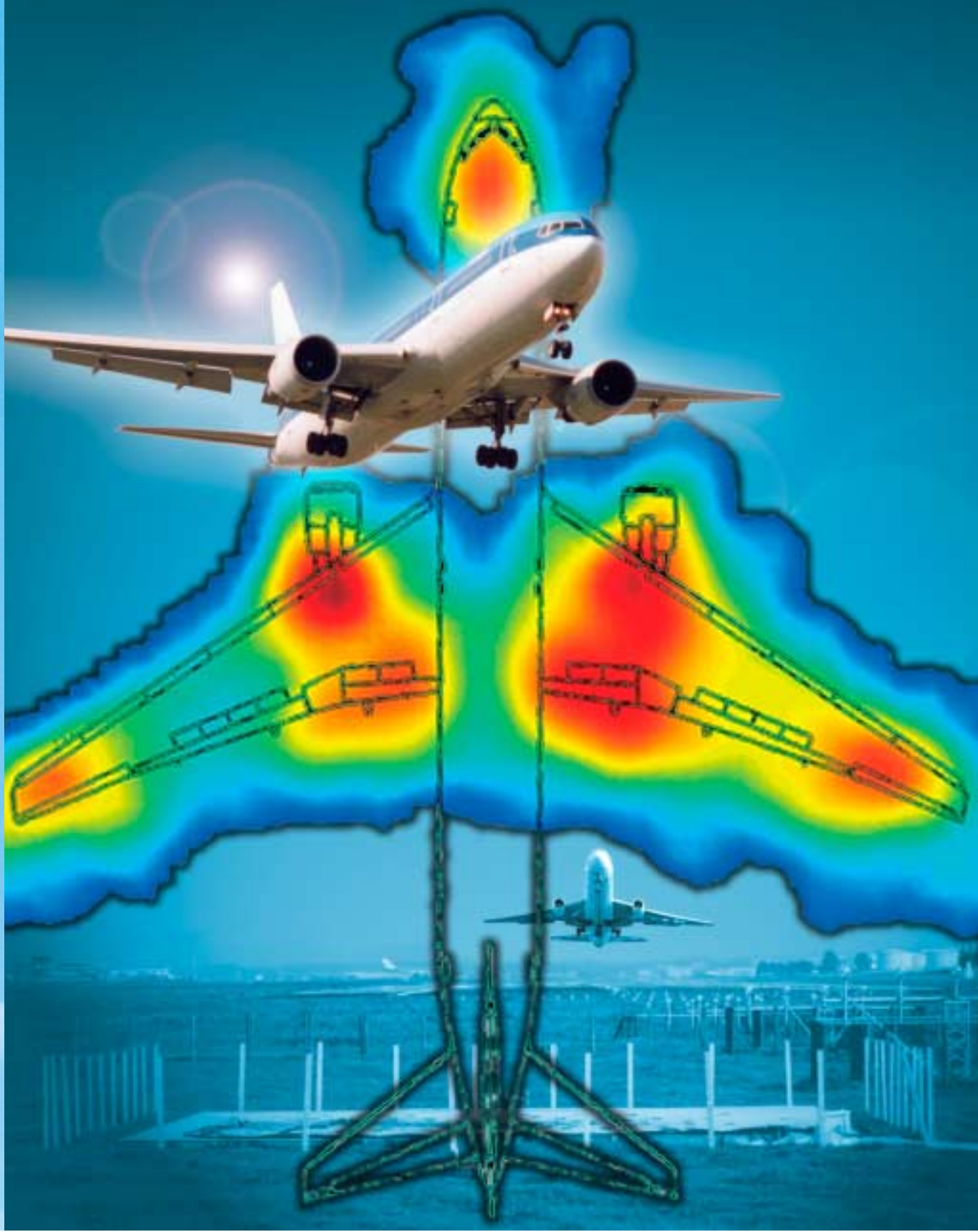
Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Annual Report 2000



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National Aerospace Laboratory NLR

Annual Report 2000

Cover: NLR measured fly-over noise characteristics at Amsterdam Airport Schiphol using the acoustic array technique

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. J.P.J.M. Remmen	Minister of Transport, for the Netherlands Department of Civil Aviation (RLD)
Drs. E.A. van Hoek	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
B.A.C. Droste	Netherlands Agency for Aerospace Programmes (NIVR)
G.H. Kroese	Air Traffic Control the Netherlands (LVNL)
Dr.ir. A.W. Veenman	Stork N.V.
Drs. P.G. Winters	Fokker Space B.V.
Ir. C.J.M. Gresnigt	KLM Royal Dutch Airlines
Ms. ir. M.E. van Lier Lels	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
Jhr.mr. J.W.E. Storm van 's Gravesande	Board of the Foundation NLR
Vacancy	Board of the Foundation NLR, upon nomination by the Works Council

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 2000

Table of Contents

1 Introduction

At the conclusion of the year 2000 the long expected launch of the Airbus A380 was announced by Airbus Industrie thereby setting the scenery for the development of the largest civil transport aircraft ever. With over 550 passengers and a range of more than 7500 nautical miles at a take-off weight of 540 tonnes and a cruising speed of Mach 0.85, the A380 not only outranks the famous Boeing 747 in size but also aims at a 15 to 20 per cent reduction in operating costs. The fact that the ambitions of Airbus are not restricted to a single configuration only, but include a family of even higher capacity and longer range versions including a freighter variant, opens great perspectives for participation by the Dutch industry, in particular the Stork Aerospace Group. To facilitate this participation, the Netherlands Agency for Aerospace Programmes (NIVR), on behalf of the Ministry of Economic Affairs, supports many of the development activities by providing part of the financing and co-ordinating the necessary research and development work. As prime institute for aerospace research and technology in the Netherlands, NLR is proud to be actively engaged in many of these technology fields in close co-operation with the industry. Areas in which NLR is involved include the application and testing of new materials (such as Fibre Metal Laminates and Composites) and new production techniques (such as Resin Transfer Moulding and Friction Stir Welding). Moreover, with its expertise in Computational Fluid Dynamics, Experimental Aerodynamics and Aeroacoustics, NLR also contributes to the design of the A380.

