia to develop their systems further.



Scenario Management of Distributed Real-Time Simulations with SmartFED

Robotics

Simulation and Control

In co-operation with the University of Twente, the Matlab-based CACE environment TRaCE (Trajectory and Constraint Evaluation) has been extended with manipulator models and impedance-based control methods to simulate constrained motion of robotic manipulators whose end-effector is in contact with a surface. Existing models such as TRaCE for simulation of constrained controlled robotic manipulators and models for the education of trainees and new employees have been integrated in the model part of ISMuS.

NLR participates in the INTAS project 96-2138 ‘Mechanical Systems with Multiple Colliding Elements’. An invited lecture on ‘Real-Time Simulation of Impact for the Aerospace Industry’ was given at the Euromech ’99 colloquium on ‘Impact in mechanical Systems’. As follow-on work, a survey paper will be made in co-orporation with ENSIEG (France) on ‘Simulation of mechanical Systems with Discontinuities’. Together with Fokker Space and the University of Twente, a project definition was initiated to investigate the influence of friction on the controlled performance of robotic manipulators. The project will provide inputs for MPTE and ERA.

Operations

The specification of the ERA Exception Handling, or Failure Detection Isolation and Recovery (FDIR) system, was modified because of changes in the ERA design and of additional restrictions imposed by the ERA subsystems. Most remaining threshold values were determined. First tests were performed on the ERA flat floor facility. Additional test requirement specifications were written to verify the system requirements related to FDIR. System engineering support was provided to solve problems found during testing.

The so-called Design Reference Missions were decomposed in generic procedures to show that ERA indeed is capable of performing the required missions. A set-up was made for the tests on the Mission Preparation and Training Equipment (MPTE) and the ERA flat floor facility showing that ERA is capable of performing the generic procedures. The writing of the diagnosis and recovery procedures was started.

In the framework of ERA Evolution, research into the use of signal analysis techniques for a predictive maintenance facility was completed. Research towards the application of several identification techniques to estimate the parameters of the non-linear ERA model was started.

Information and Communication Infrastructure

The NLR Information and Communication Infrastructure

The NLR Information and Communication Infrastructure (ICI) consists of a high-speed communication network and several facilities. Among the facilities are a supercomputer, several other UNIX-based servers and several PC servers. The network connects the facilities to workstations, X-terminals, PCs and terminal equipment for research facilities. The number of stations connected was increased from 1813 to 1941.Two additional locations of NLR, at Schiphol, were integrated by means of ISDN connections.

For further improvement of the availability, a start has been made with the improvement of the availability of the least reliable part of the ICI; the link between the two sites.

To continue making state-of-the-art supercomputer power available to NLR and its customers, the NEC SX-4 supercomputer has been replaced by an SX-5. This replacement provides a four-fold increase in processing speed and processing capacity. The SX-5 of NLR is a shared-memory supercomputer with 64 GB main memory and with eight vector processors. Each vector processor has a processing speed of 8 Gflops.

The gateway between the ICI of 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 are increasing rapidly. The ICI provides the base for several experimental and operational activities in co-operation with external customers. To maintain security, an intermediate network for co-operation and data exchange has been created, between the NLR network and the Internet. A start is made with improvement of the Internet interface by means of a firewall system within this intermediate network.

The file server facility provides to all systems a file system that can be accessed from all locations at NLR. The total size of the data on the file system on the fileserver increased from 390 GB to 800 GB. The introduction of the SAMBA protocol on the file server makes the central file system also available from the desktop PCs. During nights and weekend, the fileserver facility is used for backup. Backups can be made of all UNIX systems and all PC servers at NLR automatically. During the weekend a full dump is made. The total size of all full dumps during a weekend, increased from 450 GB to 1000 GB, and the number of files dumped increased from ten million to seventeen million.

To improve the maintainability and availability of the PC infrastructure, standard PC configurations and operational support procedures were defined. To support the use of PCs, central Windows NT servers are available. The use of the PC servers for data storage increased from 780,000 files on 57 GB to 1,081,000 files on 163 GB.

Integration of Dutch Supercomputers Sites into one Infrastructure

The computing facilities at the four HPCN sites (NLR and three universities) in the Netherlands are available to external users, but potential users such as engineering firms, industry, and the government have encountered a number of obstacles when accessing the HPCN facilities. NLR is leading an effort of the sites to integrate their facilities into one uniform infrastructure with standard webbrowsers as main user interface. The primary goal of this infrastructure is to demonstrate to interested parties that accessing the HPCN facilities is easy and that the use of HPCN facilities can be profitable and cost-effective. One central webportal is the entry point to the facilities within the infrastructure. This website contains information about the various facilities, their use, and support. It also contains application pages that allow visitors to get started by running their software on any of the facilities or by using the engineering and/or simulation applications from the standard application pages on their data.

3.7 Avionics

Summary

The main areas of activities of the Avionics Division are research and technology development for avionics systems, the design and prototyping of aerospace electronics, and the design and operation of instrumentation for flight testing and wind tunnel testing. These activities require an extensive infrastructure of partly computer-based tools, which is being built up, for avionics systems performance assessment, virtual prototyping, systems design, electronics design, and computational electromagnetics. A growing workload was experienced, with highlights in the EU (European Union) programmes for Air Traffic Management research and Integrated Modular Avionics design methodology and in the work endorsed by Boeing and Lockheed Martin in the concept definition phase (CDP) of the Joint Strike Fighter (JSF). Wind tunnel facility management systems proved to be a promising working area.

NLR has been involved in various aspects of future avionics systems, for both civil and military use. In the field of Integrated Modular Avionics, the contract activities concerned the participation in international Working Groups on the definition of standards for an Avionic Computer Resource, the completion of the EU Fourth Framework project Generic Avionics Scalable Computing Architecture, and the continuation of the EUCLID project Avionics Architecture Evaluation Tool.

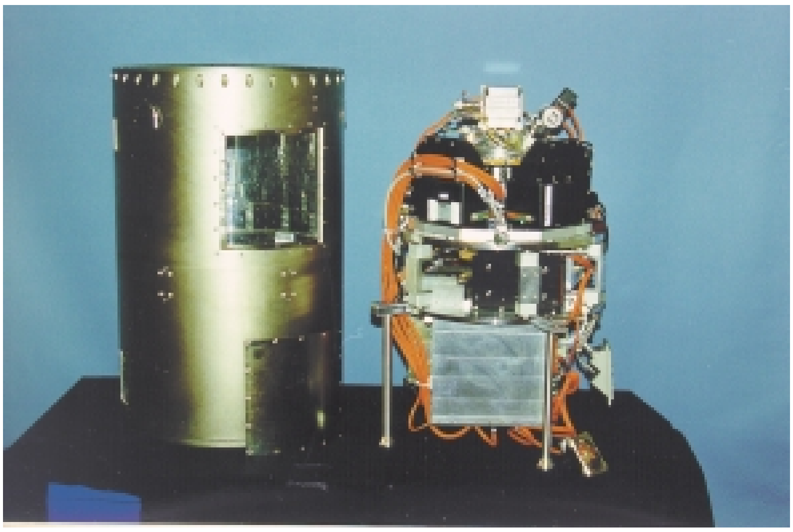
Under contract to the NIVR and in co-operation with Dutch industry, NLR studies next generation utility control systems for civil aircraft. A concept was evaluated by virtual prototyping (modelling and simulation).

Support to the RNLAF in avionics-related technologies included research on both tactical and high bandwidth imagery data links and on the modelling of avionics systems and associated architectures.

The heart of NLR's Avionics System Integration Rig has been realized. The core avionics architecture of the F-16 MLU (Mid Life Update) was modelled and with this, an F-16 MLU simulation environment was created to operate the Orpheus reconnaissance system for test purposes in the laboratory.

In the field of Computational Electromagnetics (CEM), contract work on the modelling of spacecraft antenna constellations as well as on the electromagnetic interaction of conformal antennas with the aircraft structure was continued. NLR also worked on a national technology project aimed at the performance assessment of antennas on possibly vibrating aircraft structures.

In the field of Synthetic Aperture Radar (SAR), contract work involved the completion of the EUCLID project Advanced Space SAR Sensor Technology, the start of the EUCLID project New Technologies for Lightweight SAR Sensor



Cosmic Dust Aggregation experiment (CODAG) with control electronics built by NLR (photograph courtesy Fokker Space) and the further development of PHARUS (Phased Array Universal SAR), a co-operation between NLR and TNO-FEL. In flights on NLR's Cessna Citation II laboratory aircraft, new operating modes were investigated, showing high quality imagery.

For a number of customers, a variety of environmental qualification programmes were carried out, including Electromagnetic Compatibility (EMC) tests on a CH-47D Chinook helicopter equipped with a new Electronic Warfare System.

In the field of electronics, contracts were granted to consortia of Dutch industries and NLR for participation in the development of the JSF. In co-operation with several Dutch industries and partially funded under the Netherlands JSF Preparation Programme, NLR started work on a number of JSF projects, one item being the application of Commercial-Off-The-Shelf (COTS) components. The participation in the development of avionics equipment for the NH90 helicopter was continued.

The Cosmic Dust Aggregation scientific experiment was launched on the Maser-5 sounding rocket. The experiment control electronics and ground support equipment for this experiment has been developed and built by NLR in close co-operation with Fokker Space. The development of the Temperature Data Acquisition System for use in the Large Solar Simulation Facility of ESTEC was concluded with the delivery of a prototype; ESA awarded NLR a contract for two fully equipped systems.

In the field of wind tunnel instrumentation, NLR was awarded the contract for the delivery of the Facility Management System for the future Italian Icing Wind Tunnel. Activities for the development and delivery of the safety system for the Italian Plasma Wind Tunnel were continued. Research into advanced facility management systems for wind tunnels was continued.

Research was also carried out in the application of COTS components and obsolescence management, becoming more and more important with the demise of Military Specification Components.

The major part of the instrumentation work was done to support the RNLAF. An instrumentation system developed for flight tests with the F-16 MLU was installed, made its maiden flight, and was used in a pod certification programme. In connection with the RNLAF's participation in the operation Allied Force, an on-board video system providing video images, time synchronization and annotation in a transport helicopter was installed for flight testing a flare dispenser system.
Work for the reconnaissance needs of the RNLAF has been growing steadily. Existing F-16 capabilities have been adapted to the F-16 MLU. An interface demonstrator developed to adapt the new generic reconnaissance interface of the F-16 MLU to the ORPHEUS reconnaissance system was flight-tested. Work for the adaptation of the Medium Altitude Reconnaissance System was started.

Because NLR's research aircraft are used in the testing, evaluation and demonstration of new guidance, navigation and air traffic management concepts, SATCOM data 3 and VHF digital data links mode 2 and 4 were installed. In the European project 'Multimodal Approach for GNSS-1 in European Transport', trials were carried out involving service cars of Amsterdam Airport Schiphol along with NLR's Metro II research aircraft to demonstrate Surface Movement and Control System applications. The EU project Airborne Air Traffic Management System (AATMS) was concluded. Results of this large-scale integration effort for flight trials concerning experiments with an advanced Flight Management System (FMS), were presented. In the Prototype Aeronautical Telecommunications Network (ProATN) project, flight tests and demonstration programmes were performed with NLR's Citation II research aircraft. Both in the AATMS and the ProATN projects, real time digital data link applications were demonstrated.

NLR's in-house developed GPS-based Position Reference System, adapted to provide ILS-like steering signals to the autopilot of NLR's Cessna Citation research aircraft to enable repeated flight tracks to be flown within 10 metres distance, proved to be working under operational conditions.

A strongly increasing demand for environmental testing has prompted the extension of facilities. The Vibration and Shock Test laboratory was extended with a thermal chamber on the shaker. An outdoor Antenna Test Range was officially put into service.

Avionics systems

Integrated Modular Avionics

Avionics Computer Resource (ACR)

Under contract to the RLD, NLR participated in working groups of the EUROCAE and RTCA concerning the definition of Minimal Operational Performance Standards (MOPS) for an Avionics Computing Resource. An ACR implements the integrated modular avionics concept in which software applications provide the actual avionics functionality, while generic hardware including the operating system provides the computing power. A draft document was completed for ratification.

Special attention was given to the aspect of certification of such an ACR. NLR continued the analysis for the incremental certification process and the reusability of application software. The result of the EU project GASCA (Generic Avionics Scaleable Computing Architecture) was used as a ‘target’ for the certification process.

Generic Avionics Scaleable Computing Architecture (GASCA)

The Generic Avionics Scaleable Computing Architecture (GASCA) project of the EU Fourth Framework Programme was concluded. It was aimed at defining a new architecture for future civil avionics. The GASCA architecture was designed such that it is fully configurable in flight (i.e. functionalities can be added or removed). A demonstrator was built for proving the concept.

NLR was responsible for the development of the interface between the computer platforms (the GASCA demonstrator) and the environment simulator (the ‘aircraft’). To display the major functional output of the GASCA applications (flight control, autopilot, flight management system) a display system was designed and built to simulate the primary flight displays. To provide the applications with the appropriate data, flight models were developed including a model for other simulated entities (aircraft) in the airspace. In addition, NLR was involved in configuring the GASCA operating system and preparing the demonstrator configuration tables, which define the applications that are active at a given point in time. Adding the components for providing fault tolerance severely increased the complexity of the configuration tables. NLR defined the concept validation plan, prepared the concept validation report and hosted the dissemination workshop and the final presentation to the European Commission.

Avionics Architecture Evaluation Tool (A2ET)

NLR continued its activities in the EUCLID RTP 4.2 project related to integrated modular avionics. This project is aimed at the development of an Avionics Architecture Evaluation Tool (A2ET). With this tool, avionics architectures can be modelled and their performances analysed.

In integrated modular avionics, software applications perform the actual avionics functionality, while the generic hardware, including the operating system, provides the required computing power. This concept enables the system integrator to configure the avionics architecture and its functionality flexibly. As there are many parameters to cope with, a tool is required to assist in analysing the architecture performance. The core concept of the tool is based on the ‘blueprints’, which describe the architecture of the system. NLR mainly contributed to the definition of the ‘blueprint’ formalism. The blueprints contain the most important data for each architectural building block, such as processing requirements for applications, clock speed for processor boards, transmission speed for networks, etc. Each blueprint is associated with a model, so that after architecture definition, analysis can be performed. NLR worked also on mechanism to construct a ‘run-time’ model from the individual blueprints.

Future Operation Concepts for Utility Systems (FOCUS)

Under contract to the NIVR, NLR in co-operation with Fokker Elmo studies next generation utility control systems for civil aircraft. Utility control systems control the operation of the electrical, air-conditioning, hydraulic and anti-icing systems, among other systems. Currently these utilities are operated through dedicated control panels, located in the overhead panel, and have dedicated point-to-point wiring to the respective utility systems. The goal of the project is to replace the traditional wiring and dedicated panels by an integrated systems approach using modern databuses and multifunction displays. A new system control architecture was defined, modelled and subsequently simulated, by means of 'virtual prototyping' techniques. In addition, MMI aspects were covered by modelling the existing panels as well. The modelling and simulation was accomplished using NLR's avionics system development infrastructure.

Military Avionics Technology

Support to Royal Netherlands Air Force

NLR continued to provide support to the Royal Netherlands Air Force (RNLAF) on avionics-related technologies. Activities included research on both tactical and high-bandwidth imagery data links and on the modelling of avionics systems and associated architectures.

In the area of tactical data links, the introduction of new links in the airborne platforms has been investigated. Interoperability between the various platforms was of specific interest. In addition the operational aspects of employing data links for Uninhabitated Aerial Vehicles was under investigation. In conjunction to tactical data links, the integration, by data fusion, of the available information has been investigated.

In the area of avionics modelling the so-called Generic Recce Interface (GRI), part of the F-16 MLU avionics system architecture, was modelled and simulated in order to verify the operation of the current RNLAF F-16 reconnaissance system ('ORPHEUS') with the new F-16 MLU avionics architecture.

Avionics System Integration Rig

Work on the development of the Avionics System Integration Rig was continued. The core system, a control computer with interface boards, integrated with a specific software kernel, has been realized.

As a first application, the core avionics architecture of the F-16 MLU was modelled and an F-16 MLU simulation environment was created to operate the Orpheus reconnaissance system statically, with simulated in-flight conditions. The modelling consisted among other things of a model of the Multi Function Display for pilot control, and data flow emulation on the MIL-STD-1553B interface bus.

SAR Sensor technology

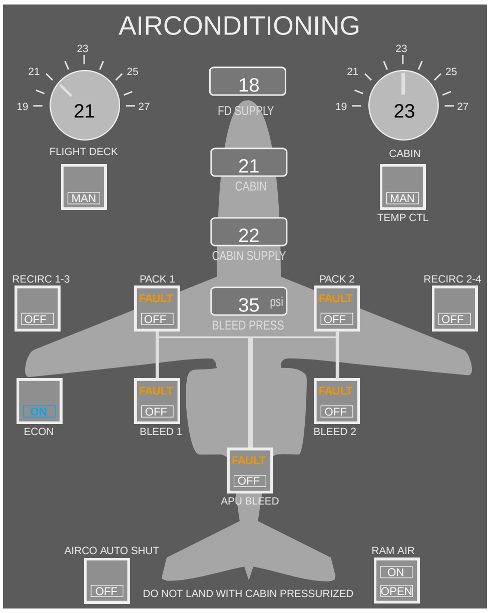
Phased Array Universal SAR (PHARUS)

NLR continued work on PHARUS (Phased Array Universal SAR), an airborne fully polarimetric Synthetic Aperture Radar for remote sensing, developed, built and operated in co-operation between NLR, TNO-FEL and DUT. PHARUS has made a number of flights on NLR's Citation II laboratory aircraft, where new operating modes resulting in high quality imagery were investigated. One application of PHARUS is change detection.

Spaceborne SAR

NLR participated in the project EUCLID RTP 9.3, in which new technologies have been developed and evaluated for future Synthetic Aperture Radar instruments. NLR's contribution was concentrated in three areas: Digital Control, Thermal Analysis and Electronic Counter Counter Measures (ECCM). The project was successfully concluded.

With respect to digital control, an architectural design was completed for three different SAR instruments, for S-band, X-band and dual band applications. A functional prototype was designed for controlling the overall instrument and its components: the tiles, containing a number of T/R (Transmit/Receive) modules and the T/R modules themselves. Design and implementation were verified by testing.



Current (left) and design for future overhead airconditioning panel

With respect to thermal analysis, detailed requirements, were identified on the basis of the SAR mission definition. From these requirements, the thermal housekeeping problem was modelled in order to calculate the expected thermal behaviour in detail. Evaluation of computational results eventually led to the definition of a thermal design baseline.

With respect to ECM (Electronic Counter Measures) and ECCM (Electronic Counter Counter Measures) activities, first the most likely ECM threat to a spaceborne SAR was defined. Measures that could counteract so-called non-intelligent, brute force jamming spread over the SAR bandwidth were studied, as were measures that can counteract intelligent jamming, viz. spoofing, which basically consists of signals generated by smart repeaters on the ground. Recommendations on counteracting these jamming threats by using the most promising ECCM techniques were formulated.

Lightweight Synthetic Aperture Radar (SAR)

The EUCLID project New technologies for lightweight SAR Sensor (RTP 9.7) was started. In this project, a follow-up of the RTP 9.3 programme, NLR participates in the areas of digital control and thermal analysis. The main goal of this project is to develop lightweight and low-cost SAR instruments. In the digital control aspect NLR is responsible for system design and for the manufacturing and testing of a prototype to verify the design. The thermal analysis work package includes modelling and performing calculations of heat transfer in the highly integrated front-end.

Avionics Computational Electro Magnetics (CEM)

Antenna Technology

NLR is involved in several projects concerning antenna performance prediction and actual antenna measurements. With respect to the antenna performance prediction more and more use is being made of NLR's extensive suite of Computational Electro Magnetics (CEM) tools in which antennas are modelled, relatively quickly providing insight in the behaviour of the subject antenna.

NLR continued research into Smart Skin Array antennas, under contract to the Netherlands Ministry of Defence. Smart Skin array antennas are conformal active phased array antennas and are constructed in the form of thin flat layers using a number of transmit/receive modules. These antennas can be constructed such that they are conformal to the aircraft's fuselage. NLR's activities are concerned with the electromagnetic interaction of these antennas with the aircraft structure (reflections/multipath).

Reflections at the aircraft structure are expected to influence the behaviour of the smart skin antenna. The project focussed on the modelling of the phenomena. A so-called hybrid method for the calculation of this interaction is being developed. To validate the model and its implementation, the results of the calculations will be compared with actual measurements of a (scaled) prototype antenna array mounted on a generic aircraft. First measurements of this antenna array were conducted at NLR's Antenna Test Range (ATR). Data analysis is currently carried out.

In order to assess the effects of surface vibrations and deformations (resulting from aerodynamics loads) on the performance of conformal antennas, NLR also works on the project CLAAS (Conformal Load-bearing Antennas on Aircraft Structures). This national technology project involves a number of disciplines: aerodynamics, aeroelasticity, structural dynamics and avionics. The aerodynamic and aeroelastic disciplines provide insight into the aerodynamic loads at the antenna locations and the amplitudes and frequencies of the resulting vibrations. Structural dynamics provide knowledge about the eigenfrequencies and vibration modes of the unloaded aircraft. In 1999 the research focused on the modelling of the vibrations and deformations at the location of the array antenna on a pod mounted underneath a fighter aircraft.

Electromagnetic Compatibility (EMC)

Computational Electromagnetics (CEM) tools were also used for solving Electromagnetic Compatibility (EMC) problems. These CEM tools, combined with NLR's EMC environmental test facilities, are used for the analysis. With the growing number of electronic systems installed in aircraft and the increasing external electromagnetic 'pollution', a good insight of the field strengths inside the aircraft is vital.

As an example, CEM tools have been developed and used to assess the penetration of electromagnetic fields through windows of the fuselage of an aircraft. The results are used to determine to the optimal location (with minimum field strength) of cable harnasses in the aircraft.

Environmental Qualification

For a number of customers, a variety of environmental qualification programmes were carried out, in which prototypes, ranging from avionics systems to cable harnasses, were subjected to many hostile environments with controlled temperature, altitude, vibration, EMI/EMC, fluid contamination, humidity, etc. For example, EMC tests were carried out on a CH-47D Chinook helicopter equipped with a new Electronic Warfare System. These tests consisted of intersystem ground tests, in-flight EMC checks and radiated susceptibility tests. They were carried out at the Open Area Test Site and heliport at NLR Noordoostpolder.

Similar tests were carried out on the Cougar helicopter.

Electronics

Instrumentation and control

Wind Tunnel Safety System

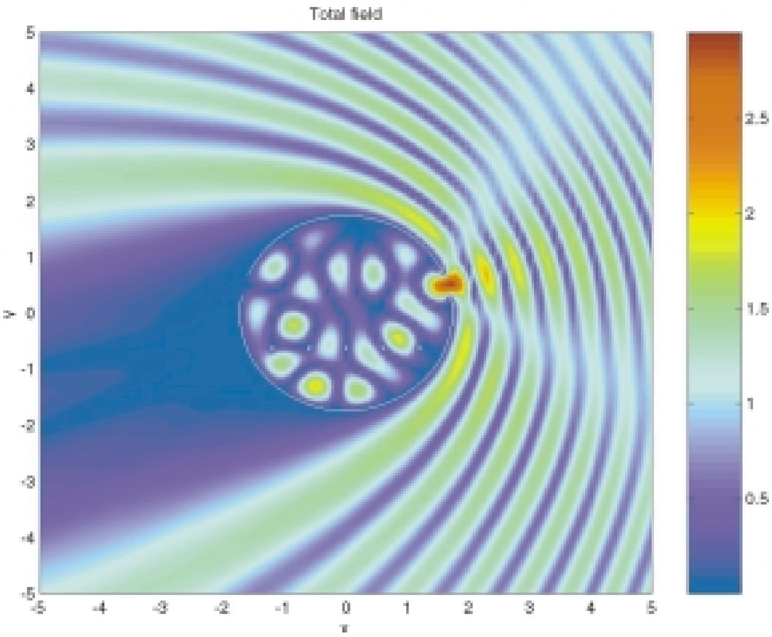
Under contract to LABEN of Italy, NLR completed the development and installation of the Safety System Subassembly of the automation system of the Italian Aerodynamic Plasma Wind Tunnel.

Wind Tunnel Facility Management System

Under contract of Turbo Luft Technik of Germany, NLR together with its sub-contractor REACT of Canada develops and installs a new generation Facility Management System for the Italian Icing Wind Tunnel. The purpose of this wind tunnel is to simulate icing conditions during flight, to investigate aerodynamic effects of icing. The concept of the facility management system is network oriented and will be realised using to maximum extent possible of commercially available hardware and software (COTS-approach).

Wind Tunnel Instrumentation and Signal Conditioning

NLR under contract to NASA has developed and produced two Rotating Amplifier Systems. These systems, shaft-mounted sets of 256 conditioning units, were developed for pressure and strength



Computed 2D electric field inside and outside the fuselage of a metallic aircraft, generated by an electromagnetic wave entering from the right

measurements on powered propeller blades. The system has to operate under an acceleration of maximum 600 g (continuous), and because of volume limits has been realised using thick film technology. In 1999, NASA awarded NLR a supplemental contract.

Positioning System for Borehole Radar

In co-operation with T&A RADAR and TNO-FEL, NLR is involved in the development of an advanced borehole radar instrument. State-of-the-art technologies are used to implement a new measurement concept for locating and imaging unexploded ordinances in the subsurface of the earth. Compared with conventional techniques, concept simulations indicate accurate images within significantly less measurement time. Input of NLR is in the field of mechatronics. Experts in mechanics, electronics and computer science have collaborated to realize a positioning system that is in balance with the whole measurement system.

Aviation

NH90 Remote Frequency Indicator

NLR continued its support to Dutch Industry in the design and development of avionics equipment for the NH90 helicopter. Under contract to Schreiner Components (formerly BFGoodrich Aerospace) of Zevenaar, the programmatic and technical co-ordination of the development activities, the environmental testing and the execution of analyses required for the delivery of the Remote Frequency Indicator were continued.

NH90 Fuel Panels

Under contract to Schreiner Components of Zevenaar, activities were continued to support Fuel Panels design and development.

Electrical Power Distribution

Under contract to the NIVR, new concepts for electrical power distribution and for switching/fusing techniques have been evaluated. The aims being to enhance systems reliability (by removing electromechanical parts), energy conservation (by power on, on demand) and mass savings (by decentralized switching/fusing).

Advanced Data Link Processor

Under contract to Eurocontrol, NLR delivered five Advanced Data Link Processor (ADLP) units. The development, initiated in 1997, was finished. One of the major milestones of the project was the JAA (Joint Aviation Authorities) approval, which allows the ADLP to be fitted in commercial aircraft. The ADLP provides communication functions and applications in conjunction with a Mode S Transponder. For this purpose the ADLP is connected to the ARINC429 avionics buses and the Mode S transponder of the aircraft. Communication protocols of the ADLP are compliant with the

ICAO annex 10 document, Volume III Chapter 5. The ADLP has been delivered with a number of protocols and applications. The ADLP is fitted among other things with the Enhanced Surveillance application, Compact Positioning Reporting algorithm (CPR) application, Dataflash application, Mode S Specific protocol and the ISO8208 protocol.

Space

Sounding Rocket Instrumentation

In April 1999, the first Cosmic Dust Aggregation (CODAG-1) experiment of the European Space Agency (ESA) was successfully launched on the Swedish MASER-7 sounding rocket. During this six-minute experiment, defined by German and French scientists, the early phase of dust aggregation in proto-planetary disks has been simulated and observed, in a small vacuum chamber. As a sub-contractor to Fokker-Space, NLR was responsible for the design and development of the system control, data management and operator interface systems. The service electronics system for CODAG is based on many of the elements previously developed for the Cells In Space programme. Since the CODAG experiment system consists of several computer-based subsystems, the existing distributed control concept was re-used although extended with telecommand capabilities for real-time in-flight interaction.

Temperature Data Acquisition System

Under contract to ESA, NLR completed the design and manufacture of the prototype Data Collection Unit (DCU). Two partners of the European Space Research and Technology Centre (ESTEC), IABG of Germany and Intespace of France are also involved in the project. The DCU is part of a new Temperature Data Acquisition System (TEMPDAS), which will handle measurement signals generated by thermocouples placed on the test object, a satellite, during thermal testing in the Large Space Simulator at ESTEC, Noordwijk, which provides simulation of in-orbit conditions. The purpose of TEMPDAS is to enlarge the number of thermocouple channels that can be measured, reduce the number of slip ring units for information transmission, reduce the possibility for data corruption and provide a self-calibration capability. The DCU is space-qualified equipment. ESTEC awarded a supplemental contract to NLR for the delivery of a two complete DCUs.

IEEE 1355 High Speed Data Bus

Under contract to ESA, NLR designed, developed and delivered a PMC interfaces board and the driver for the carrier VME processor board. The board contains three IEEE-1355 communication channels. It is of a novel design, exploring a newly defined high-speed communication protocol, IEEE-1355, developed for use on board future spacecraft. The design of the VME IEEE-1355 is based on a PMC module inserted in a COTS PowerPC carrier board. Depending of the type of Power PC VME board chosen, one or two PMC modules can be inserted. In this way one PowerPC VME board can provide a maximum of six IEEE-1355 DS links.

Mass Storage Device (MSD) for International Space Station (ISS)

NLR has supported Signaal Special Products in the design and qualification of a non-volatile mass memory, under contract to ESA/MATRA, for use in the ISS.
Each Mass Storage Device (MSD) unit contains two hermetically sealed and vibration-protected COTS Personal Computer Memory Card International Association (PCMCIA) hard-disk drives. Discussions with MATRA were started about a next generation MSD incorporating PCMCIA solid state flash-disks for Columbus, based among other things on a study contracted by the NIVR.

Instrumentation

Measurement and Analysis Techniques for In-Flight Research

Position Reference System

The so-called LAMBDA algorithm, developed by the Delft University of Technology for the solution of the phase ambiguities of GPS signals, was implemented in the flight test data processing station DVSV. Comparative tests with a commercially available software package showed the position solutions were within 0.2 m, which increased confidence in both packages.

Flight Guidance for Repeat Pass Interferometry

The Position Reference System PRS, adapted to provide ILS-like steering signals in real time for the autopilot of the NLR Cessna Citation to enable the aircraft to fly repeatedly the same tracks with a reproducibility of better than 10 m, was enhanced by simplifying the interface with the autopilot. This system was used for interferometric measurements of the PHARUS synthetic aperture radar.

Support to the European Union

Prototype Aeronautical Telecommunication Network

The EU project Prototype Aeronautical Telecommunication Network (ProATN), intended to provide the communication network for the EU project European Pre-Operational Data Link Applications (EOLIA), was continued. In advance of the coming installation of the Air Traffic Services Unit (ATSU) developed by Aerospatiale, a Research Flight Management System (RFMS) and the Satellite Data Unit (SDU) were installed in NLR's Cessna Citation and integrated with Command and Display Units. Flight trials were conducted at the Paris Air Show at Le Bourget and in a ProATN/EOLIA flight trial campaign in the Netherlands.

Demonstration flights were made with NLR's Citation II research aircraft, which communicated via the ATN satellite communications subnetwerk with the EOLIA ground station at the Thomson CSF exhibition stand at the Paris Air Show. The aircraft could be followed using the EOLIA ADS (Automatic Dependent Surveillance) service on the air traffic controller's display. Controller-Pilot Data Link Communications messages (pilot requests and ATC clearances) were exchanged. The trials received ample attention from air traffic, communication and avionics journalists and from EU representatives.

At the end of the year a second series of ProATN/EOLIA flight trials took place. For these trials Aerospatiale delivered an improved version of the ATSU. After integration tests in the laboratory and in the Cessna Citation, a total of five EOLIA/ProATN flights were made. Representatives of the EU, Eurocontrol and KLM were on board the aircraft to attend the flight trials.

Airbome Air Traffic Management System

The EU project Airborne Air Traffic Management System (AATMS) was concluded with the delivery of the report on the flight tests with a newly developed Advanced Flight Management System (AFMS) installed in NLR's Citation research aircraft. This AFMS was designed as a near term replacement of current FMSs. It featured the functionality defined in the FANS ATM-1 data link specification using two data link subnetworks: SATCOM and VHF Data Link (VDL) Mode 2 for digital data communication between the aircraft and the NLR Air Traffic Management Research Simulator (NARSIM). NLR contributed to the Evaluation Report, the Final Report and the Technology Implementation Plan.

Controller-Pilot Datalink Communications in the EOLIA ProATN programmes: Pilot request and ATC clearance

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's contribution is 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, Automatic Dependent Surveillance (ADS) and Surface Movement and Ground Control System (SMGCS) tests involving NLR's Metro II research aircraft and two service cars of the airport authority were carried out. Bi-directional VHF data links of the Self-organizing Time Division Multiple Access (STDMA) type were used, both for position reporting and for improving the GPS position with differential corrections from a local ground station. In another experiment a GNSS receiver, using differential corrections from EGNOS test signals ('signals in space') that were temporarily made available, was installed in NLR's Metro II research aircraft. Several flights were conducted both at Eelde Airport and at Amsterdam Airport Schiphol. Results were compared with an independent reference system that is intended for the calibration of Instrument Landing Systems up to Cat 3 accuracies. The project was concluded.

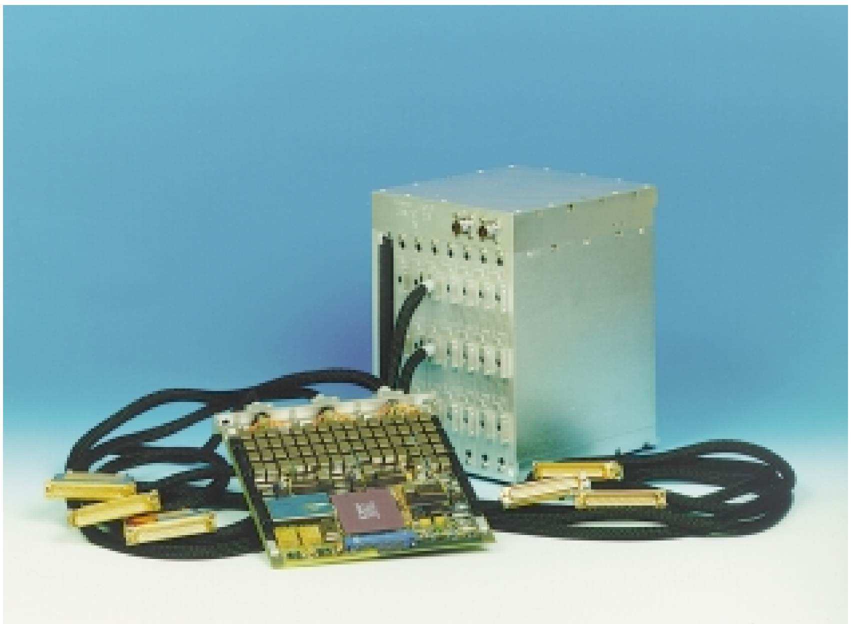
Innovative Navigation European System

For the Innovative Navigation European System (INES) project, aimed at exploring the possibilities of a low cost European satellite navigation system, work was done in the area of Inertial Hybridization and Civil Aviation Implementation.