The year 2000 was further characterized by the discussion about the successor of the F-16 of the Royal Netherlands Air Force. NLR contributes to the development and evaluation of potential candidates, such as the Eurofighter, the Rafale and the Joint Strike Fighter, with studies about new technologies and procedures that will lead to more sophisticated fighter aircraft that are cheaper to maintain. Together with several industrial partners, NLR has demonstrated the viability and potential of many of these new technologies in various disciplines such as avionics, acoustics, embedded training, prognostic health management, structures, electrical cabling and power distribution systems, cooling and simulation. Many of these studies, which are funded by the government, serve to help the Dutch industry to qualify as preferred supplier and will continue in 2001. In order to maintain sufficient momentum, however, it is essential that a decision about the selected candidate by the Dutch authorities be taken as soon as possible.

Considerable effort was given to support the government and the airworthiness and air traffic control authorities with the congestion issue and future development of Mainport Amsterdam Schiphol. With its know-how and experience in such fields as air traffic management and airport traffic management and not in the least with its research simulators, NLR is highly qualified to support the sector with the development of new technology in order to accommodate the foreseeable growth in air traffic within the legally prescribed limits for safety, noise and emissions. NLR's expertise was highlighted during a symposium for the sector in Amsterdam on 21 June 2000, which drew a lot of attention also from politicians.

Considerable effort was also attributed to space activities. NLR supports the Dutch industry in ESA programmes such as the Crew Rescue Vehicle for the International Space Station, the simulation of space missions and the development of structural components of launchers. NLR further supports the launch of a small satellite, Sloshsat FLEVO, for the study of sloshing problems during interplanetary missions and docking manoeuvres. Currently, the launch of this satellite is foreseen for 2002. NLR, with support of the Ministry of Economic Affairs, the Province Flevoland and the Community Noordoostpolder, is also involved in the exploitation of Geomaticapark Noordoostpolder, a business centre for the provision of remote sensing products from satellite data by so-called value adding industries for a wide variety of applications to both national and international customers.

As in previous years NLR was and will remain actively involved in international technology programmes, especially the Fifth Framework Programme of the European Union. NLR further participates in the Group for Aeronautical Research and Technology in Europe (GARTEUR) and in research programmes of the Western European Armament Organization (WEAO). Active participation in international research and technology programmes is one of the keystones of NLR's policy to keep up to date with the progress in aeronautical sciences in an efficient and cost effective way. NLR is also a strong supporter of international co-operation within EREA, the association of European Research Establishments

in Aerospace, and with American organizations such as NASA and FAA. Most of this international work is reflected in a large number of mutual publications for the benefit of all participating partners.

In 2001, NLR and DLR, the *Deutsches Zentrum für Luft- und Raumfahrt*, can look back on 25 years of successful bilateral co-operation in the Foundation *Deutsch Niederländische Windkanäle/ Duits Nederlandse Windtunnels*. DNW is probably the first European enterprise avant la lettre for intereuropean co-operation between industrial test facilities and has developed over the years into a Centre of Excellence for aerodynamic and aeroacoustic testing worldwide. Similarly, the four-nation (France, Germany, the Netherlands, the United Kingdom) supported European Transonic Windtunnel (ETW), after a difficult starting period, has now overcome the initial technical problems associated with cryogenic wind tunnel testing and is emerging as an internationally recognised facility for full Reynolds number testing. Both DNW and ETW will play major roles in future aircraft development programmes such as the Airbus A380 and the successor of the Lockheed Martin F-16.

It is my pleasure to present to you this report.

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 maintain 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 2000

In 2000 NLR's turnover amounted to 168 million guilders. The revenues from contracts totalled 128 million guilders. About 50 per cent of NLR's activities were related to the development and 50 per cent to the operation of aircraft and spacecraft; 85 per cent of the activities were related to aeronautics and 15 per cent to space. Civil and military research amounted to 60 per cent and 40 per cent, respectively. About 40 per cent 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 76 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 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

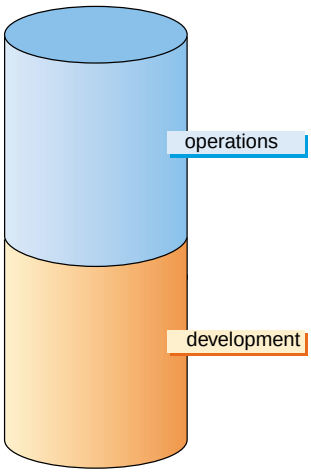
Research carried out under contract to international customers amounted to 51 million guilders. Major customers were the European Space Agency, the European Union and EUROCONTROL. Work was also done for industries in Europe, North America and the Far East.

Research and Equipment

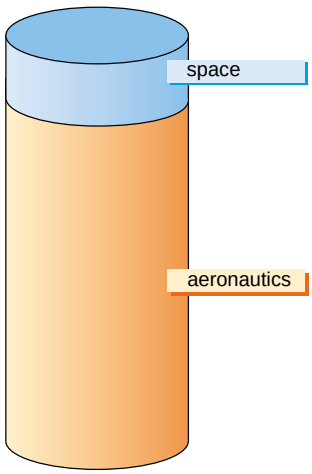
NLR spent 30 million guilders on its basic aerospace research programme supported by the government, aimed at preserving NLR's capability to support its customers in the future. Research aimed at the development and modernization of NLR's research facilities amounted to 13 million guilders. A total of 10 million guilders was used for capital investments, of which investments in a Tower Research Simulator and in the DNW wind tunnels were the most important ones.

National and International Co-operation

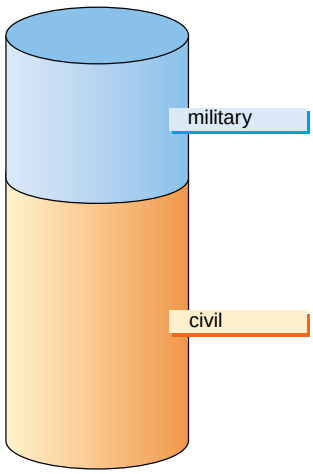
A large part of NLR's basic research is carried out as NLR's own contributions to European research projects both on the civil (European Union, EUROCONTROL) and military (West European Armament Organization, under the European Co-operation for the Long Term in Defence) sides. Another significant part 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, Sweden and Italy take part.



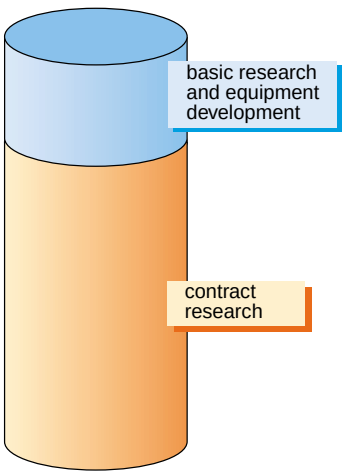
Division of the work into development and operations support



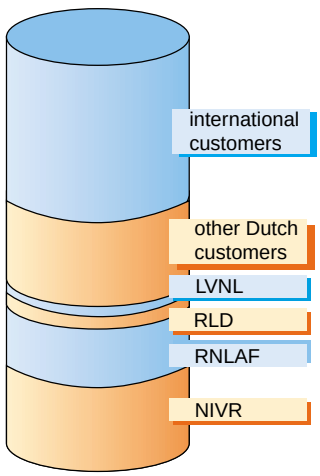
Division of the work into aeronautics and spaceflight support



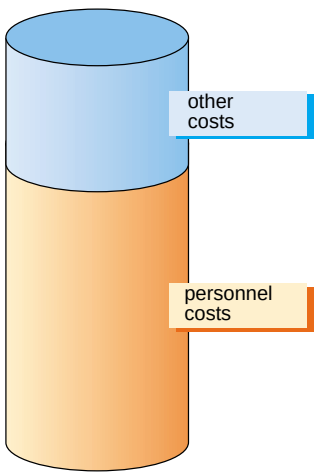
Division of the work into civil and military support



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

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 as of 1 January 2000 has been operating all aeronautical wind tunnels owned by DLR and NLR.

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 (TU Delft) 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 TU Delft Faculty of Aerospace Technology. Another member was a professor at the Cranfield Institute of Technology, UK.

Collaborative activities of the research institutes Aero-Gas Dynamics and Vibration Laboratory (LAGG) of Serpong and NLR, and the universities TU Delft and *Institut Teknologi Bandung* were continued under the aegis of the Dutch-Indonesian Aerospace Programme for Education, Research and Technology (APERT 95).

Like in 1999, 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 the US Federal Aviation Administration (FAA) included research on air-ground integration for Air Traffic Control, Free Flight and external safety studies.

Quality Assurance

NLR maintained the ISO 9001: 1994 / AQAP-110 quality assurance certificates for all its divisions. In addition, NLR maintained its accreditations for for EMC (Electromagnetic Compatibility) testing and for the calibration of forces, pressures and electronic quantities. NLR continued the preparations for obtaining in 2001 one ISO9001: 2000 / AQAP-110 certificate for the entire NLR organization, including the services and support staff.

Outlook for the Coming Years

The outlook for NLR for the coming years is positive. It is expected that there will be an unchanged great demand for technological support by NLR from the aerospace industry, operators and other organizations in the Netherlands and abroad, both military and civil. Challenging projects such as the A400M, the A380 and the replacement of the F-16 fighter aircraft of the RNLAF, projects in which the Netherlands aerospace industry will participate, will be much determining NLR's contract work during the next few years. Increasing the capacity of the air transport system and improving its safety will be important topics within NLR's research programme. The research programme will be largely attuned to European research programmes such as the aeronautics parts of the Fifth Framework Programme of the European Union, which will be executed in the period 2001/2003 and in which NLR will have a prominent position.

Important new facilities such as the Tower Research Simulator and a new, civil cockpit for the Research Flight Simulator will enter operation and will be involved in some of the European co-operative research projects.

The coming years will see a further tuning of NLR's activities to those of its European partner institutes, especially DLR. The integration of the wind tunnels of DLR and NLR within the DNW will be followed by further steps. The ATC/ATM activities of DLR and NLR will be combined as well as the activities of the workshops of both institutes. NLR will more and more become part of a European knowledge infrastructure in aerospace.

BO-105 model in the 3/4-open test section of the DNW Large Low-speed Facility

2.3 Organization and Personnel

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

Several new members were appointed in the Board of the Foundation. The Minister of Transport appointed Ir. J.P.J.M. Remmen, who succeeded Ir. H.N. Wolleswinkel. The Minister of Defence appointed Drs. E.A. van Hoek, who succeeded Cdr.D. van Dord. The Netherlands Agency for Aerospace Programmes (NIVR) appointed Mr. B.A.C. Droste.
Fokker Space B.V. appointed Drs. P.G. Winters.
Amsterdam Airport Schiphol appointed Ms. Ir. M.E. van Lier Lels who succeeded Ir. R. Uijlenhoet. Ms prof.dr. A.J.M. Roobeek resigned.

The laboratory was headed by the directors mentioned on page 3.
Drs. A. de Graaff was Associate Director.
Mr. E. Folkers was General Secretary.

The Board of Directors was further assisted by Ir. J.C.A. van Ditshuizen, Head Marketing and Communication.
Ir. W.F. Wessels, head of the General Services, left the Laboratory.

On 31 December 2000 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
Vacancy
General Services
Drs. L.W. Esselman R.A.
Administrative Services

As of 1 January 2000, the Transonic and Supersonic Wind Tunnels Department was incorporated in the German-Dutch Wind Tunnels organization.
As of 1 January 2000, the Administration Department was split into a Financial Administration Department and a Financial Planning and Control Department. Mr. M.W.H. Puijk was appointed head of the Financial Planning and Control Department. Drs. B.P.E Haeck, head of the Administration Department, left the Laboratory.
Mr. J.H. Halm was appointed head of the Technical Design Department, succeeding Mr. A. van den Berg, who retired.
The organization of the laboratory on 31 December 2000 is shown on page14.

At the end of 2000 NLR employed a staff of 943 (compared with 938 at the end of 1999), of whom 425 (427) were university graduates. Of the total, 802 (818) were employed on a permanent basis, and 141 (119) had temporary appointments. About 60 per cent of the staff were posted in Amsterdam, 40 per cent in the Noordoostpolder. A breakdown of the staff is given on page 15.