Support to Eurocontrol

Automatic Dependent Surveillance Tests

NLR's Cessna Citation II research aircraft flew in Automatic Dependent Surveillance Broadcast (ADS-B) trials conducted by Eurocontrol in France. The trials were aimed at assessing the performance and maturity of three candidate ADS-B technologies. The Citation II was equipped with three experimental datalink systems, namely a Mode S Extended Squitter, a VHF Datalink Mode 4 and a Universal Access receiver. Mainly air-to-ground communication was tested in the trials. NLR's Fairchild Metro II research aircraft also took part in follow-on trials where, in addition to pursuing the goals of the first tests, air-to-air communication was tested in the airspace near Paris.



TEMPDAS, Temperature data acquisition system for ESTEC

Lockheed Martin F-16 MLU flight test display console

Military Flight Test Support

Helicopter/Ship Qualification Instrumentation

For the qualification tests of the Sea King helicopter of the Royal Navy on board the new Amphibious Transport Ship 'HMS Rotterdam' of the Royal Netherlands Navy, a data acquisition system, capable of receiving and processing telemetry data of a Sea King instrumented by the UK Defence Evaluation and Research Agency (DERA), was installed on HMS Rotterdam.

Flare Dispenser Test Instrumentation

The Kosovo crisis spurred test programmes including the flight testing of a flare dispenser system for a transport helicopter of the Royal Netherlands Air Force. For this programme an on-board video system, providing video images, time synchronization and annotation was installed.

F-16 MLU Flight Test Instrumentation

Work under a contract awarded by the RNLAF for the development and installation of a flight test measurement system in an F-16B MLU aircraft was largely completed. In close co-operation with the RNLAF, the system was installed in the aircraft after extensive integration tests at NLR. The system uses remotely located data acquisition units, controlled by a central system and interconnected by means of an instrumentation bus. A cockpit control panel operated by the pilot controls the basic system functions. Flight test data is displayed in the aft cockpit on a PC-compatible computer with LCD display for which a special console was developed. A video interface presents flight test data on the Multi Function Display of the forward cockpit as well. The system records the data on the Mil Std 1553 Mux A bus. The extension to record three additional buses is foreseen for the year 2000. Modification of the AMRAAM launchers for installation of high speed cameras for separation tests was started. The new flight test instrumentation system was used for in-flight calibration of an angle-of-attack and side-slip vanes on an instrumented nose boom and, after installation of additional strain gauges, for a pod certification programme.

F-16 MLU/ORPHEUS Interface

In preparation for the transition of the ORPHEUS reconnaissance system of the RNLAF to the F-16 MLU, an ORPHEUS MLU Interface Demonstrator (OMID) was developed. This unit was designed to fit in the F-16 pylon in order to avoid modification of the ORPHEUS

EMC test on a Chinook helicopter at the Open Area Test site

system itself. OMID converts the commands on the F-16 'Generic Recce Interface' into signals compatible with the current ORPHEUS. The OMID was installed in an F-16 MLU, ground tested, including a safety-of-flight test, and finally flight-tested. During these tests the feasibility of the concept was proven and the results allowed a go-ahead for the production of more units, taking into account the findings of this demonstrator programme.

Instrumentation for Testing High Voltage Railway Power Supply System

Based on its broad experience in developing, operating and managing large measurement systems for the flight testing of aircraft, NLR was contracted by the directorate *Railinfrabeheer* of the Netherlands Railways to design and realize a distributed data acquisition system for testing the new 25-kV power supply system to be used for high speed passenger trains and heavy duty freight trains. The system will measure some 300 voltages, currents and safety switch activation parameters at ten locations along a railway track and on a train, with a total sample rate of 625 k per second. Data will be routed from the remote locations to a central site for monitoring purposes by means of fibre optic transmission cables. The design of the system was completed and EMC qualification tests at the High Energy Laboratory of the Eindhoven Technical University were successfully concluded.

Facilities and Equipment

Environmental Testing

A large increase in activities in the field of environmental testing was observed, prompting the extension of NLR capabilities in this field. The capabilities of the Vibration and Shock Test (VST) laboratory were extended with a thermal chamber on the shaker to perform tests in a combined temperature/vibration environment (temperatures ranging from -70 to + 200 °C, with 30 °C/minute temperature change rate). In addition a laser vibrometer, allowing for vibration measurements without any mass loading, was acquired.

A new outdoor Antenna Test Range (ATR) for antenna research was officially put into service. The test range features a 14-m high wooden tower equipped with an azimuth-over-elevation positioner capable of carrying, for example, an aircraft model of scale 1:20. A transmitter is positioned at a distance of 160 m.

Installation of ORPHEUS with OMID interface on an F-16 MLU

Instrumentation for Research Aircraft
The Future Avionics System Testbed (FAST) activities were aimed at the integration of the equipment under test in a number of Air Traffic Management research and demonstration projects. Besides the implementation of the SATCOM Data 3 data link, a Research Flight Management System, developed for use in flight simulators, was integrated in the aircraft to generate flight plans in connection with the Air Traffic Service Unit used in the EU projects EOLIA and ProATN. FAST proved to be very valuable for ATM experimental research with NLR aircraft.

Facilities for the Acquisition and Processing of Flight Test Measurement Data
A concept was developed for using single board computers built to the PC-104 standard for real-time presentation of flight data on board aircraft during flight tests. This concept might be used in an F-16 MLU aircraft. The development of data acquisition channels was directed to the measurement of ice condition, generator currents, steering forces and exhaust gas concentrations.

The flight test data processing station DVSV was updated for the processing of the data acquired at higher rates by the new flight test instrumentation system of the F-16 MLU. The software package for the processing of GPS data was adapted to the higher data rates of new phase-tracking GPS receivers by changing the weighing factors in the fusion process of GPS and inertial data. New operating system versions were implemented to prevent any millennium problems.

ORPHEUS MLU Interface Demonstrator (OMID)

Vibration and Shock Test facility with thermal chamber

Test, Measurement and Calibration Equipment

The development and environmental qualification of a generic Mil Std. 1553 mux bus interface adapter based on COTS VME computer modules was completed. For laboratory testing of such systems, a tool was developed that emulates the behaviour of the bus. Extensive use of this test tool was made to generate the generic reconnaissance interface of the F-16 MLU fighter.

To support measurements for human factors research, a set-up was developed enabling three head/eye-tracking systems to be used at the same time without magnetic interference problems. The head/eye tracking systems were extensively used in ATM simulations at Eurocontrol.

The Data Acquisition Equipment Calibration Laboratory (DACLAB), accredited for pressure calibrations, successfully passed its yearly audit by the Dutch Council for Accreditation. Calibrations for external and internal customers were carried out. New European rules for establishing the accuracy of calibration standards were applied to the high-pressure standard of DACLAB.

Outdoor Antenna Test Range, with a transmitter at 160m from the tower

3.8 Engineering and Technical Services

The year 1999 was a busy one for the Engineering and Technical Services. The various divisions of NLR demanded a lot of support activities, and on top of that there was a significant increase in the work under contract to external customers. The amount of work was such that almost continually one or two additional design engineers were temporarily engaged, and quite some production work was subcontracted.

Models and Test Equipment

A large number of wind tunnel models were produced for a wide variety of international customers. Most of those models were to be tested in the various wind tunnels operated by the DNW, in particular the DNW-HST, DNW-SST and DNW-LST. Various models were built, for AerMacchi of Italy, IPTN of Indonesia, Dornier of Germany, Cessna of the USA, Aerospatiale of France and Embraer of Brazil. Apart from that, several modifications and adaptations were made to existing wind tunnel models, stings, sting adapters and balance housings for models to be tested in one of the wind tunnels operated by the DNW.

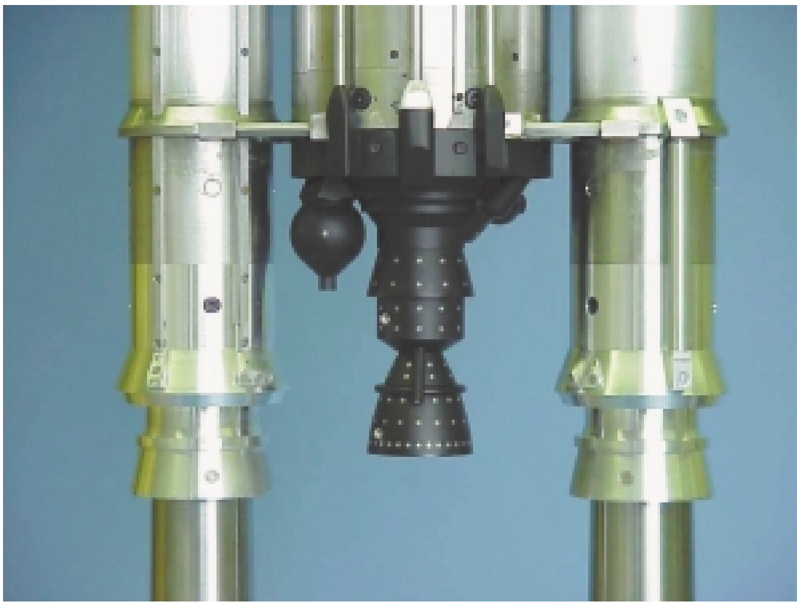
In some cases co-operation was sought with other European model builders such as DLR of Germany and ONERA of France. The main argument to do so was to meet the extremely short lead times demanded by the customer, by splitting-up the model and dividing the total work between the partners, to overcome local capacity problems. This co-operation worked well and will be repeated in the future when short lead times are required.
For one model, apart from remotely controlled rudder and elevators, also remotely controlled ailerons were required. Since this was the first time for such a requirement to be met, a prototype was developed first, to be followed by the final version, which was designed, built and tested successfully as part of the real model.

As usual, a number of non-aerospace models were also built: models of ships, bridges, buildings, ventilation tunnels, traffic portals, etc, to be tested in the DNW-LST or DNW-LLF.

A variety of wind tunnel equipment and instrumentation was developed, modified or repaired in support of the wind tunnels. Some of the facilities of the DNW-HST were modified with regard to occupational health and safety.

Strain Gauge Balances

Research on strain gauge balances was continued. A significant effort was made to improve the performance of the rotary balances for the APIAN programme of the EU. The development of a heavy-load six-component sting balance for

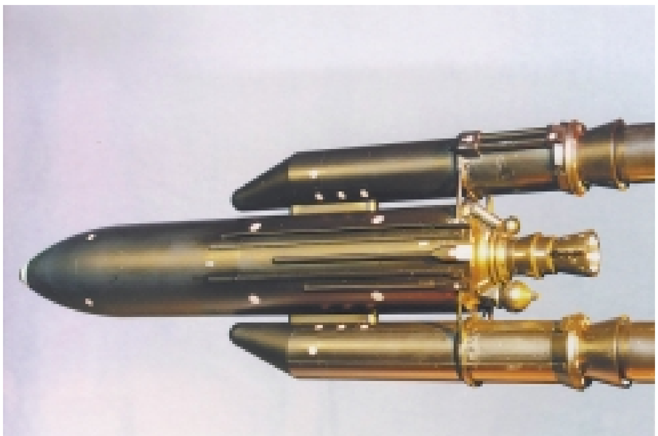


Detail of a model of the Ariane 5 launcher, the nozzle equipped with test instruments

fighter type aircraft models for the DNW-HST wind tunnel was completed.
The contract for the development of two cryogenic balances, for the twin sting rig that had been delivered by NLR to ETW in 1997, was acquired.
For the Dutch nautical research institute MARIN, a large number of balances were instrumented, using the knowledge and experience in the field of strain gauges developed for applications at NLR.

Support

Supporting activities for the various divisions of NLR included many short operational support activities, but also larger design and production work under programmes conducted for customers. Various fuselage panel test installations were designed and built, test articles were machined, moulds for composite products were made, and stir-welding experiments were supported.
Various engineering mock-ups and modifications to simulators were designed and built. A missile launcher was equipped with high-speed cameras for store jettison trials on a fighter type aircraft.
Many other jobs, such as the production of electronic racks, breadboards, panels and consoles were performed.



Wind tunnel model of the Ariane 5 launcher, equipped with thrust simulation and instrumentation on the main engine

Tail part of a Dornier 728 low-speed model, equipped with an adjustable stabilizer and remote controlled rudders and elevators

Research

Basic research activities were focused for a large part on the reduction of lead times in the design and production of wind tunnel models. The pressure on lead times has increased significantly the past few years, and measures were necessary in order to stay competitive in this field.
These varied from continuous updates of the CATIA CAD/CAM system used as design and parts programming tool, to studies and practices on new rapid prototyping techniques such as five-axis high-speed milling, stereo-lithography and laser sintering, and to organizational measures. The measures have resulted in significant lead time reductions, with lead times for wind tunnel models down to three to five months instead of five to eight months some five years ago, and will be pursued further.

Quality

The Engineering and Technical Services acquired an ISO 9001 and AQAP-110 certificate for the design and production of mechatronic precision products.

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

- Mr. W. de Boer, director-general of the Netherlands Department of Civil Aviation;
- Mr. R. Koppelaar of the Ministry of Economic Affairs;
- Mr. G.H. Kroese, Chairman of Air Traffic Control the Netherlands;
- Prof. Dr. J. Berkhout, member of the Board of the Delft University of Technology;
- Mr. R.J.J.M. Pans, Secretary-General of the Ministry of Transport;
- Ms. E.S.J. Schless of the Ministry of Economic Affairs;
- Ms. T. Netelenbos, Minister of Transport;
- Mr. W.L.F.C. Ridder van Rappard, Mayor of the Noordoostpolder;
- Members of the Flevo Society, consisting of leading persons in the Noordoostpolder;
- Mr. C. van Bochove, Director with the Ministry of Education, Culture and Science);
- Ms. G. Korthals Altes of the Ministry of Economic Affairs;
- Messrs. J. van Beek, D.J. van Eck, C.M.E. Ebbinkhuijsen and J.R. Vree of Air Traffic Control the Netherlands;
- Drs. G.J. Cerfontaine, President of Amsterdam Airport Schiphol;
- Col. P.C. Berlijn, representative of the RNLAF with the JSF Program Office, Washington DC;
- Mr. M.J.E.M. Jager, Royal Commissionar of Flevoland.

The Royal Commissioner of Flevoland, Mr. M.J.E.M. Jager, was shown around NLR Noordoostpolder

The Prince of Orange and the Minister of Economic Affairs, Mrs. A. Jorritsma-Lebbink, were welcomed by Dr.ir. B.M. Spee at the exhibition of the International Astronomical Federation Congress

Foreign Visitors

- Staff of General Electric connected to the JSF-program;
- Mr. M. Scheller, President of ONERA, together with Mr. J. Vedel and Mr. H. Consigny;
- Prof. Santarek and Col. Stanislaw Kwintal of the Polish Air Force;
- Prof. P.V. Straznicky of Mechanical and Aerospace Engineering of the Carleton University, Canada;
- Messrs B. Luddy, M. Mann and N. Nijhawan of NASA;
- Mr. G. Guyot of Airbus Industry;
- Mr. J. Ahlers, Director Defence Technology, South Africa;
- Air Wing Commodore S.K. Sofat, Air Attaché of the Embassy of India.

Excursions

- Students of the J.M. Burgerscentrum of Delft;
- Students of Ergonomics from the University of Rouen;
- Students of the Zuyderzee College, for job orientation;
- Students of the Von Kármán-Institute, Brussels;
- Students of Christiaan Huygens, Study Society of the Delft University of Technology;
- Members of the ATC-Society, Automobile Technical Centre of the Ministry of Transport;
- Students of the Study Society for Technical Mechanics *'Mohres leren'* of the University of Twente;
- Staff of the Aeromedical Centre of Soesterberg;
- Participants of the 11th European Chapter Symposium of the Society of Flight Test Engineers;
- Participants of the World Wide TAAM User Group Conference, organized in Amsterdam;
- Participants of the 50th IAF (International Astronomical Federation) Congres, who paid a touristic visit to the Schokland Museum and were shown NLR Noordoostpolder;
- Members of the Electronic Press Club, ELPEC;
- Representatives of NedTrain Consulting;
- Members of the Study Society 'Sir Isaac Newton' of the University of Twente.

Exhibitions

- At the Maastricht Exhibition and Congress Centre, MECC, NLR participated with a stand at the ATC 1999 Conference, and showed its capabilities in the area of Air Traffic Management research;
- Many visitors contacted the NLR staff during '*Het Instrument*' held at Utrecht;
- During the Air Traffic Control Open Days, held in Rotterdam, NLR participated with an exhibition;
- At the International Training Equipment Conference (ITEC) in the Congress Centre in the Hague, NLR showed its simulation capabilities within the stand of NISP (the Netherlands Industrial Simulator Platform);
- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) at the Paris Air Show;
- In the field of materials, NLR participated in the *Journées Européennes de Composites* (JEC), Paris;
- At the 50th International Astronomical Congress organized by the International Astronomical Federation (IAF) in Amsterdam, NLR participated in the International Exhibition;
- At a symposium 'Big and Little within Europe', organized by the Netherlands Defence Manufacturers Association (NIID) in the Hague, NLR showed its activities for the industry on posters.