Organization Diagram

31 December 2000

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 Facilities 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**
- *Co-ordinator Occupational Health and Safety, and Environmental*	Drs. H. van Bremen	AMC
Company Welfare Work	Ms. J.H. van Dijk-Bol	DW
	Ms. C. Diekema-Schipaanboord	DW

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

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
Ir. J.H. Halm **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
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**

Financial Administration **OA**

Financial Planning and Control
M.W.H. Puijk **OC**

Purchasing
G.S. Wijdeveld **OI**

Breakdown of the staff at the end of 2000

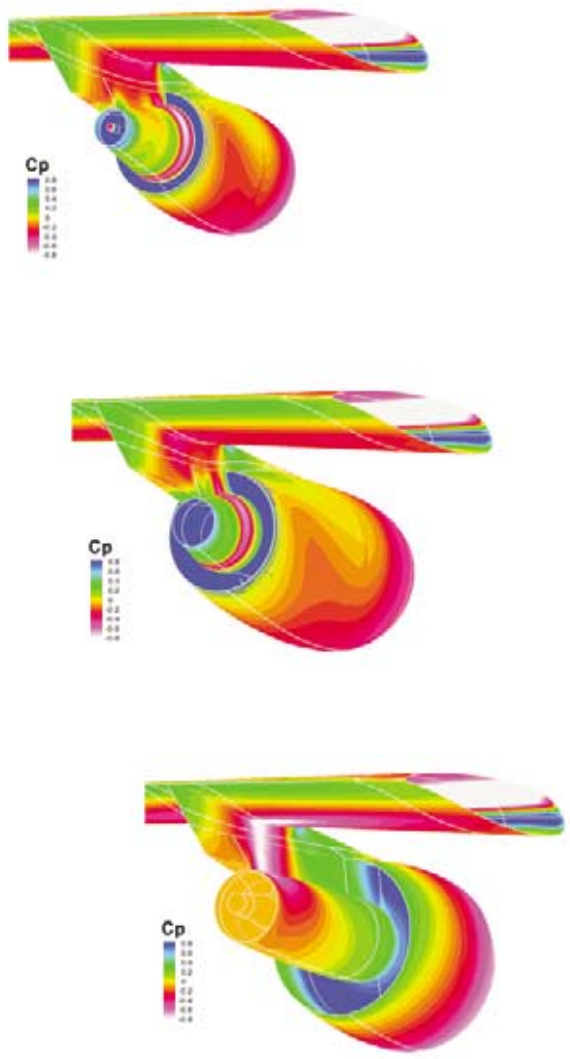
(Cat. I: university graduates, Cat. II: advanced technical college graduates, Cat. III: others; between brackets the numbers at the end of 1999)

		Cat. I		Cat. II		Cat. III		Total	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
- Support Staff		16	(18)	9	(9)	13	(12)	38	(39)
		19	(21)	9	(9)	13	(12)	41	(42)
Fluid Dynamics Division	A	4	(4)	2	(2)	2	(2)	8	(8)
- Transonic and Supersonic Wind Tunnels *)	AF	–	(9)	–	(23)	–	(4)	–	(36)
- Aeroacoustics	AK	8	(8)	4	(4)	1	(1)	13	(13)
- Computational Fluid Dynamics and Aeroelastics	AT	19	(18)	–	(–)	–	(–)	19	(18)
- Aerodynamic Engineering and Vibration Research	AE	8	(8)	3	(3)	–	(–)	11	(11)
- German-Dutch Wind Tunnels *)	WA/WN	13	(4)	44	(20)	22	(19)	79	(43)
		52	(51)	53	(52)	25	(26)	130	(129)
Flight Division	V	3	(3)	1	(1)	1	(1)	5	(5)
- Flight Simulation	VS	10	(10)	15	(15)	1	(2)	26	(27)
- Operations Research	VO	23	(23)	5	(5)	2	(2)	30	(30)
- Man Machine Integration	VE	21	(20)	1	(1)	1	(1)	23	(22)
- Helicopters	VH	15	(15)	1	(1)	1	(–)	17	(16)
- Flight Mechanics	VM	12	(13)	–	(–)	1	(1)	13	(14)
		84	(84)	23	(23)	7	(7)	114	(114)
Air Transport Division	L	2	(2)	–	(–)	1	(1)	3	(3)
- Flight Testing and Safety	LV	15	(15)	7	(6)	1	(2)	23	(23)
- Airports	LA	11	(12)	2	(2)	–	(–)	13	(14)
- Air Traffic Management	LL	27	(25)	4	(5)	1	(1)	32	(31)
- Transport and Environmental Studies	LT	8	(10)	7	(7)	1	(1)	16	(18)
		63	(64)	20	(20)	4	(5)	87	(89)
Structures and Materials Division	S	1	(1)	3	(3)	1	(1)	5	(5)
- Loads and Fatigue	SB	20	(18)	5	(6)	1	(1)	26	(25)
- Structures Technology	SC	14	(13)	5	(5)	–	(1)	19	(19)
- Laboratory Facilities	SL	1	(1)	28	(24)	17	(17)	46	(42)
		36	(33)	41	(38)	19	(20)	96	(91)
Space Division	R	1	(1)	2	(–)	–	(2)	3	(3)
- Remote Sensing	RR	8	(8)	4	(4)	–	(–)	12	(12)
- Systems	RS	17	(17)	–	(–)	–	(–)	17	(17)
- Labatories and Thermal Control	RL	10	(10)	5	(5)	–	(–)	15	(15)
		36	(36)	11	(9)	–	(2)	47	(47)
Information and Communication Technology Division	I	1	(1)	1	(1)	5	(3)	7	(5)
- Mathematical Models and Methods	IW	19	(17)	–	(–)	–	(–)	19	(17)
- Software Applications	IA	20	(19)	6	(6)	1	(1)	27	(26)
- Data and Knowledge Systems	ID	25	(24)	11	(11)	–	(–)	36	(35)
- Information and Communication Services	IC	15	(15)	17	(14)	7	(9)	39	(38)
- Embedded Systems	IS	10	(12)	7	(7)	–	(–)	17	(19)
		90	(88)	42	(39)	13	(13)	145	(140)
Avionics Division	E	2	(2)	–	(–)	1	(2)	3	(4)
- Avionics Systems	EA	18	(21)	8	(7)	–	(–)	26	(28)
- Electronics	EE	6	(6)	22	(21)	3	(5)	31	(32)
- Instrumentation	EI	8	(8)	21	(19)	5	(5)	34	(32)
		34	(37)	51	(47)	9	(12)	94	(96)
Engineering and Technical Services	T	4	(4)	–	(–)	1	(1)	5	(5)
- Technical Projects	TP	2	(2)	5	(4)	–	(–)	7	(6)
- Technical Design	TO	1	(1)	7	(7)	1	(1)	9	(9)
- Production Workshop	TW	–	(–)	7	(7)	10	(11)	17	(18)
- Production Control	TV	–	(–)	7	(6)	–	(–)	7	(6)
- Service Workshop	TS	–	(–)	4	(3)	4	(5)	8	(8)
		7	(7)	30	(27)	16	(18)	53	(52)
General Services	G	–	(1)	1	(1)	–	(–)	1	(2)
- Electrical Engineering	GE	–	(–)	5	(5)	5	(6)	10	(11)
- General Facilities	GF	–	(–)	4	(4)	39	(41)	43	(45)
- Library and Information Services	GB	1	(1)	3	(3)	4	(5)	8	(9)
- Document Processing	GT	–	(–)	5	(5)	27	(27)	32	(32)
		1	(2)	18	(18)	75	(79)	94	(99)
Administrative Services	O								
- Financial Administration	OA	–	(2)	20	(19)	12	(11)	32	(32)
- Financial Planning and Control	OC	1	(–)	1	(–)	–	(–)	2	(–)
- Purchasing	OI	2	(2)	5	(5)	1	(–)	8	(7)
		3	(4)	26	(24)	13	(11)	42	(39)
Grand total		425	(427)	324	(306)	194	(205)	943	(938)

**) The Transonic and Supersonic Wind Tunnels Department was incorporated in the German-Dutch Wind Tunnels organization as of 1 January 2000*

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. 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.



Engine installation effect studies using Navier-Stokes computations

3.1 Fluid Dynamics

Summary

For the Fluid Dynamics Division the year 2000 was one of significant change in the sense that, as a consequence of the transfer to DNW, per 1 January 2000, of the full operational responsibility for the HST and SST wind tunnels, the major part of the volume of contracted experimental aerodynamic R&D work was also transferred to DNW. The remaining volume of contracted aerodynamic research was, however, almost the same as that in 1999. Of this volume, 45% concerned civil aircraft, 35% was defence related, 5% was related to space vehicles, 10% was of a non-aerospace nature and 5% was contracted by DNW for test and research support.

NLR participated in as many as twenty aerodynamics, aeroelastics and aeroacoustics projects of the Fourth and Fifth Framework Programmes 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 ten Action Groups and three 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.

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.

Research was also continued in such areas as high-lift system configuration aerodynamics and aeroacoustics, computational aeroelastics, im-

provement and extension of CFD codes including time accuracy and weapons-bay acoustics. This research, as well as the continued stationing of a senior aerodynamicist with the Large Aircraft Division of Airbus in Toulouse (to support Fokker Aerostructures' envisaged participation in theA380 aircraft project), was all partly funded by the NIVR.

Research for the Ministry of Defence and/or the Royal Netherlands Air Force involved the computational aerodynamic and aero-elastic modelling of combat aircraft, radar cross-section prediction methods and the aerodynamic and acoustic characteristics of engine test-run facilities.

Highlights in CFD comprised the first computations of complex viscous flows using Reynolds-Averaged Navier-Stokes (RANS) modelling and unstructured grids, the integration, for the first time, of RANS and elasto-mechnical modelling, and the first simulation, with accurate wake capturing, of the flow around a helicopter rotor in forward flight using the Euler equations.

A highlight in experimental aeroacoustics was the successful demonstration, at Schiphol airport, of the capability of the acoustic array technique to accurately measure the fly-over noise characteristics (noise source and level identification) of aircraft.

Support to the DNW organization for further development of measurement techniques in wind tunnel testing was continued. Subjects addressed included techniques for the suppression of model support vibrations in the DNW-HST, methods for the calibration of strain gauges, correction methods for wind tunnel wall interference, techniques for acoustic measurements in open and 'hard-walled' test sections, pressure sensitive paint, and the calibration of turbine powered simulators (model engines).

Contracted research in the non-aerospace area included road traffic tunnel ventilation aerodynamics (for the Ministry of Transport), the aerodynamics of high-speed trains entering tunnels, the aeroacoustic properties of trucks, and the aeroelastic behaviour of a road traffic bridge.

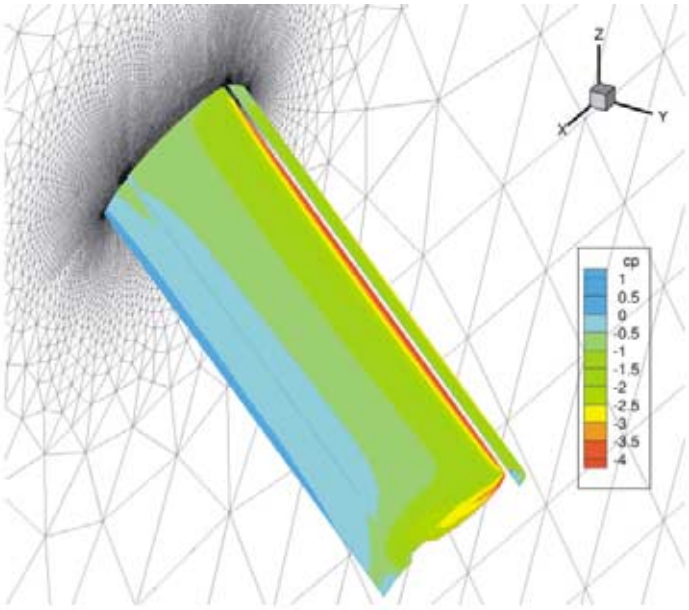
Applied Aerodynamics

Aerodynamics of Civil Transport Aircraft

In the framework of the NIVR Basic Research Programme, the effects of thickening of 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. The results of wind tunnel tests in the DNW-HST on a 2D model of a modern transport wing section with flap and slat, as well as tests in the DNW-LST on a 3D semi-span model, performed in 1999, were analysed and partially reported.

An experimental exploration in the DNW-LST of the effects of flap tip devices on the low-speed aerodynamics and airframe noise characteristics of a transport aircraft wing-body configuration was completed. The results indicate a potential for a significant reduction of flap tip generated airframe noise and some improvement of lift/drag ratio for the take-off/climb configuration.A change in the near-field trailing vortex signature was also found. The consequences of the latter for the far-field trailing vortex signature are, as yet, unknown.