Events

- Well-attended New Year Receptions for NLR staff in Amsterdam and Noordoostpolder.
- Introductory meetings for new employees in Amsterdam and Noordoostpolder.
- The handing over of ISO 9001 Certificates to the heads of the Avionics Division, the Flight Division, the Air Transport Division and the Engineering and Technical Services;
- The signing of the Protocol for Research and Development;
- An International P-3 SLAP meeting of representatives of the US Navy, the Australian Air Force and the Royal Netherlands Navy to support operations with the P-3 Orion Aircraft;
- The inauguration of the Antenna Test Range at NLR Noordoostpolder;
- The opening of the NLR Test House at Schiphol;
- A visit by partners of the NLR Board members to Amsterdam Airport Schiphol;
- Participation with the Fairchild Metro II Research Aircraft in the Static show of the Royal International Air Tattoo in Fairford, U.K.;
- A PHARE PD/3 demonstration held at the Air Traffic Control Association Conference in San Diego.

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 1998 under the Programme for basic research and development of facilities of NLR;
  - the Preliminary Work Plan for 2000;
  - the Programme for basic research and development of facilities for 2001;

- To the Boards of Directors of NLR and NIVR, on:
  - the reports NLR submitted to the Committee to be assessed for scientific value or for suitability as scientific publications;
  - proposals for new research in the framework of the NIVR Basic Research Programme.

Membership of the Scientific Committee

There were two vacancies. The vacancy caused by the resignation of Ir. Holwerda, appointed by NIVR, remained open. The directors of NIVR have indicated they hope to be able to name a candidate before too long. Steps in preparation of the replacement of Prof.ir. C.J. Hoogendoorn, who wishes to resign, were expected to lead to a result by 1 January 2001.

At the end of 1999 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 1999, for various reasons the following members of the subcommittees resigned:

- Prof. J.H.D. Blom (Subcommittee for Flying Qualities and Flight Operations)
- Ir. C.W. van Santen (Subcommittee for Structures and Materials)
- Prof.dr. G.J. Olsder (Subcommittee for Applied Mathematics and Information Technology)

It was decided to appoint as of 1 January 2000 Prof.Dipl.-Ing. H. Stoewer as chairman of the Subcommittee for Space Technology, succeeding Prof.ir. H. Wittenberg.

In an appropriate manner leave was taken of Prof. J.H.D. Blom, chairman of the Subcommittee for Flying Qualities and Flight Operations/Air Transport since 1971 and active in subcommittees for 41 years.

Two new members were appointed in the Subcommittee for Flying Qualities and Flight Operations/ Air Transport, two new members in the Subcommittee for Electronics and Instrumentation, and one new member in the Subcommittee for Applied Mathematics and Information Technology.

At the end of 1999 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. 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.ir. J. Schalkwijk
Prof.dr.ir. H.J. Sips
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.ir. E. Obert, *chairman*
KTZSD b.d. ir. K. Bakker
Ir. H. Benedictus
Ir. W.G. de Boer
J. Hofstra
Prof.dr.ir. Th. van Holten
Ir. R.J.A.W. Hosman
Ir. H.J. Kamphuis
Maj. H.J. Koolstra
Ir. H. Tigchelaar
Dr.ir. H.G. Visser
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
Ir. O. van de Kuijt
Ir. P.J.G. Loos
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 Scientific Committee has observed a number of developments occurring and tendencies coming up that must partly be considered favourable but partly causing concern. It must certainly be judged positive that the situation concerning the position of NIVR was beginning to take shape. The extension of the objectives of NIVR in the direction of aircraft operations on the one hand and of scientific and support activities on the other hand will require substantial efforts to complete. The fact that the extended objectives, in addition to the strategic advising of the government and the industry and the initiating and controlling of development projects and programmes, include in particular the promotion of scientific activities, is appreciated. The appointment of the Scientific Committee as scientific advice platform beside the other advice platforms of the NIVR Board and Advisory Council appears natural; whether this will have consequences for the Committee's method of working towards NIVR will have to be studied.

Concerning NLR the Committee has observed that, in the discussion on the independence of scientific institutes that advise the government, NLR has sufficient robustness to remain standing. In the government's position regarding the report by the Advisory Council for Science and Technology Policy (AWT) on the Large Technological Institutes (GTI), a positive position with regard to NLR is also being held. It remains worrying, however, that opposing tendencies sometimes prevail in the government's acting, such as in the reduction of the government's involvement in NLR and its Board, and the lack of clarity on, or lack of active government support in, the process of increasing international co-operation on its speciality domain that NLR experiences as necessary. Manifestations of this co-operation are the transfer of the operation of all Dutch and German wind tunnels to the Foundation DNW and the alliance that ONERA of France is seeking with DNW, as well as the increasing volume of the research carried out under the framework programmes of the European Union; the latter, however, by uncertainties in the process of proposals and selection, having a large influence on the annual occupation of NLR's divisions and on the basic research carried out. The Committee therefore advocates simple and flexible mechanisms to endure partial funding and sudden occupation variations (by matching), such that the research rather than the paper war on funding gets full attention.

A number of research subjects and aspects, in particular discussed by the Committee, are expected to require significant attention also in the next few years. These are attention for quality assurance in general, and in space projects that are unique and not recoverable in particular, and the neighbouring area of the application of COTS (Commercial Off The Shelf) technology, having become necessary because some components are only available commercially but do not satisfy the traditional requirements for spaceflight, military or civil aviation. These components on the one hand have to be adapted for these applications and on the other hand have such short commercial lives that they tend to be technically obsolete at the time of eventual application. This technology still requires a great deal of attention.

A trend that is especially becoming visible in information and communication technology concerns the electronic revolution: the attention is shifting to systems, functionalities and abstract architectures for business and management support at the expense of underlying concrete technological challenges; at the least it can be stated that new disciplines are requiring attention.

In the area of space, in addition to much that goes well, some subjects could use more attention and therefore budgets. In the area of *smallsats*, the Netherlands could possibly play a role as systems integrator by applying the available system knowledge, but for smallsats not having been named a policy priority. Netherlands activities are now limited to partial contributions to ESA projects and research by universities. A second area concerns the further extension of satellite navigation, of which the Galileo project constitutes the European branch. Annexation of this large project by the 'Big Four' on the one hand, and the highly limited Netherlands' participation (1 per cent) by which, in addition, several aims would have to be reached (including support to the SME in this area) on the other hand, make the carrying out of a proper system study by the Netherlands/

NLR highly improbable. The combination of these systems with additional, ground-based, components is a complex problem, but worth to be dealt with by the Netherlands.

In the areas of aircraft development and air transport/aircraft operations, the Committee recognizes that regarding turbulence modelling, by both theoretical and experimental research, improvements in aerodynamic CFD methods are still possible. In the area of Air Traffic Management, the Committee has noted that NLR in an early stage made a step from the conventional Air Traffic Control concept (keeping the aircraft on a string) to the Free Flight concept, originally mainly advocated by the USA. By this step NLR has now attained good positions in both fields, and it deserves all support required to exploit these positions. In the area of airport capacity and related subjects, the Committee thinks a study on runway allocation/noise load/wind warning is in order, especially on the question which modern information system technology can help improve safety and steer the political discussion in the right direction.

The Committee would finally like to state that the reports submitted by NLR to be assessed for publication or for scientific value have in general been read with much satisfaction. The Work Plans of NLR and proposals for new research to be commenced under contract to NIVR were also welcomed. The Committee still feels to be able to state that the activities performed by NLR and NIVR are to a reasonable extent tuned to the future requirements of the potential users: government offices, public bodies and private companies. Sufficient support, in words (policy) and actions (funding) by the national government, is of continuing importance for this.

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 R&T Board (RTB) were:

– Cdr. Ir. D. van Dord	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	Prof.drs. P.G.A.M. Jorna
SET	Ir. H.A.T. Timmers
IST	Ir. W. Loeve
AVT	Prof.ir. J.W. Slooff

National Co-ordinator

Drs. G.A.M. Claessens MBA (Netherlands Ministry of Defence) was appointed as national co-ordinator after the retirement of Ir. L. Sombroek (NLR) in December 1998.

Highlights

- The North Atlantic Council (NAC) approved the NATO Research and Technology Strategy in December 1999, charging the RTO with the responsibility of implementing this strategy across NATO.
- The Board held a closed session to elect the new chairman and RTA director. Mr. N. Holme of Norway will succeed Mr. Yarymovych as chairman of the RTB and Mr. K. Peebles of Canada will succeed Mr. E.A. van Hoek as RTA director in July 2000.
- The Von Karman Medal 1999 was awarded to Professor P. Santini of Italy.
- Dr. H. Steeneken (of TNO-TM, the Netherlands) and Dr. R.K. Moore (of the UK) received RTO Scientific Achievement Awards.

6.2 German-Dutch Wind Tunnels (DNW)

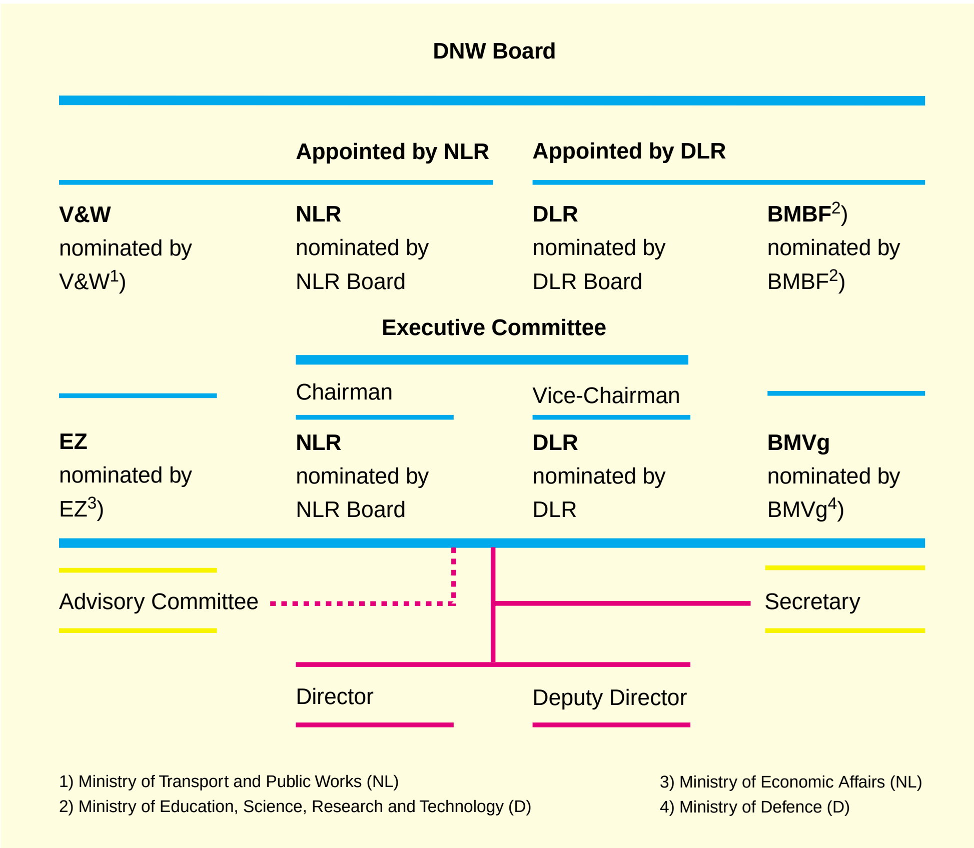
The Foundation German-Dutch Wind Tunnels (DNW) was jointly established in 1976 by NLR and the German Aerospace Center (DLR) as a non-profit organization under Dutch law. The main objective of the DNW organization is to provide a wide spectrum of wind tunnel test and simulation capabilities to customers from industry, government and research.

DNW operates the largest low-speed wind tunnel in Europe, the LLF, and two smaller low-speed wind tunnels, the 3-m wind tunnels LST (located in the Noordoostpolder near the LLF) and the NWB (located in Braunschweig). Effective from 1 January 2000 the transonic and supersonic wind tunnels of NLR and DLR are fully integrated in the DNW organization. The wind tunnels operated by DNW will be grouped in the three business units 'Noordoostpolder' (NOP), 'Amsterdam' (ASD) and 'Göttingen und Köln' (GUK).

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 1999 the Board consisted of:

Dr.ir. B.M. Spee, *Chairman*
NLR
Prof. V. von Tein, *Vice-Chairman*
DLR
Min.Rat Dr. H.-M. Spilker
Ministry for Education, Science Research and Technology of Germany (BMBF)
D. Elflein
Ministry of Defence of Germany (BMVg)
Prof. Dr.-Ing. H. Körner
DLR
Drs. L.W. Esselman, R.A.
NLR
Ir. H.N. Wolleswinkel
Ministry of Transport of the Netherlands (RLD)
Secretary: Dipl.Kff. A. Stader
DNW



Schematic of the organization of the Foundation DNW

Airbus A340-500/600 model in the reverse thrust configuration, with a moving belt ground plane for the simulation of ground effects

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 1999 the Advisory Committee consisted of:

Prof.ir. J.W. Slooff, *Chairman*
NLR
Prof. Dr.-Ing. P. Hamel
DLR
Mr. A. Garcia
Airbus Industrie
Dr.-Ing. J. Szodruch
DaimlerChrysler Aerospace Airbus
Dipl.-Ing. B. Haftmann
DaimlerChryslerAerospace 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
DNW

The Board of Directors

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

DNW-LLF

After a very successful 1998, the DNW-LLF achieved a good result in 1999 too. Especially the development of theA340-500/600 contributed to the positive result, with extensive tunnel entries. In order to run all requested tests within the desired timeline it was necessary to operate the facility over extended periods for 12 hours a day. Besides many standard projects from the aerospace and the car/truck industry, a number of highlights can be noted. The most challenging test series were two campaigns with an Airbus A340 model equipped with engine simulators. With different configurations such as take-off, landing and reverse thrust, a huge database could be established characterizing the performance and controllability of the new aircraft in ground proximity. The tests were led by a German-French test team from DaimlerChrysler Aerospace Airbus and Aerospatiale Matra Airbus.

One of the other sigificant tests addressed the identification of noise sources of a full-scale wing. For this purpose an actual Airbus A320 wing was instrumented and placed in the open-jet test section of the DNW-LLF. The project was initiated and carried out by the DLR Institute of Design Aerodynamics and was supported by DaimlerChrysler Aerospace Airbus. DNW provided the acoustic measuring techniques. It was demonstrated that low noise levels can be achieved with minor modifications to construction details.

The identification of noise sources on a full-scale wing of an Airbus A320 is achieved with an acoustic mirror and a microphone array

DNW-LST

Contracts for aeronautical as well as non-aeronautical testing contributed to a good occupation of the LST. In the first category a test worth mentioning was an investigation with a semi-span model in which aerodynamic and acoustic measurements were combined. The acoustic measurements were taken by means of a group of irregularly distributed microphones flush mounted in the closed sidewall of the wind-tunnel test section. The capability to do this type of measurements has only recently been developed for the LLF. The fact that this technique is now already available in the LST is an excellent demonstration of how the smaller facilities benefit from the developments initiated for the LLF.

Non-aeronautical testing covered a wide range of objectives like drag reduction of racing cyclists, wind loads on a sunshade and hosting a TV-talk show in the test section. However, the main part of the contract work was related to ships. Objectives for these tests ranged from optimizing the smoke-stack to make sure that the smoke does not annoy the passengers while taking a rest on the decks, to the safety of helicopters landing under harsh weather conditions.

Acoustic measurements on a semi-span model in the DNW-LST

DNW-NWB

The NWB could log a good occupation in 1999. Tests for the aerospace industry and for car manufacturers covered a wide range of test objectives. The successful demonstration of the capabilities of the Oscillating Motion Support (MOD) in 1998 has led to an extensive test campaign with different Airbus A3XX configurations. It was the first time that dynamic derivatives of this new aircraft were evaluated. The required lightweight model was built by DLR from carbon-fibre composite and weighs in total less than 8 kg. Another highlight was the first 3-component Particle Image Velocimetry (PIV) measurement with the enhanced DNW system. The new measurement technique provides all three components of the flow vector in a selected cross-section. In the particular test the wake of a 40% car model was determined and analysed to provide a database for Computational Fluid Dynamics (CFD).

6.3 European Transonic Windtunnel (ETW)

On behalf of the Netherlands, NLR is a 7% shareholder in the European Transonic Windtunnel GmbH, established in 1988. The ETW provides Europe with a unique capability for transonic testing at realistic Reynolds numbers.

Although no decision had been taken by Airbus on the A3XX project, the Governments participating in the ETW have decided to make available a limited amount of additional funding until the end of 2003. The actual development of market expectations for the ETW will be closely followed.

A semi-span model capability was realized, enabling the ETW to supply the growing need for semi-span model testing.