The EUROLIFT project was kicked off in January. The main objectives are: (i) to improve current understanding of dominant flow phenomena associated with flaps and slats, in combination with their dependency on the Reynolds number, (ii) to improve the capability to account for scale effects on aerodynamic characteristics such as maximum lift and drag in take-off and climb in the early stages of the design process, (iii) to improve the extrapolation of aerodynamic data from wind tunnel to free flight conditions (reducing the risk of undesirable scale effects). NLR contributed to the EUROLIFT code validation and improvement effort by conducting a number of the computations on high-lift geometries using the FASTFLO CFD system, and by setting up a database of existing measurement data for 2D multi-element aerofoils (to be used for CFD code validation and improvement). Further, NLR actively contributed to the definition of the wind tunnel test programme for measurements on 3D high-lift models, representative of A380 aircraft, in the LSWT of Deutsche



Calculation of the flow around a constant-chord swept wing in high-lift configuration

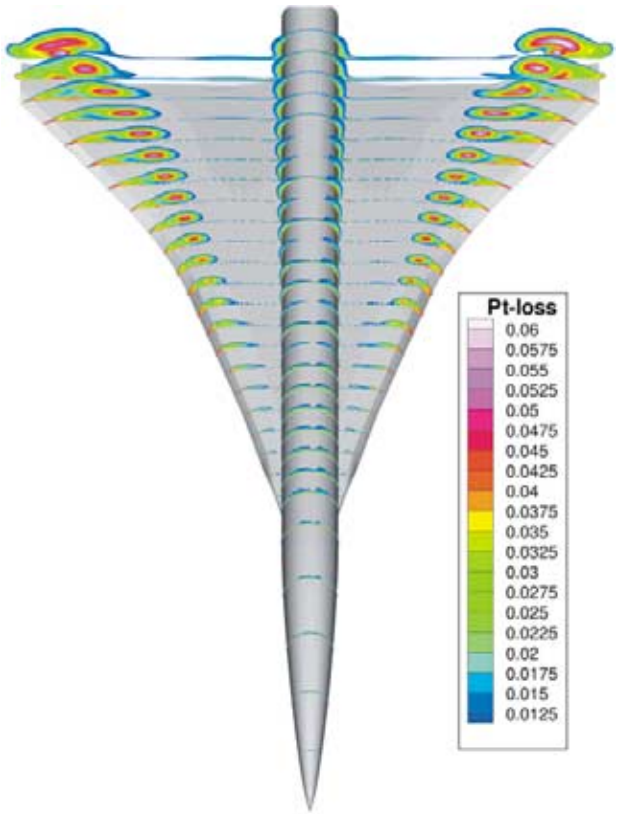
Airbus (low Reynolds number, detailed flow field measurements) and the ETW (the same model, high Reynolds number).

NLR also participated in GARTEUR Action Group (AD) AG-36 '3D High Lift'. A constant chord swept wing (slat-wing-flap, sweep angle 40 degrees) has been used as a generic test case. The objective of this activity is to demonstrate and validate capabilities of the FASTFLO CFD system using a generic slat-wing-flap configuration. Hybrid unstructured grids with various grid dimensions are generated, as well as Navier-Stokes solutions.

In the European Project for the Improvement of Supersonic Transport Low-speed Efficiency, EPISTLE, additional experimental data have been obtained during a one-week test campaign in the DNW-HST wind tunnel. Computations have been performed on improved, much finer grids employing the two-equation (k-omega) turbulence model. The computations show a satisfactory prediction of flow development. Some differences with experimental data for flows containing large separations have still been observed. However, in terms of industrial accuracy requirements for such configurations the NLR ENFLOW Navier-Stokes method appears to be a sufficiently reliable tool.

NLR has also finalized its contribution to GARTEUR Action Group (AD)AG-30 'CFD for Supersonic Transport High-Lift Evaluation and Configuration Development'. Exploratory Navier-Stokes analysis of the aerodynamic characteristics at low speed for a state-of-the-art European supersonic civil transport (ESCT) configuration with deflected leading edges has been performed. The computational results have been compared with available DNW-HST wind tunnel data. The comparison of CFD data with experiment is shown to be good.

Participation in GARTEUR Action Group (AD)AG-26 'Navier-Stokes Computations of Transonic Flows About Wing-Bodies with High Aspect Ratio Wings' was continued. A start has been made with the final report containing comparisons of the pressure distributions for the AS28G configuration as computed by the participants with experimental data. A number of wing stations has been selected for comparisons of



Navier-Stokes computations of the vortical flow around a Supersonic Transport generic Aircraft in low-speed configuration: solution on grid with 1.5 million and 5.2 million cells on the left-hand and right-hand part, respectively

detailed boundary layer characteristics. The locations have been selected such that in the future comparison of boundary layer data with the experiments to be carried out within GARTEUR (AD) AG-28 will be possible.

The objective of the EU Targeted Research Action in Aerospace Aerodynamics, TRA3, is to develop a strategy to maximize the industrial return of European RTD investment in aerospace aerodynamics through enhanced co-ordination and strategic alignment with industrial requirements. In 2000 activities under this Targeted Research Action have resulted in recommendations for future aerodynamics research, using European wind tunnels and CFD technology to solve aerodynamic problems.

NLR participates in the EU project MOB (a study incorporating multi-disciplinary design and optimization for a blended wing body configuration). Preliminary studies for a very large aircraft have indicated that the concept of a 'flying wing' has the potential for a significant improvement in terms of aerodynamic as well as aircraft structural mass efficiency. This potential improvement is obtained by reduced wetted area in combination with the spanwise distribution of payload providing wing bending moment mitigation. Due to the strong interdependencies of all disciplines for this particular configuration, the optimization of a blended wing body configuration calls for a multi-disciplinary approach. The MOB project features the idea of a 'Computational Design Engine' implemented across a number of sites in Europe.

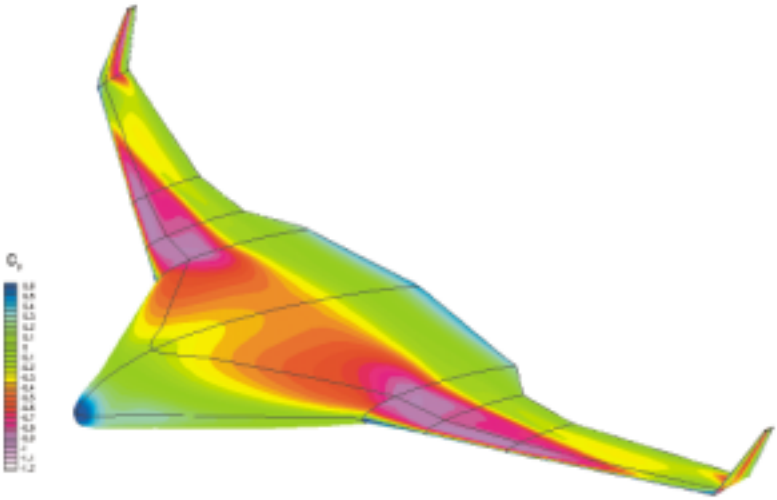
NLR contributes to the project by providing ways and means for network communication and control. Furthermore, NLR provides inputs for aerodynamic performance assessment (computed with NLR's ENFLOW CFD system), structural optimization and weight estimation results (computed with NLR's B2000 system), and inputs for handling qualities assessment.