Supervisory Board

At the end of 1999, the membership of the Supervisory Board was as follows:

France

ICA X. Bouis, Chairman	ONERA
ICA H. Moraillon	DGAC/DPAC
ICA A. Brémard	DGA/DSP/ SREA/PEA

Germany

Dr. J. Bandel	BMWi
Prof. V. von Tein	DLR
Dr.-Ing. H. Körner	DLR

United Kingdom

Dr. R. Kingcombe	DTI
Dr. D.J. Mowbray	DERA

The Netherlands

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

Mr. J.F. Moutte (F), Managing Director, retired on 31 December 1999. The Board appointed as his successor Dr. W. Burgsmüller (G). The Managing Director was assisted by:

Dr. G. Hefer (G)
Manager Aerodynamics and Projects

J.P. Hancy (F)
Manager Technical Operations

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. In 1999 all preparations for the admission of Italy have been made, and five of the seven nations concerned have signed the related updated annex to the memorandum of understanding.

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]) associated with 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 1999 the GARTEUR Council was composed as follows.

France

IGA G. Bretéscher	DGA/DSA/SPAé *)
ICA M. Moraillon	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. D.M. Way	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. Näsström	FMV

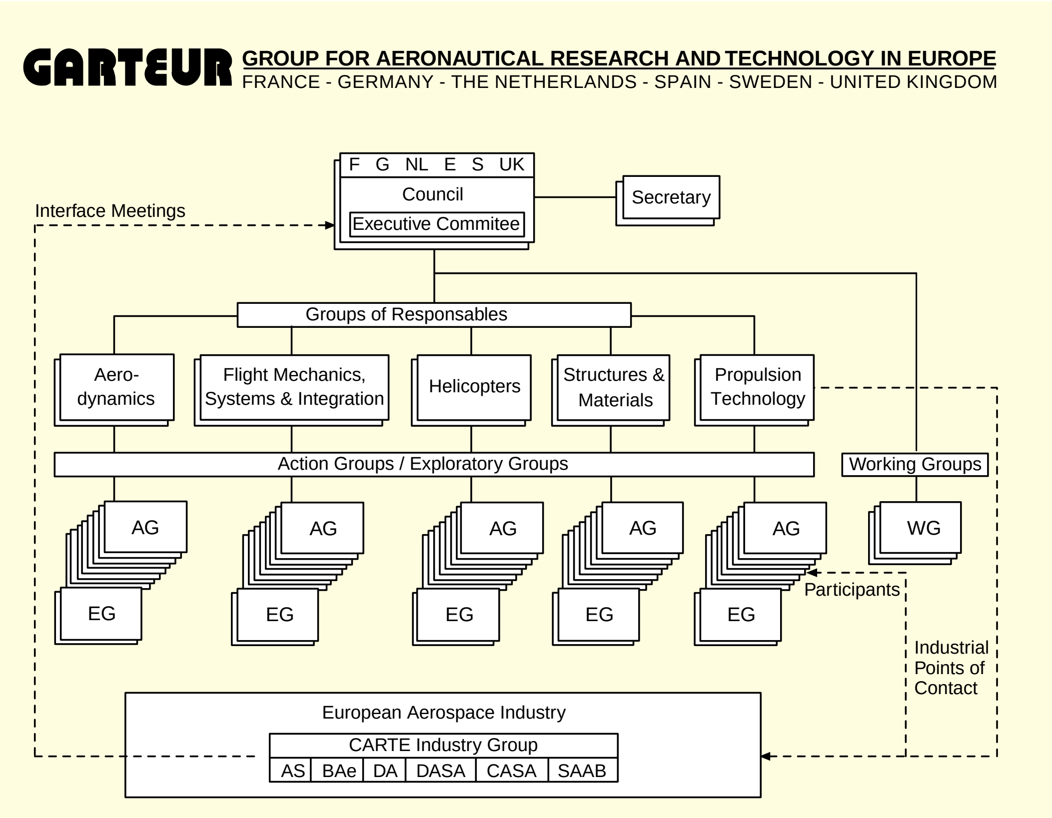
The Netherlands

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 1998 and 1999, the United Kingdom provided the chairman for the GARTEUR Council and the chairman for the Executive Committee as well as the Secretary. The persons involved were:

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



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

NLR Participation

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

Table 1 – Numbers of Action Groups

Group of Responsables	Action Groups	
	Total	NLR
Aerodynamics	13	9
Flight Mechanics	2	2
Helicopters	1	1
Structures and Materials	8	8
Total	24	20

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. 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 Joint Executive Board at the End of 1999:

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).

A milestone in the co-operation was reached by the decision to embed all aeronautical wind tunnels of NLR and DLR into the DNW organization.

DLR-NLR Programme Committee

The DLR-NLR Programme Committee, established to stimulate and monitor the bilateral precompetitive DLR-NLR research met twice. The members were:

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

The following projects were continued:

- Low-speed Propulsion-Airframe Integration
- CFD for Complete Aircraft
- Development of B2000

Joint Executive Board Working Groups

Two Joint Executive Board Working Groups were active:

- Integration of DLR-NLR Air Traffic Management Research;
- Integration of DLR-NLR Workshops.

DLR and NLR reached a basic agreement to investigate the integration of the DLR and NLR workshops for wind tunnel model design and manufacturing.

To investigate the potential of closer DLR-NLR co-operation in the field of ATM, a feasibility study was made with the assistance of an external consultant. The aim of this study was to establish the added value of a possible integration of the respective activities.

DLR and NLR have been discussing possible broadened co-operation and integration with other organizations, including ONERA and CIRA.

EREA: 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 European aeronautical technology base in line with the integration of industries and governmental responsibilities on a European level. The process should ultimately 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 Centres of Excellence.

In 1994 EREA started a modest action plan comprising facilities, basic research, joint acquisition and personnel exchange.
In 1999 a formal association under Dutch law was created, turning EREA into a legal entity that can enter into contracts with other organizations.

Organization

The association EREA is governed by the General Assembly and the Board of the association. At the end of 1999 the Board was composed of:

IGA J.P. Rabault, *Chairman*	ONERA – F
Prof. W. Kröll	DLR – D
Dr. D. Byrne	DERA – UK
Prof. S. Vetrella	CIRA – I
J. van Houwelingen	NLR – NL
B.Gen. H. Dellner	FFA – S
Mr. A.L. Moratilla Ramos	INTA – E

The Board is assisted by an Executive Secretariat, chaired by Mr. A. Gustafsson (FFA), and a treasurer, Drs. A. de Graaff (NLR).

Activities

In order to reduce the number of standing committees and to promote the idea of a project organization, EREA changed a number of committees into networks and dissolved other groups. The networks are charged to define projects aimed at integrating the capabilities in specific technological areas. Projects and networks exist in the following domains:

- Smart Aircraft/adaptive airfoil
- Acoustics
- New Measurement Techniques for wind tunnels
- Turbulence Modelling
- Safety
- Information technology
- Environment
- Research aircraft
- Simulation techniques
- CFIT

The Board decided that from 1999 co-operation in research projects will as much as possible be delegated to GARTEUR, EU, WEAO and other fora. EREA will concentrate on the process of integration.
The Board agreed to establish an Internet site of EREA and to implement an Intranet site, in order to stimulate the establishment of virtual institutes.
EREA approached Airbus Industrie to strengthen the ties between the two organizations. Inventories of potential collaborative efforts were made in the areas of human factors, safety, environment and future configurations. In the last-mentioned area, a separate EREA work package dealing with very advanced aircraft configurations has been incorporated in an Airbus Industrie-led proposal, called RACE+, to the EU.

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.

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 European Commission

Since 1989, the aeronautical research establishments have worked together in the Aeronautical Research Group (ARG) to facilitate the communication and to promote joint interests with the European Commission and the European industry, as well as to promote the information exchange amongst the establishments on EU-related issues. The ARG, chaired by Drs. De Graaff (of NLR), is part of EREA. Besides exchanging information and preparing project proposals for calls for proposals, the ARG was actively involved in the preparation of the EU's Sixth Framework Programme. The ARG established links to research organizations and universities outside the seven EU nations involved in EREA and to Israel. ARG will also enable contacts to be established with research organizations in the new member states of the EU.

6.6 Co-operation with Indonesia

Introduction

In 1999 the co-operation with Indonesia centred around the APERT project and its succession. There were also other contacts with the aerospace community in Indonesia, varying from NLR support of Indonesian students in the Netherlands via VNO/NCW fellowships to direct two-way contract work between the two aerospace communities.

APERT 95

The interim Aerospace Programme for Education, Research and Technology (APERT) was started in 1992 as follow up of the TTA-79 programmes running from 1981 to 1991. 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.
The programme is supported by the Netherlands Ministry of Education, Culture and Science (OC&W) and is monitored by the Royal Netherlands Academy of Sciences (KNAW) on behalf of OC&W.

Organization

Within APERT 95 a Governing Group has been established, which was constituted in early 1999 as follows:

Indonesia

Prof.dr.ir. Djoko Suharto (ITB)
Prof.dr.ir. H. Djojodihardjo (LAPAN)
Prof.dr.ir. Sularso, MSME (Min. E&C)
Dr. Ir. S. Kamil (Asst. to Min R&T)
Dr. Said Jeni (BPPT)
Dr.Ing. Ilham A. Habibie (IPTN)

Project Co-ordinator

Ir. R. Mangkoesoebroto (IPTN)

The Netherlands

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

Project Co-ordinator

Ir. R. Ross (NLR)

Status

In early 1999 most research activities were finalized and reported. At the end of 1999, in the field of Education a PhD study was still going on, while a short course in Bandung was planned. Furthermore, the transfer of the PHST, a small wind tunnel from NLR Amsterdam to Indonesia, foreseen in the Laboratory Development programme, was delayed due to a local shortage in funding.

Continuation

The Indonesian and Netherlands project co-ordinators met twice to draft a follow-up programme of APERT 95. The proposal is called Joint Aerospace Research Programme Indonesia Netherlands (JARPIN). It was drafted after extensive communication with the Indonesian and Netherlands Governing Group members and positive letters between the President of the Republic of Indonesia and the Netherlands Prime Minister. It takes the new situation of Indonesia into account.
At the end of 1999 the draft programme was in the process of being submitted to the Netherlands Ministry of OC&W.

Capita Selecta

1 PHARE Demonstration 3: A contribution to the future of Air Traffic Management

From 1989 until 1999 NLR has participated in the Programme for Harmonised ATM Research in EUROCONTROL (PHARE). From 1994 onwards the main activity was PHARE Demonstration 3 (PD/3), which was organized to further develop and validate an operational concept for future ATM that should contribute to the definition of EUROCONTROL's target concept of operations, now known as the OCD (Operational Concept Document). The concept developed and validated in PHARE was designed in particular to take the current ATC performance hurdle that is choking airline operations more and more. With a target ATM system capacity of at least twice that of 1995 the concept was designed to be drastically different from today's.

PROGRAMME FOR HARMONISED AIR TRAFFIC MANAGEMENT RESEARCH IN EUROCONTROL

PHARE

EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION, EUROCONTROL

Introduction

In Europe, growing delays in air traffic around 1990 led among other things to the start of the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP). This programme was managed by EUROCONTROL on behalf of the European Civil Aviation Conference (ECAC). In this four-phase programme the harmonisation and integration of existing European ATC systems would be followed by the definition of a European Air Traffic Management System (EATMS) that should provide Europe with the means to manage air traffic even by the year 2015. Also, around 1989, a number of European research establishments, assisted by the ATC authorities concerned, decided to combine their research efforts in a comprehensive effort to *'prove and demonstrate the feasibility and merits of future air-ground integrated ATM in all phases of flight'*. This was the beginning of the Programme for Harmonised ATM Research in EUROCONTROL (PHARE). The programme was later put under the EATCHIP umbrella as support for the definition of the EATMS.

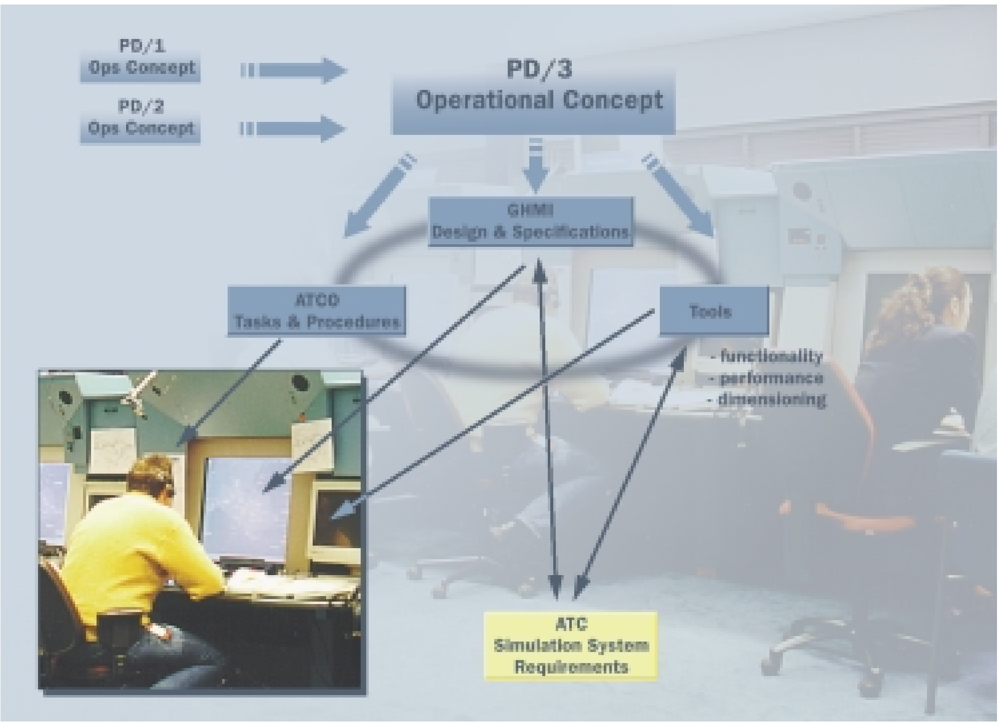


Fig.1 – The process of developing the PD/3 concept and system specifications

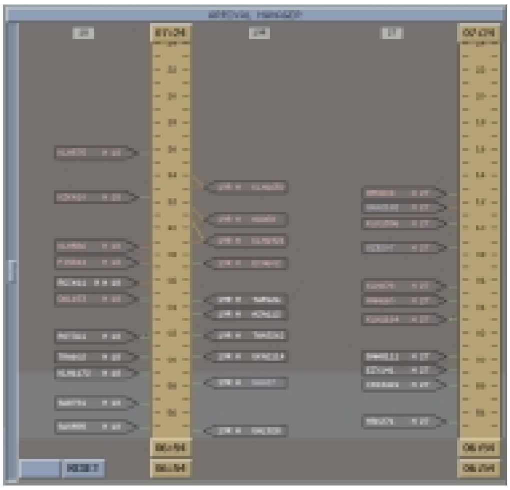


Fig. 2 – Arrival management display

Within PHARE, advanced ATM tools have been developed in support of a line of advanced operational concepts. The feasibilities and merits of these concepts were validated through a series of large-scale real-time simulations, called PHARE Demonstrations (PDs). The last of these demonstrations was PD/3, which was planned to investigate multi-sector, multi-centre and Terminal Area planning issues for the 2005 to 2015 time frame. It concluded the PHARE programme.

Besides the EUROCONTROL Experimental Centre (EEC) and the *Centre d'Études de la Navigation Aérienne* (CENA) of France, the National Aerospace Laboratory NLR of the Netherlands was one of the sites at which PD/3 took place. Other establishments that contributed to PD/3 were National Air Traffic Services (NATS) of the UK and the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) of Germany.

Operational Concept Development

The PHARE programme was started in 1989 to develop a new gate-to-gate operational concept with double the capacity of 'current' ATM operations. Although the principle ideas of the concept had been present from the beginning, the work involved in elaborating them to the current level of detail was significant.

The first description of the operational concept of PHARE was completed in 1990. It was a collection of novel ideas the essence of which is the exchange of flight status and planning information between on-board systems and the ATC system, which allows air traffic controllers to work more pro-actively than reactively. This was expected to reduce the amount of work for dealing with a flight, thus allowing more flights to be handled. On the basis of this concept, the development of a number of advanced automated tools for air traffic controllers and of a new type of Flight Management System was begun. Together with the development of a number of advanced applications on top of an ICAO-compliant Aeronautical Telecommunication Network (ATN) demonstrator these developments would make it possible to demonstrate the merits and acceptability of the advanced concept. This demonstration was performed through a number of large-scale simulation exercises called PHARE Demonstrations (PDs).

The first PHARE demonstration (PD/1), performed for the ATC service organization in the UK, NATS, was limited to en-route traffic handling. It explored the ideas of negotiating planned trajectories between air and ground and the accompanying changes in controller roles. While PD/1 was successful in demonstrating the feasibility of the operational concept, it proved difficult to quantify a capacity increase potential. Yet, many lessons were learnt that helped to refine the operational concept further.

The second demonstration of PHARE was focused on the principles of arrival management within the new concept. It was performed successfully by DLR in 1997. Technical limitations of the simulation system prevented the issue to be fully explored, but valuable lessons were learnt that contributed to further refinement of the concept.

Already before PD/1 was completed, the work on PD/3 had started. The large gate-to-gate scope of this final demonstration forced the simulations to be spread over three separate simulations, of which each of the PD/3 partners covered one.

In the preparation for the final demonstrations, each of the partners performed an internal operational research project that allowed operational aspects to be studied that had not been explored before. At NLR the focus in this study aligned with the subject of the final demonstration:

optimum integration of en-route and arrival traffic management. Shortly after the PD/2 trials at DLR, NLR performed small-scale real-time experiments on this topic that contributed to the definition of the final concept demonstrated. The study highlighted, for example, the need to eliminate explicit co-ordination between different sectors as much as possible and to distribute arrival time constraints as early as possible.
The refinement of the final operational concept was to a large extent related to the functionality that was available from the advanced tools and the Human Machine Interface (HMI) between the air traffic controllers and the system. The whole development process that is described above is illustrated in Figure 1 and the concept is explained briefly below.