In collaboration with Stanford University NLR performed design studies for the wing of a medium-range transport aircraft. The design was to meet stringent fuel-tank volume requirements, while improving the buffet-onset performance and enhancing the aerodynamic cruise efficiency of a base configuration.

Within a framework of collaboration between EREA and Airbus on the subject of new aircraft configurations, a pilot study, with a contribution of ADSE (Aircraft Development & System Engineering B.V.), was performed of a twin fuselage civil transport aircraft configuration.

Propulsion-Airframe Interaction

The EU project AIRDATA (Aircraft Drag And Thrust Analysis) had its final meeting. One of the main conclusions was that engine installation drag prediction with the required accuracy and based on accurate block-structured CFD systems has been enabled through the AIRDATA project. A number of flow modelling aspects have been investigated (engine boundary conditions, turbulence models, numerical schemes) and their impact on engine installation drag predictions was evaluated. The



Navier-Stokes computation of the flow around a blended wing body configuration

quality and density of the underlying numerical grids needed for accurate drag predictions is a second topic of research. Thrust/drag bookkeeping in CFD was dealt with. Furthermore, algorithms have been developed to decompose aerodynamic drag in its physical components of vortex drag, wave drag, and viscous drag. Numerical results for wing/body/pylon/nacelle configurations representing different engine concepts have been produced using NLR's ENFLOW CFD system. The results have been compared with experimental data obtained in the EU project ENIFAIR.

In the framework of the DLR-NLR collaboration on propulsion-airframe interaction, theoretical and experimental studies are being performed for a low-speed transport aircraft configuration model with a CRUF (Counter Rotating Ultra-high by-pass Fan) type engine simulator. Results from wind tunnel tests performed earlier were analysed and partially reported.
Theoretical work in this framework focuses on enhanced modelling of the fan duct flow for the ALVAST model with CRUF engine simulators. For this purpose the airframe flow model (RANS equations in a fixed frame of reference; ENFLOW) is coupled with a model of the counter-rotating fans (RANS equations in a rotating frame of reference; FINETURBO). The results of this coupled solution will be compared with experimental (PIV) results obtained in the DNW-LST.

NLR's contribution to the EU project ENIFAIR (ENgine Integration for Future AIRcraft) was completed. 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.

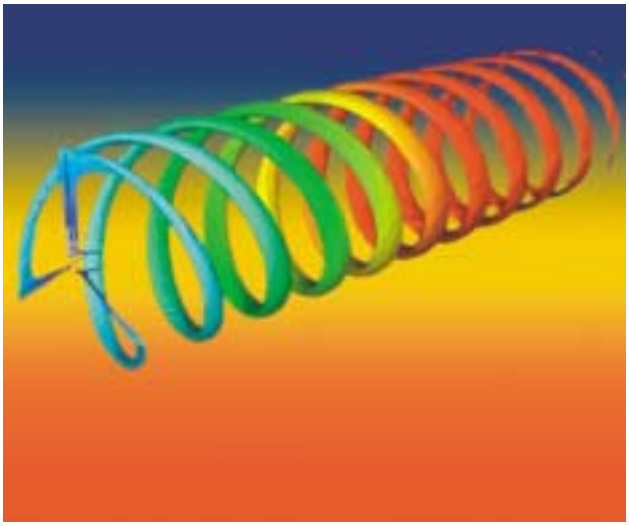
Aerodynamics of Air Combat Vehicles

The collaborative TA-15 programme 'Computational Methods in Aerodynamics' of the Western European Armaments Organization (WEAO) has been concluded. Main activities have been the completion of a study on Navier-Stokes simulations for fighter aircraft afterbody flows and a study on Reynolds number effects for vortex flows about generic delta wing configurations by means of Navier-Stokes computations. Results of the latter were compared with experimental data covering a wide range of Reynolds numbers. A 'common exercise' on time-accurate inviscid flow computations has been concluded.

In addition 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. Detailed analysis of the subsonic and transonic flow phenomena around a sharp-edged cropped delta wing has been completed. Results provide, on the one hand, an experimental database for the validation of CFD methods for vortex dominated flows that are typical for fighter aircraft and, on the other hand, improve insight in the occurrence of physical phenomena such as vortex burst as a function of angle-of-attack and/or side slip angle.
The TA-15 programme came to a successful end, and a new collaborative activity, in a THALES framework called 'Joint Programme 12.15', has been initiated.

NLR's participation in the GARTEUR Action Group (AD) AG-24, with the objective to assess the performance of CFD methods for missile type configuration in supersonic flow, has been completed. Satisfactory results have been obtained for ogive-cylinder configurations with laminar and turbulent flow as well as for a complex missile configuration in turbulent flow.

Studies, in the framework of the GARTEUR Action Group (AD) AG-34 'Aerodynamics of Supersonic Air Intakes', of the aerodynamic characteristics of a 'bump diverter' type of air intake, as applied to combat aircraft with low radar signature, were continued. A similar air-intake concept is part of the integrated air-intake subsystem of the JSF design by Lockheed-Martin. Traditional designs for air-intakes of the next generation of (supersonic) fighter aircraft become less attractive due to more stringent radar-signature requirements.



Typical three-bladed tilt rotor in cruise flight computed with HEXADAP: rotary stagnation pressure loss

Helicopter Aerodynamics

NLR's participation in the Design and Development Phase of the NH90 helicopter included support with the preparation of a wind tunnel model and measuring unsteady flow phenomena in the DNW-LST.

The objective of the EU project ROSAA (ROtorcraft Simulation with Advanced Aerodynamics) is the development of an integrated simulation system in which (improved) codes from different disciplines can be integrated in order to improve overall numerical prediction capability. This simulation system consists of codes representing the following disciplines: grid generation, aerodynamics, aeroacoustics, structural dynamics and flow visualization. The user can select a comprehensive rotor code, an aerodynamic code and an aeroacoustic code in a simulation process where the comprehensive rotor code and the aerodynamic and aeroacoustic codes are coupled. In this project NLR was responsible for the development of a full potential code, HELIFPX, which contains viscous-inviscid interaction techniques, a boundary element methodology for wake prediction and convergence acceleration techniques. The final version of HELIFPX has been validated against a set of experimental data.