Final PD/3 Operational Concept

Controller Workload

An essential element of controller workload is related to the detection and resolution of potential conflicts. In current operations, accurate planning over more than a few minutes is not possible since flight execution is an open-loop process without feedback from trajectory planning.

Closed Planning Loop

The basis of the PHARE concept is to close the planning loop. This is done by generating an accurate trajectory prediction for every flight. For future aircraft equipped with data-link and an advanced 4D Flight Management System (4D FMS), the prediction can be made onboard the aircraft itself and then down-linked to the ATC system. The aircraft crew therefore has the opportunity to plan an optimal flight for their specific purposes or route, satisfying company and other preferences. For other aircraft, the ground system will make a prediction by using a Trajectory Predictor tool.
The predictions will be based on a set of so-called constraints that describe the freedom that is available in all four dimensions to execute the flight. The Negotiation Manager tool supports the data-link negotiation process that exchanges these constraints and the resulting trajectories between air and ground. The idea is presented in Figure 3.

Once a prediction has been made, it is the basis for the further execution of the flight. When the trajectory is also negotiated with the aircrew, the 4D FMS will accurately guide the aircraft along the planned trajectory, both in position and time.

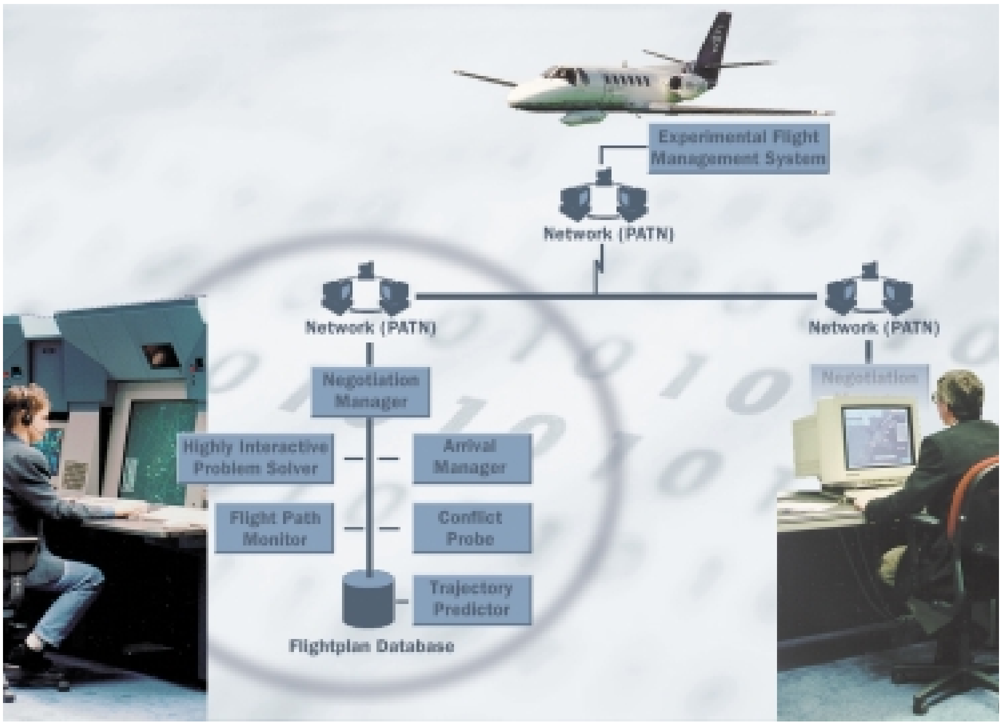


Fig. 3 – The linked processes of flight planning, co-ordination and negotiation

For every flight that has a detailed trajectory prediction, the advanced Conflict Probe tool in the ATC system will be able to detect potential conflicts with other predicted trajectories. Another advanced tool, the Problem Solver, supports the air traffic controller interactively in resolving potential conflicts in the planning of a flight through a sector. Every replanning will lead to a change in the predicted trajectory of the flight. Figure 4 illustrates the working of the problem solver.
The green line shows the planned trajectory of a flight. The red 'blob' shows a no-go zone where the planned flight will meet another flight too close to avoid a conflict, unless the planning of the flight is changed by moving the green trajectory. The yellow 'blob' shows a risk area, indicating the imposed restrictions for successfully moving the planned green trajectory during a replanning action.
The benefits of this concept increase as flights follow their predicted trajectory more accurately. An advanced Flight Path Monitor tool is therefore introduced to support the controllers in monitoring the adherence to the predicted trajectory. Deviations are reported so that the controller team can take appropriate action to ensure that flight planning and execution match closely. Also, the controller is released of the mentally intensive task of monitoring if aircraft stay on their contracted trajectory. The capacity of the controller is thus increased.

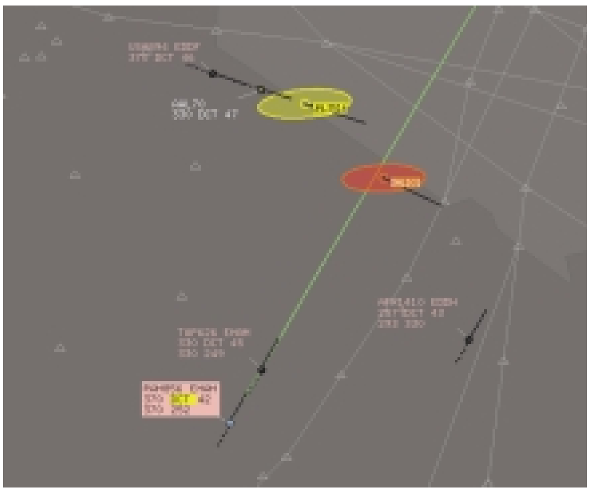


Fig. 4 – Display of conflict zone (red - where a conflict will occur) and no-go zone (yellow - where a conflict could easily be created) by the Highly Interactive Problem Solver

For aircraft that do not have data-link equipment, the planned trajectory is only available in the ATC system, since R/T is not suitable to transferring trajectory information. The ATC system will therefore advise the air traffic controller on R/T clearances that are required to keep the flight as close as possible to its planning.

User Preferred Trajectories

In order to increase flight efficiency and system capacity, User Preferred Trajectories are included in the concept. This allows operators to select optimal flight profiles and routes and, with the process described above, negotiate them via data-link with ATC. There is no need to follow any standard route network. As a consequence, crossing of sector boundaries will no longer occur at fixed waypoints and at flight levels that follow relevant letters of agreement, which will significantly reduce the number of potential conflicts, again enhancing the capacity.

The PHARE advanced support tools will allow the planning controller to plan the flight across the whole sector. In order to support the controllers in the co-ordination of plans between sectors, the Negotiation Manager tool indicates when co-ordination is required, and facilitates the electronic co-ordination process. For aircraft that have data-link equipment, the Negotiation Manager also automatically takes care of the sector hand-over process. Only non-data-link-equipped aircraft need to be transferred via R/T. Again, automation helps the controller to execute his work faster and more efficiently, making available capacity to handle more aircraft.

Arrival Management

Building a good arrival sequence for inbound aircraft is currently one of the most labour intensive tasks of ATC. An advanced Arrival Manager tool therefore supports the planning of inbound aircraft. It optimizes the arrival sequence for every landing runway in use. In order to do so it uses the flight plan information of aircraft that are still in the en-route flight phase, or that have not taken off yet. As soon as such plans become available, the tool will automatically allocate a landing runway to each flight, taking into account a rule base that includes minimum wake vortex separation, minimum flying distance and any other optimiza-

Fig. 5 – A PD/3 simulation running on the NLR ATC Research Simulator (NARSIM)

tion rule that is defined. It will also allocate a scheduled time of arrival (STA) for each of these flights on the basis of the estimated time of arrival and the available runway slots. This process is automatically updated for every flight until it has approached its initial top of descent to within a configurable number of minutes. The allocated runway and the STA are disseminated to each centre that will handle the flight. Any subsequent sector planning will aim to comply to these 'constraints' so that early convergence is achieved.

When a flight has approached the top of descent to within the configurable time limit, its arrival schedule is frozen, and the system stops the optimization of the arrival sequence for this flight. It is now the responsibility of the arrival sequence planning controller to eliminate any remaining planning conflicts for the Terminal Manoeuvring Area (TMA), by re-planning trajectories or changing the arrival sequence or runway allocation.
Finally, upon entry into the TMA, the aircraft is taken under control of the approach controller who will make sure that the aircraft meets its arrival plan. During the approach, the aircraft will be able to make full use of its optimum continuous descent profile, reducing its contribution to the environmental pollution and considerably reducing the noise load on the ground.

Demonstrations at NLR

PHARE demonstrations 3 were held twice at NLR. In May 1998 a baseline scenario was simulated for two weeks. In this period also several flights were made with NLR's Cessna Citation II research aircraft, which was equipped with a 4D EFMS and an ATN end system. These were coupled to an ATN end system that was integrated with the NLR ATC Research Simulator (NARSIM). The flights demonstrated the actual operational integration of flight management systems with the air traffic management system.

The advanced operational concept was demonstrated to the ATC community in November 1998. In each of three days, groups of some 25 to 30 visitors from all over Europe witnessed the demonstrations at NLR. Fourteen air traffic controllers and the same number of pseudo-pilots had been trained for only seven days to operate a system totally new to them. On each of the demonstration days they performed two extensive real-time simulation sessions that lasted more than an hour each. The sessions covered a simulated area that ranged from the North of France to the North of the Netherlands and from the Dutch / English FIR boundary to Luxembourg. Over a period of one hour nearly four hundred aircraft entered this airspace, which represents nearly twice the traffic level of the busiest day in 1996. Schiphol was operated with the future five-runway layout and with five active runways (three for landing and two for departures), whereas the normal configuration is three active runways. The three controllers working in the Terminal Manoeuvring Area (TMA) managed to handle the increased traffic load while allowing the inbound aircraft to follow continuous descents and the outbound aircraft nearly unrestricted climbs. Comments from controllers were generally positive and very enthusiastic, with remarks such as 'I wish I had this operational at [ATC Centre]' and 'It works great! Where can I buy it?'. Critical controllers stated 'What is it doing now' and 'What if the system makes a mistake?' or 'Are you sure that was 5 NM?'.

Operational Lessons

Although no objective measurements of the merits of the final operational concept became available, a number of issues are apparent.

In general less work is spent per aircraft, resulting in an increase of the number of flights that can be handled by a sector. Contributions to the reduction of work come from the advanced support provided by the system in detecting conflicts in the planning and in the inter-sector co-ordination and hand-over processes, as explained above. The applications of User Preferred Routing and RVSM also reduce the conflict occurrence, while the Highly Interactive Problem Solver reduces the effort to solve a planning conflict.

As a consequence of the changing roles and tasks of the air traffic controllers, their situational awareness changes. Taking up more of a managing role than a controlling role, they may not always be aware of every detail of every flight in their sector. This may be the only way to break the current human workload barrier, and if so it will have large consequences for system reliability requirements.

Concerning the integration of arrival traffic handling and en-route traffic handling, it was noticed that by disseminating arrival time constraints as early as possible to up-stream sectors it is possible to generate a smoother flow of traffic into the TMA. Consequently, stacks were hardly used and arrival time predictability increased. These effects can be considered as significant operational benefits. In addition, the concept appears to make it possible to apply User Preferred Continuous Descent Approaches even at high traffic density. This will also provide important operational benefits.

Concept Validation

During the lifetime of PHARE, the issue of the validation of new operational concepts has become more and more important. The need for validation of the fulfilment of requirements is now very strong, due to high investment costs and long lead times in introducing new systems and operations. The validation process performed in PHARE has certainly contributed to the knowledge gained over the past decade in the field of ATM validation. In PHARE, validation meant the preparation and execution of a number of large-scale real-time simulations enabling a comparison to be made against a reference system. Measurements could be made of controller's workload, system use, flight efficiency, et cetera by the three PHARE demonstrations set-up as described before. Only in PD/3 were there preparatory fast-time and small-scale investigations into previously unexplored issues.

The PHARE Demonstration 3 was aimed at demonstrating the feasibility of a new 4D ATM concept. In principle, no issues were found that would refute it. The concept holds significant potential benefits to the customers: more capacity, more optimal profiles, less delay, lower fuel costs, less environmental pollution and less noise. At this stage, no definitive measurements have been made to substantiate the above claims. This will be realized in subsequent EUROCONTROL programmes.

Concluding Remarks

In the PD/3 project, all aspects related to the development and evaluation of new Air Traffic Management operational concepts were dealt with. The following are considered to be the most important conclusions.

The development and validation of a new concept of operations for ATM is a lengthy and expensive task. The high level operational description of the early days of PHARE has matured for over a decade, which ultimately has resulted in a number of realistic real-time demonstrations. During this decade, more and more details were elaborated. Side branches were explored and often discarded as not the way forward. The reasons for discarding are also among the results of the PHARE programme. The 'validation' performed through the three demonstrations should be considered as a number of checks that the concept development was going in the right direction.

The operational concept of PHARE, to integrate air and ground systems in support of an advanced layered planning system, has proven to be viable, operationally acceptable and, most of all, holds the promise of providing the ATM capacity that will be required within two decades. The concept also supports the ATM users to fly their user preferred routing and levels with minimal intervention.

With PHARE a target for future ATM operations has been set that should be the guide for developments in the shorter term. The experience gained within the programme should be used to its maximum to provide input to these developments. We can already see existing and new programmes within EUROCONTROL taking on board the PHARE knowledge.

PHARE will be a *guiding light* for many developments to follow.

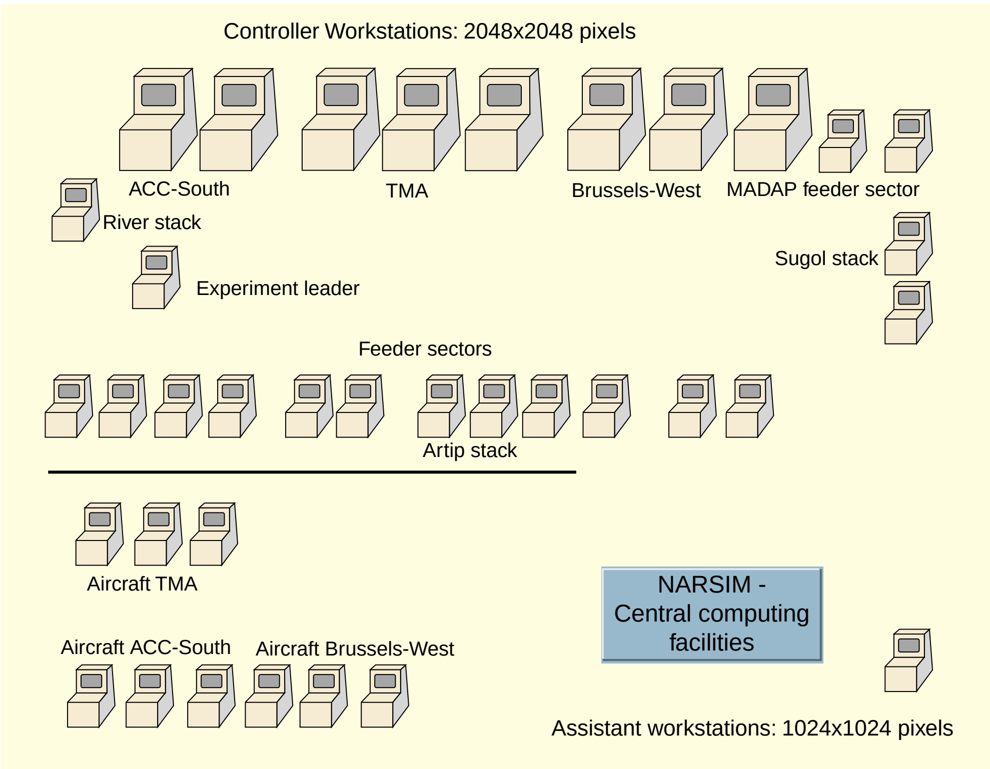


Fig. 6 – Set-up of the NARSIM facility for the PD/3 Continuation Trials

2 RAPIDS - A mobile ground station for near-real-time acquisition and processing of satellite data

NLR has operated a mobile ground station called RAPIDS (Real timeAcquisition and Processing Integrated Data System) since the end of 1997. The system has been jointly developed by the RAPIDS consortium, consisting of Bradford University Remote Sensing Ltd (BURS), the Natural Resources Institute (NRI) of the UK and NLR. The consortium has developed the system in order to provide end users with an affordable spaceborne remote sensing capability for decision making. The system is promoted by giving demonstrations and by carrying out actual projects, world-wide.

Introduction

NLR has a long history in the processing of remote sensing data and images, and in the extraction of information from them. The processing of satellite images is playing an ever increasing role, next to airborne remote sensing. This growth is driven by developments in the space industry, with a growing number of data providers, an increasing number of satellites, improving performance of satellite sensors, lower-cost image data, and inexpensive hardware for the reception and processing of data. These developments have made possible the development of the RAPIDS system, aiming at the capabilities required by various potential end users.

Fig. 1 – RAPIDS system at NLR-NOP

Specifications

The design objective of the RAPIDS ground station is to provide a solution that meets the national and/or local needs for timely and relatively inexpensive access to modest amounts of environmental data specific to local areas and context. This is done by tuning the information supply to match the resources and responsibilities of the recipient or end user. The principal design requirement is, therefore, for the system to capture moderate amounts of data for local areas regularly. This requires the system to maximize control during overhead passes where the rate of change of the satellite position is highest.Acquisition of the data from within 45° from the vertical enables users to capture small volumes of data of local interest, within a radius of about 1000 km, which meet real-time needs (see also Figure 2). The system also has to be robust to minimise the effect of wind forces during tracking, and simple to maintain and operate. Standard PCs were selected as the platforms for the management, tracking, capturing and processing of data, because of their increasing performance/cost advantage over workstations and their widespread availability and use in developing countries. This makes local maintenance and cost-effective integration with existing capacity easier.

The specifications of the RAPIDS system have been aimed at:

- providing a turn-key application system infrastructure to the value adding industry
- supporting data distribution services
- supporting defence applications
- making possible temporary rapid deployment in remote areas

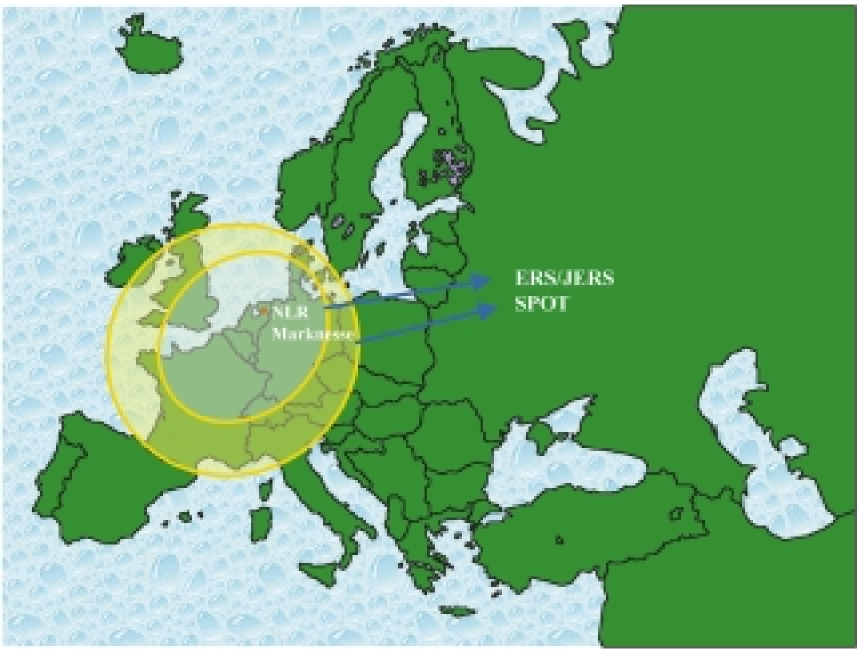


Fig. 2 – Spatial coverage (footprint) of ERS and SPOT satellites received by RAPIDS deployed at NLR-NOP

Design

The RAPIDS system features an advanced electronic tracking system instead of a programmed dish pointing system. This leads to low cost and small size, with the antenna dish diameter being only 2.7 metre compared to 9 metre for fixed stations.

This feature make RAPIDS a fault tolerant, robust, easily transportable and affordable system. Since the system is PC-based, spare parts are available world-wide when necessary. Specially developed software for processing SAR (Synthetic Aperture Radar) data and optical data generates bitmap images that can be read with any simple graphical software package (see Figure 3). Owing to hydraulic dish drives and the use of standard PCs, the system only requires a minimum of maintenance and training, as proven in our experience during in-house operational use and in overseas demonstrations and projects.

The RAPIDS system is currently capable of capturing data signals from the ERS and SPOT Earth Observation (EO) satellites. Overseas demonstrations have shown that RAPIDS is capable of being operated successfully in tropical conditions. They have promoted greater awareness and appreciation of the practicality and usefulness of near-real-time local data delivery in support of real-world management decisions. Near-real-time

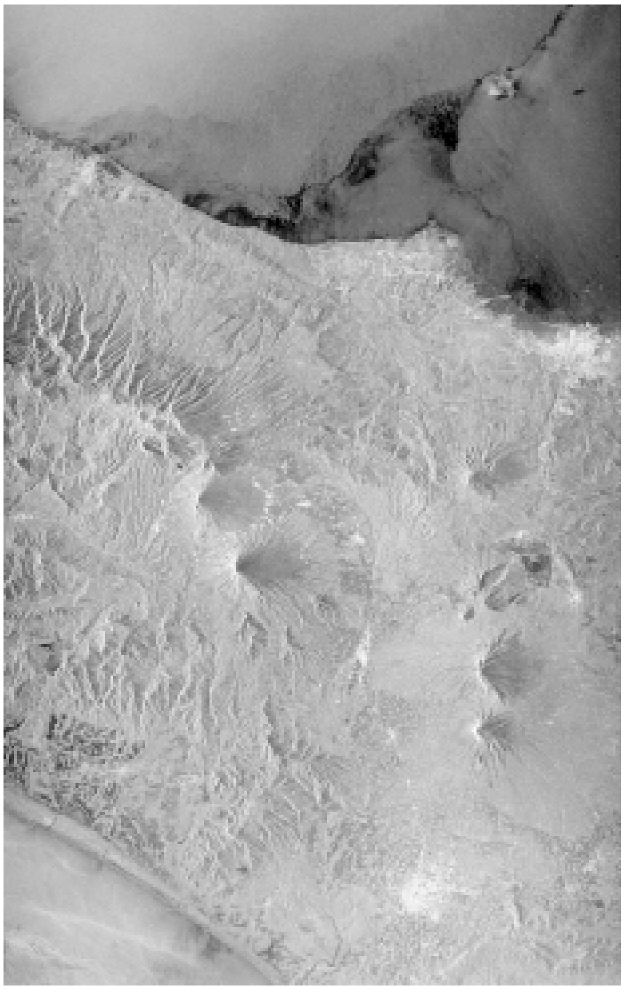


Fig. 3a – ERS-2 image of volcanoes near Semarang on Java recorded by RAPIDS – © ESA 1998

Fig. 3b – Multispectral SPOT image of main polder areas in the Netherlands recorded by RAPIDS © SPOTImage 1999

delivery of data offers significant advantages for the distribution and analysis of information from sensors on satellites. More such information is expected to become available in the future.

Projects

RAPIDS has been used in various projects, three of which are described in some detail below.

Demonstration in Indonesia

In 1998, a successful demonstration project was carried out in Indonesia. The RAPIDS system was installed at Lapan, the National Institude of Aeronautics and Space, (see Figure 4), and used for such applications as forestry, bathymetry, coastal zone management and rice monitoring. The project showed the RAPIDS system operating under harsh tropical conditions. It resulted in an ERS-2 archive to be used for future studies in the application areas mentioned above.

Flood Monitoring in Bangladesh

One project carried out in 1999 was an ESA-sponsored Data User Programme (ESA-DUP) project called Flood monitoring service in Bangladesh. This seven-month ESA-DUP project was aimed at locally demonstrating a capability for flood monitoring and food security using the ERS-2 satellite. It was carried out by NLR as a subcontractor of Synoptics BV, a value adding company of the Netherlands. NLR was responsible for the provision of the satellite data receiving and processing capability to the Bangladesh institutes EGIS (Environment and Geographic Information System Supply Project for Water Sector Planing) and SPARRSO (Space Research and Remote Sensing Organization), including system operations training. Synoptics BV was responsible for information extraction software and training. The work of Synoptics and NLR provided a flood monitoring capability using ERS-2 satellite data. These data were processed into time series (see Figure 6, left) and classified images (flood maps, see Figure 6, right). The project resulted in a better understanding of user and operational requirements, and a valuable archive containing over 100 gigabytes of ERS-2 data, which can be used for future studies.

Project for Military Applications

A project started in 1999, which will run up to the year 2002, is a EUCLID (European Co-operation for the Long Time in Defence) project called On-board and on-ground processing and handling of satellite data. This project is carried out by Kongsberg Spacetec of Norway, Dornier of Germany, Alenia of Italy, and NLR. It is funded by

Fig. 4 – RAPIDS installed at Lapan, Indonesia

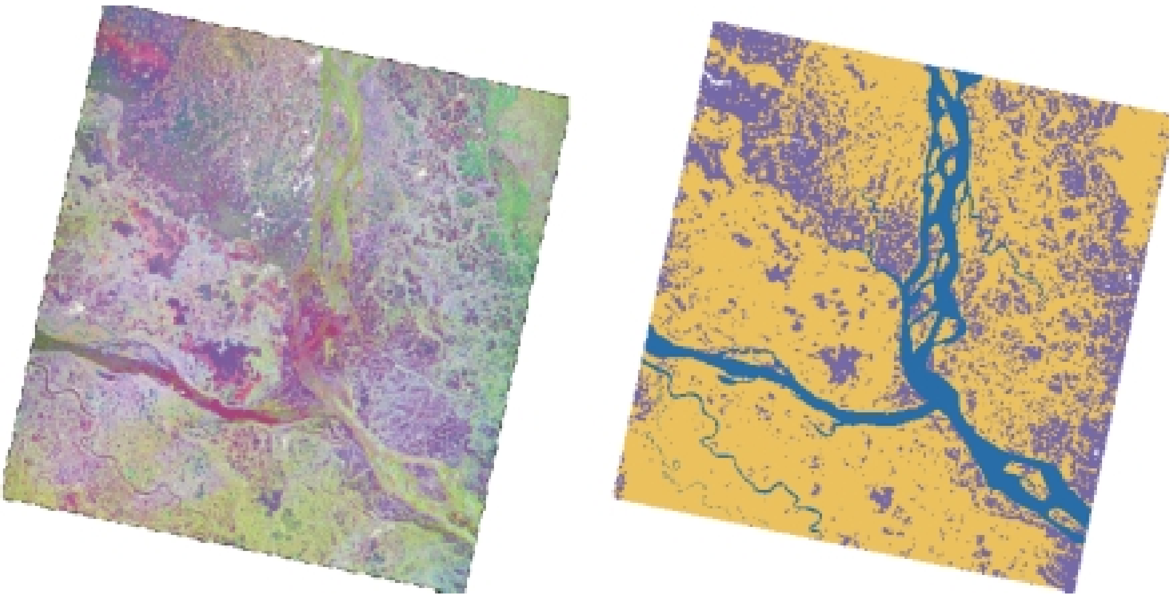


Fig. 6 – ERS-2 data of the area where the Ganges and Brahmaputra or Jamuna rivers converge, Bangladesh (courtesy Synoptics BV). On the left a multi-temporal ERS-2 image (from three data sets; colours provide information on the period when changes occurred), on the right a flood map of the same area (brown = non-flooded, blue = flooded area)

the ministries of defence of the participating countries. The project aims at the investigation, development and demonstration of data acquisition, processing and distribution tasks for military applications.

In this three-year EUCLID project, data acquisition, processing and distribution capabilities will be developed or extended. The goal of the project is to develop a complete processing chain from satellite data reception to information distribution, in a military context. Developments include hardware and software upgrades. The project is concluded with a series of demonstrations, with the RAPIDS system being the backbone. In an initial demonstration at the Royal Netherlands Air Force base Volkel (see Figure 7), current capabilities were shown and discussions on user requirements were held.

Future Outlook

Rapid developments in space technology and the short lifetime of satellite platforms necessitate efforts to be continuously spent on RAPIDS in order to be able to provide an up-to-date service / product to customers. An implementation project for the reception of data from Envisat ASAR, the successor of the ERS-2 radar satellite, was started. In this project, NLR co-operates with the TNO Physics and Electronics Laboratory (FEL) on the software for processing Synthetic Aperture Radar (SAR) data.

Commercial initiatives to provide satellite data now mainly concern optical data, often at high resolution. Within the boundaries of technical and financial possibilities, a RAPIDS capability for the reception and processing of high resolution optical data is therefore being prepared. Using feedback received from end-users in various projects, a continuous programme of improvements to the

Fig. 7 – RAPIDS installation at Volkel Air Base, June 1999

system is being executed. Improvements include greater user friendliness, robustness and processing speed.

End-user awareness of the capabilities of satellite remote sensing data using a mobile ground station is growing, resulting in numerous requests for information. Also satellite operators such as ESA (European Space Agency) and Spot Image have become aware of the existence of mobile ground stations. By developments in the space industry, a range of opportunities will arise in the near future. One key issue now is to implement the capability for decision making provided by RAPIDS in the local management structure. At the moment, for developing countries it is not the technology, but the institutional issues that are the hurdle to take. Potential military users are specifically interested in data at high resolution, of the order of 1 metre. Such data will become commercially available within one or two years, which may result in an increasing interest of military for spaceborne remote sensing, as it no longer requires owning a satellite or an expensive ground station.

Fig. 5 – RAPIDS being installed in Dhaka, Bangladesh

Concluding Remarks

The RAPIDS system differs from other ground stations, both technically and in cost. The use of mobile stations opens up a wide range of applications where the facilities of the big, fixed stations are not always suitable. Reducing costs of satellites, ground stations and data make these affordable for an ever increasing group of potential customers. Satellite sensor resolutions are becoming better. The 1-metre ground resolution barrier has been broken for commercial optical sensors, so that military relevant data is becoming commercially available, and will be widely available soon. If the RAPIDS system can be upgraded to provide the capability of receiving such data, without violating its advantages, the operational use of spaceborne remote sensing using such mobile ground stations is expected to follow. This would provide autonomous, direct access to the data and information in real time or near real time.

A new way of thinking towards satellite remote sensing is growing, and is expected to result in the acceptance of the new capability as a valuable management tool. This process is under way, although it requires time and continued marketing efforts. One observes that technology institutes and high-end customers, such as the military, are the first to appreciate the capabilities that are becoming available. Acceptance by developing countries will require further demonstration projects, which may be funded by satellite operators, donor agencies and donor governments.

Acknowledgements

The co-operation by the management and staff of LAPAN, EGIS and SPARRSO in providing facilities, equipment and personnel in support of RAPIDS operations in Indonesia and Bangladesh are gratefully acknowledged The support of management and staff at ESA mission scheduling operations, the ESA-DUP and Synoptics B.V. is gratefully acknowledged as well. Demonstrations of SPOT data captures were kindly permitted through the courtesy of SPOT Image. The RAPIDS project has been funded partly by the British National Space Centre (BNSC), the Netherlands Remote Sensing Board (BCRS), the Netherlands Agency for Aerospace Programmes (NIVR) and the Netherlands Ministry of Defence.

Appendices

Appendices

1 Publications

In 1999, NLR published a total of 586 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

NLR-TP-98139
Impact damage prediction and failure analysis of heavy loaded, blade-stiffened composite wing panels
Published in the journal Composite Structures
Wiggenraad, J.F.M.; Zuang, X.;
Davies, G.A.O.

NLR-TP-98184
GEROS: A European grid generator for rotorcraft simulation methods
Presented at the 6th International Conference on Numerical Grid Generation in Computational Field Simulation, University of Greenwich, London, England, 6–9 July 1998
Hounjet, M.H.L.; Allen, C.R.; Gasparini, L.;
Vigevano, L.; Pagano, A.

NLR-TP-98226
From a non-disciplinary to a multi-disciplinary approach in aerospace as seen from information and communication technology perspective
Presented at the 21st ICAS Congress, Melbourne, 13–18 September 1998
Vogels, M.E.S.; Arendsen, P.; Krol, R.J.;
Laban, M.; Pruis, G.W.;

NLR-TP-98239
Space-time discontinuous Galerkin finite element method with dynamic grid motion for inviscid compressible flows
Published in the Journal of Computational Physics, by the Academic Press
Vegt, J.J.W. van der

NLR-TP-98333
Het veiligheidssysteem van ERA (in Dutch)
Gepubliceerd in: Ruimtevaart, februari 1998, uitgegeven door de Nederlandse Vereniging voor Ruimtevaart, en gebaseerd op de publicatie 'Failure detection and recovery system concept for the European Robotic Arm', oorspronkelijk gepubliceerd in de Proceedings van de International Conference on Safety and Reliability (ESREL'97), Lisbon, Portugal, 17–20 June 1997
Bos, J.F.T.; Oort, M.J.A.

NLR-TP-98338
AIRSIM, a desktop research flight simulator
Presented at the AIAA Modelling and Simulation Technologies Conference, Boston, USA, 10–12 August 1998
Groeneweg, J.

NLR-TP-98343
Analysis of the data from a distributed set of accelerometers for reconstruction of set geometry and its rigid body motion
Presented at the Space Technology and Applications International Forum (STAIF-99), Conference on International Space Station Utilization, Albuquerque, New Mexico, USA, 31 January – 4 February 1999
Vreeburg, J.P.B.

NLR-TP-98367
Rapids - A PC-based local ground station
Presented at UN/IAF workshop on Expanding the User Community of Space Technology Applications in Developing Countries, Melbourne, Australia, 24–27 September 1998
Looyen, W.J.; Oostdijk, A.; Kamp, A. van der;
Dowey, I.D.; et al.

NLR-TP-98390
In-flight spectroscopic aircraft emission measurements
Presented at the RTO-AVT Symposium 'Gas Turbine Engine Combustion, Emissions and Alternative Fuels', Lisbon, Portugal, 12–16 October 1998
Jentink, H.W.; Veen, J.J.F. van

NLR-TP-98400

Residual strength tests on stiffened panels with multiple site damage

Presented at the Fatigue 99 Conference, Beying, China, 8–12 June 1999

Hoeve, H.J. ten; Ottens, H.H.; Schra, L.; Vlieger, H.

NLR-TP-98415

Resin transfer moulding as fabrication method for complex shaped composite components for space applications

Presented at the European Conference of Space-craft Structures, Materials and Mechanical Testing, Braunschweig, Germany, 4–6 November 1998

Thuis, H.G.S.J.

NLR-TP-98417

Efficient harmonisation of simulation competence in a CACE working environment – Its use in the development of a generic vehicle behaviour federate

Presented at the 5th International Workshop on Simulation for European Space Programmes, SESP '98, ESTEC, Noordwijk, The Netherlands, 3–5 November 1998

Kos, J.; Dam, A.A. ten; Pruis, G.W.; Vankan, W.J.;

NLR-TP-98423

Advances in the modelling of cracks and their behaviour in space structures

Presented at the European Conference of Space-craft Structures, Materials and Mechanical Testing, Braunschweig, Germany, 4–6 November 1998

Koning, A.U. de; Hoeve, H.J. ten; Grooteman, F.P.; Lof, C.J.

NLR-TP-98448

A pilot model for helicopter manoeuvres

Presented at the 24th European Rotorcraft Forum, Marseille, France, 15–7 September 1998

Vorst, J. van der

NLR-TP-98462

A tool kit for turning heterogeneous computer networks into application environments

Published in: NEC Research & Development, October 1998

Baalbergen, E.H.; Ven, H. van der

NLR-TP-98463

SPINEware – A framework for user-oriented and tailorable metacomputers

Published in the Special Issue on Metacomputing of the International Journal on Future Generation Computer Systems 15 (1999) p. 549–558, Elsevier Publ.

Baalbergen, E.H.; Ven, H. van der

NLR-TP-98478

SPINEware: A practical and holistic approach to metacomputing

Published in Proceedings of High-Performance Computing and Networking HPCN Europe 1998, Springer Lecture Notes in Computer Science 1401, April 1998

Baalbergen, E.H.

NLR-TP-98480

Data system in flight and emission modelling

Presented at the DASIA'98 Conference on Data Systems in Aerospace, Athens, Greece, 25–28 May 1998

Witte, T.D. de

NLR-TP-98484

On the suitability of genetic-based algorithms for data mining

Published in the Proc. Intern. Workshop on Advances in Database Technologies, by Springer Verlag (Series LNCS) 1998

Choenni, S.

NLR-TP-98510

Progress report on aerodynamic analysis of a surface piercing hydrofoil-controlled wing-in-ground effect SEABUS configuration

Presented at the RTO Applied Vehicle Technology Panel Symposium on Fluid Dynamics Problems of Vehicles Operating near or in the Air-Sea Interface, Amsterdam, 5–8 October 1998

Beek, C.M. van; Oskam, B.; Fantacci, G.

NLR-TP-98577

The scenario management tool SMARTFED for real-time interactive high performance networked simulations

Presented at the HPCN Europe '99 Conference, Amsterdam, 20–24 April 1999

Sterkenburg, R.P. van; Dam, A.A. ten

NLR-TP-98616

Piloted evaluation of flight director go-around modes and windshear icon concepts

Presented at the AIAA Atmospheric Flight Mechanics Conference and Exhibit, AIAA paper 98-4286, Boston, Massachusetts, USA, 10–12 August 1998, and at the Cockpit Design Issues Workshops organized by the Corporate Advisory Committee and the European Advisory Committee of the Flight Safety Foundation, held in Cedar Rapids, Iowa, USA, 24–25 August 1998

Rouwhorst, W.F.J.A.; Haverdings, H; Huynh, H.T.; Descatoire, F; Hahn K.-U.; and König, R.

NLR-TP-98629

Modelling effects of operating conditions and alternative fuels on gas turbine performance and emissions

Presented at the RTO-AVT Symposium 'Gas Turbine Engine Combustion, Emission and Alternative Fuels', Lisbon, Portugal, 12–16 October 1998

Visser, W.P.J.; Kluiters, S.C.A.

NLR-TP-99007

An agent-based resource allocator for close air support

Presented at the Fourth International Conference and Exhibition on the Practical Application of Intelligent Agents and Multi-Agents (PAAM99), London, 19–21 April 1999

Vijver, Y.A.J.R. van de

NLR-TP-99015

Accident risk assessment for advanced ATM

Presented at the Second USA/Europe Air Traffic Management R&D Seminar, Orlando, 1–4 December 1998

Blom, H.A.P.; Bakker, G.J.; Blanker, P.J.G.; Daams, J.; Everdij, M.H.C.; Klompstra, M.B.

NLR-TP-99022

RAPIDS - Enabling local user access to remote sensing: recent experiences from Indonesia

Presented at ESA Euro-Asian Space Week, Singapore, 23–27 November 1998

Looyen, W.J.; Oostdijk, A.; Noorbergen, H.; Kamp, A. van der; (NLR);
Downey, I.; Archer, D.; Perryman, A.; Williams, J.; (Natural Resources Institute);
Sandford, T.; Stephenson, J.;
Stephenson, R. (Bradford University Remote Sensing Ltd.)

NLR-TP-99026

Development of a composite torque link for helicopter landing gear applications

Published in the proceedings of the Twelfth International Conference on Composite Materials, Paris, France, 5–9 July 1999

Thuis, H.G.S.J.

NLR-TP-99029

The information and communication technology's contribution to the MDO project

Presented at the Royal Aeronautical Society Conference on Multidisciplinary Design Optimisation, London (UK), 26–27 October 1998

Vogels, M.E.S.; Allwright, S.E.; Stettner, M.; Sims, Ph.; Barhtolomew, P.

NLR-TP-99033

Development and evaluation of a hard patch repair method for composite stiffened wing panels

Presented at the JEC/SAMPE Conference, Paris, France, 13–15 April 1999

Michielsen, A.L.P.J.; Ubels, L.C.; Baas, F.

NLR-TP-99062

Development of liquid flow metering assemblies for space

Presented as SAE paper 1999-01-1981 at the 29th International Conference on Environmental Systems, Denver, Co, USA, July 1999

Delil A.A.M.; Put, P. van; M. Dubois, M.; Supper, W

NLR-TP-99063

Full-scale measurements on the Erasmus bridge after rain/wind induced cable vibrations

Presented at the 10th International Conference on Wind Engineering, Copenhagen, Denmark, 21–24 June 1999

Persoon, A.J.; Noorlander, K.

NLR-TP-99064

Unsteady leading edge suction effects on rotor-stator interaction noise

Published as AIAA paper 99-1951 in the Proceedings of the 5th AIAA/CEAS Aeroacoustics Conference, Greater Seattle, Washington, USA, 10–12 May 1999

Schulten, J.B.H.M.

NLR-TP-99066

Analysis of conformal antennas on aircraft structures

Presented at the NATO RTA SET Symposium on High Resolution Radar Techniques, Granada, Spain, 22–24 March 1999

Schippers, H.; Klinker, F.

NLR-TP-99068

A PHARE ATM concept in support of a European ATM programme

Jonge, H.W.G. de

NLR-TP-99093

Simulaties verschaffen inzicht in zuigerkoeling (in Dutch)

Published in De Constructeur.

Nies, J.J.; Veldman, A.E.P.; Ven, H. van der

NLR-TP-99104

Flow field investigations on a wing installed couter rotating ultra-high-bypass fan engine simulator in the low speed wind tunnel DNW-LST

Presented at the 7th European Propulsion Forum on Aspects of Engine/Airframe Integration, Pau, France, 10–12 March 1999

Hegen, G.H.; Puffert-Meissner, W.; Dieterle, L.; Volmers, H.

NLR-TP-99108

Source location by phase array measurements in closed wind tunnel test sections

Published as AIAA paper 99-1814 in the Proceedings of the 5th AIAA/CEAS Aeroacoustics Conference, Greater Seattle, Washington, USA, 10–12 May 1999

Sijtsma, P.; Holthusen, H.

NLR-TP-99124

Design, fabrication and testing of composite structures

Presented at the Symposium Weight watching: a new approach, organized by ISAAC Newton, University of Twente, Enschede, the Netherlands, 22 April 1999

Michielsen, A.P.J.; Thuis, H.G.S.J.

NLR-TP-99133

Sound diffraction by the splitter of a turbofan engine

Presented at the sixth International Congress on Sound and Vibration, Lyngby, Demark, 5–8 July 1999

Nijboer, R.J.; Sijtsma, P.

NLR-TP-99141

Attentional effects of superimposing flight instrument and tunnel-in-the-sky symbology of the world

Presented at the 2nd International Conference on Engineering Psychology and Cognitive Ergonomics, Oxford, United Kingdom, 27–30 October 1999

Houten, Y.A. van

NLR-TP-99142

Component based software development at NLR: Assembling aerospace applications

Presented at the Euroforum Software Congress ‘Component based development’, Utrecht, The Netherlands, 15 December 1998

Kesseler, E.; Baalbergen, E.H.

NLR-TP-99168

Thermo-mechanische modellering van gasturbine componenten met het Eindige Elementen pakket MARC (in Dutch)

Gepresenteerd tijdens de MARC gebruikers-bijeenkomst, Voorburg, 27 mei 1999

Tinga, T.

NLR-TP-99188

Review of aeronautical fatigue investigations in the Netherlands during the period March 1997 – March 1999

Published in the Proceedings of the 26th ICAF Conference, Bellevue, Washington, USA, 12–16 July 1999

Ottens, H.H.

NLR-TP-99206

Wat is COTS-Technologie? COTS Elektronica onder extreme omstandigheden (in Dutch)

Gepresenteerd tijdens het door FHI Het Instrument georganiseerde seminar 'Elektronica in Aerospace & Defence', Utrecht, 5 maart 1999

Aartman, L.J.

NLR-TP-99227

Information and Communication Technology for industrial design using parallel CFD

Presented at the 4th ECCOMAS CFD Congress, Athens, Greece, 7–11 September 1998

Vogels, M.E.S.

NLR-TP-99231

A framework for the automation of air defence systems

Presented at the RTA SCI Symposium on Warfare Automation: Procedures and Techniques for Unmanned Vehicles, Ankara, Turkey, 26–28 April 1999

Choenni, R.; Leijnse, C.

NLR-TP-99236

Simulation of liquid dynamics onboard Sloshsat FLEVO

Presented at the Space Technology and Applications International Forum (STAIF-99), Conference on Applications of Thermophysics in Microgravity and Breakthrough Propulsion Physics, Albuquerque, New Mexico, U.S.A., 31 January –4 Februari 1999

Vreeburg, J.P.B.

NLR-TP-99240

A method for predicting the rolling resistance of aircraft tires in dry snow

Published in the Journal of Aircraft, December 1999, by AIAA

Es, G.W.H. van

NLR-TP-99248

Mission preparation and training facility for the European Robotic Arm (ERA)

Presented at the 5th International Symposium on Artificial Intelligence, Robotics and Automation in Space (I-SAIRAS), Noordwijk, The Netherlands, 1–3 June 1999

Pronk, Z.; Schoonmade, R.

NLR-TP-99255

Evaluation of windshear hazard displays and go-around procedures using piloted simulations at NLR

Presented at the 21st ICAS Congress, Melbourne, Australia, 13–18 September 1998

Haverdings, H.; Rouwhorst, W.F.J.A.

NLR-TP-99256

Frequency domain unsteady aerodynamics in/from aeroelastic simulation

Presented at the CEAS/AIAA/ICASE/NASA Langley International Forum on Aeroelasticity and Structural Dynamics, Williamsburg, Virginia, U.S.A., 22–25 June 1999

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

NLR-TP-99265

Fractographic investigation of pressure cabin MSD

Published in the Proceedings of the ICAF 99 Conference, Bellevue, Washington, USA, July 1999

Wanhill, R.J.H.; Hoeven, W. van der; Hoeve, H.J. ten; Ottens, H.H.

NLR-TP-99272

Quality first: Measuring a safety-critical embedded software development process

Presented at the VTT Symposium, Oulu, Finland, 22–24 June 1998

Kesseler, E.

NLR-TP-99273

Flight tests to investigate supercooled large droplets in icing conditions

Presented at the 11th Annual Symposium of the European Chapter of the Society of Flight Test Engineers, Delft, The Netherlands, 21–23 June 1999

Jentink, H.W.

NLR-TP-99279

MANTEA departure sequencer: increasing airport capacity by planning optimal sequences

Presented at the FAA/Eurocontrol ATM '98 Conference, Orlando (Fl), USA, 1–4 December 1998

Hesselink, H.H.; Basjes, N.

NLR-TP-99289

Real-time simulation of impact for the aerospace industry

Presented at the EUROMECH'99 Conference 'Impact in Mechanical Systems', Grenoble, France, 30 June–2 July 1999

Dam, A.A. ten; Kos, J.

NLR-TP-99295

Resolving the dependence on free-stream values for the k-omega turbulence model

AIAA Journal, June 2000

Kok, J.C.

NLR-TP-99304

Accuracy, resolution, and computational complexity of a discontinuous Galerkin finite element method

Presented at the First International Symposium on Discontinuous Galerkin Methods, Newport, Rhode Islands, U.S.A., 24–26 May 1999

Ven, H. van der; Vegt, J.J.W. van der

NLR-TP-99307

Runway incursion alert using knowledge rules

Presented at the 'A-SMGCS Technical Interchange Meeting – FAA/Eurocontrol Co-operative Effort on Air Traffic Management Decision Support Tools' workshop, Braunschweig, Germany 10–12 November 1998

Hesselink, H.H.

NLR-TP-99308

Time-critical allocation of tactical air resources to targets

Presented at the NATO RTO Symposium 'Advanced Mission Management and System Integration Technologies for Improved Tactical Operations', Florence, Italy, 27–29 September 1999

Vijver, Y.A.R. van de

NLR-TP-99313

Stress intensity factor solutions for fasteners in NASGRO 3.0

Presented at the Second Symposium on Structural Integrity of Fasteners, ASTM, Seattle, Washington, 19 May 1999

Mettu, S.E.; Koning, A.U. de; Lof, C.J.; Schra, L.; McMahon, J.J.; and Forman, R.G.

NLR-TP-99353

Unsolved aerospace heat and mass transfer research issues for the development of two-phase thermal control systems for space

Presented as Invited Lecture at the Workshop on Non-Compression Refrigeration & Cooling, Odessa, Ukraine, 7–11 June 1999

Delil, A.A.M.

NLR-TP-99354

Some critical issues in developing two-phase thermal control systems for space
Presented at the 11th International Heat Pipe Conference, Tokyo, Japan, 12–16 September 1999
Delil, A.A.M.

NLR-TP-99379

Flight simulator evaluation of the safety benefits of terrain awareness and warning systems
Presented at the AIAA Guidance, Navigation and Control Conference, Portland (OR), U.S.A. 9–11 August 1999
Muynck, R.J.; Khatwa, R.

NLR-TP-99381

Growing pains of major European airports Case study: Amsterdam Airport Schiphol
Presented at the 2nd USA/Europe Air Traffic Management R&D seminar, Orlando, USA, 1–4 December 1998
Offerman, H.A.J.M.; Bakker, M.W.P.

NLR-TP-99386

Development of noise abatement procedures in the Netherlands
Presented at the New Aviation Technologies International Symposium, Zhukovsky, Moscow Region, Russia, 17–22 August 1999
Erkelens, L.J.J.

NLR-TP-99392

Significance of dwell cracking for IN718 turbine discs
Published in a special issue of the International Journal of Fatigue
Wanhill R.J.H.

NLR-TP-99398

Advanced stochastic method for probabilistic analysis
Published in the Proceedings of the Euromech 405 Colloquium, Valenciennes, France, 18–19 November 1999
Grooteman, F.P.

NLR-TP-99408

Corrosion and fatigue assessment of aircraft pressure cabin longitudinal lap splices
Published in the Proceedings of the 5th International Aerospace Corrosion Control Symposium, Amsterdam, 3–5 November 1999
R.J.H. Wanhill

NLR-TP-99429

Microgravity two-phase flow and heat transfer
Published as Chapter 9 of 'Fluid Physics in Microgravity', Rodolfo Monti (Editor), Overseas Publishing Associates (Gordon and Breach Science Publishers & Harwood Academic Publishers), Reading, United Kingdom.
Delil, A.A.M.

NLR-TP-99434

Development of a composite cargo door for an aircraft
Presented at the 10th International Conference on Composite Structures ICCS-10, Monash, 15–17 November 1999
Thuis, H.G.S.J.

2 Abbreviations

AECMA	Association Européenne des Constructeurs de Matériel Aérospatial (The European Association of Aerospace Industries)
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)
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 Windtunnels (German-Dutch Wind Tunnels)
EFIS	Electronic Flight Instrument System
EMI	Electro-Magnetic Interference
EREA	Association of European Research Establishments in Aeronautics
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESPRIT	European Strategic Programme for Research and Development in Information Technology
ESTEC	European Space Research and Technology Centre
ETW	European Transonic Windtunnel
EU	European Union
EUCLID	European Co-operation for the Long term In Defence
Eurocontrol	European Organization for the Safety of Air Navigation
EZ	Ministerie van Economische Zaken (Ministry of Economic Affairs)
FAA	Federal Aviation Administration (USA)
FAO	Food and Agriculture Organization (UN)
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
HMI	Human Machine Interface
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)
ITB	Institut Teknologi Bandung (Indonesië) (Technological Institute of Bandung, Indonesia)
JAR	Joint Airworthiness Requirements
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)
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
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)
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

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

E-mail: info@nlr.nl
Web site: www.nlr.nl