At the level of the Euler equations NLR has simulated the flow field around an isolated rotor in forward flight using the time-accurate CFD solver HEXADAP. The CFD results indicate that accurate trimming of the whole rotor, by prescribing the correct pitch and flap motion of the blades, is of utmost importance, overriding the importance of the modelling of viscous effects. This CFD application, which is partly funded by the Boeing (Mesa) Company, aims at providing aerodynamic response predictions to enable accurate Blade/Vortex Interaction (BVI) noise predictions. In this project the advantages of the boundary conforming Arbitrary Lagrangian/Eulerian (ALE) approach for simulations of rotors in forward flight have been demonstrated for the first time, making this method a good candidate for coupling with structural dynamics calculation methods. Essential for good BVI noise predictions is the accurate capturing of persistent tip vortices. Accurate tip vortex capturing has been obtained by local grid refinement within the vortex core. The resulting blade surface pressures, which are used as input for aeroacoustic prediction methods, are in agreement with experimental results.

The ALE method has also been demonstrated in the simulation of the flow field around an isolated tilt-rotor with highly twisted blades. The CFD results of the tilt-rotor under hover flow conditions are characterized by a counter-rotating vortex pair, as found on a tilt-rotor aeroacoustics model (TRAM) tested in the DNW-LLF facility.

Operations- and Safety-related Aerodynamics Research

For the EU project S-WAKE (assessment of wake vortex safety), NLR acts as co-ordinator, and has performed a parameter study on the consequences for following aircraft of the strength of wake vortices.

Within the framework of the EU project C-WAKE (wake vortex characterization and control), wake vortex measurements have been executed in the DNW-LST. Detailed cross-flow velocity profiles have been derived both from PIV measurements and from 5-hole rake wake measurements.

The GARTEUR Action Group (AD) AG-32 'Aircraft Icing Effects' has the objective to update and validate prediction methods for the aerody-

namic effects of ice accretion. NLR completed its contribution by documenting available experimental data.

Under contract to the Royal Netherlands Air Force, studies of facilities for engine testing of aircraft with propeller propulsion were continued. The attention was mainly focused on unsteady aerodynamic effects inside the facility and environmental (noise) effects. A pilot configuration of such a facility was tested in the DNW-LST.

Hypersonic and Space Vehicle Aerothermodynamics

An inventory of hypersonic CFD codes has been made, together with an inventory of functional requirements relevant for hypersonic applications, in support of Fokker Space, for the rudders of the X-38 space plane.

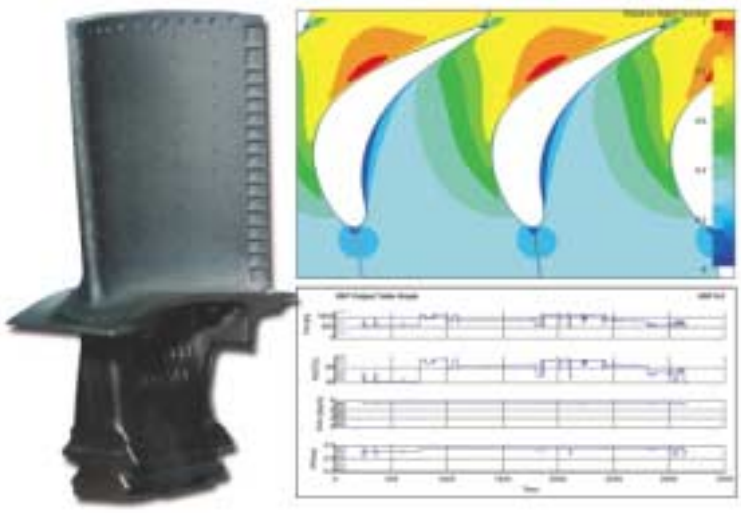
NLR also has participated in the Future European Space Technologies Investigation Programme (FESTIP 2). The objective of the project was to advance the aerothermodynamics technology needed to develop a future reusable/partially reusable launch vehicle. It was concluded that more enhanced flow models (such as Large Eddy Simulation) are needed for accurate modelling of aerothermodynamic unsteadiness in base flows.

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

NLR has developed capabilities to assess and analyse the fatigue life consumption of gas turbine components under service loading by integrating five disciplines: engine system performance, fluid dynamics analysis, thermal analysis, stress analysis and fatigue life assessment. The objective of this research project, which is funded by NIVR, is to compute the service life of coated turbine blades by numerical analysis in various disciplines.
For aerothermodynamic analysis a CFD code (FINE/Turbo), based on Reynolds-averaged Navier-Stokes equations, has been applied to predict the surface heat transfer of turbine blades with film cooling. The code is applied to the high-pressure turbine rotor and stator stages of a turbofan engine for military aircraft. Because surface heat transfer is strongly dependent on blade film cooling, emphasis has been put on the modelling of film cooling for turbine blades. The heat transfer has been assessed for a range of engine operating conditions. The CFD results have subsequently been used for thermal analysis to determine the impact of the temperature induced



Fatigue life of engine parts (left) studied using CFD (Computational Fluid Dynamics, top right) and GSP (Gas Turbine Simulation Program, bottom right)

mechanical stresses on the fatigue life.
As a tool for the rapid assessment of heat loads an engineering method has been formulated and applied for the prediction of the aerodynamic heat load at the first stage turbine blades of a military turbofan engine including the effects of cooling air.

A second application of CFD for turbo-machinery has been initiated. This application involves CFD modelling of the blades of a counter-rotating ultra-high-bypass ratio fan of an engine simulator for wind tunnel testing. This modelling effort aims at deriving complete fan outflow boundary conditions that are needed for analysis of, for example, jet effects on high-lift devices.

Non-Aerospace Aerodynamics

NLR continued its contribution to the aerodynamic design of a Wing-In-Ground effect vehicle in the framework of the EU project SEABUS-HYDAER. The concept vehicle features a large aerodynamic wing in proximity of the water surface, in combination with small hydrodynamic control surfaces. Instead of the earlier queried water jet propulsion system, the project team has decided to apply propellers for efficiency reasons. NLR takes part in a design review board of the SEABUS project that has been established to remedy system integration shortcomings of the vehicle. In the framework of a planned experiment in the DNW-LST on the SEABUS configuration, the specification and design of the wind tunnel model has been made, and the test campaign has been defined.

Under contract to the Ministry of Transport and Public Works, several studies were performed on the aerodynamics aspects of the ventilation of road traffic tunnels. Continued studies of the airflow characteristics in road traffic tunnels were performed in the test facility owned by the Ministry of Transport and Public Works.

Wind tunnel tests on bridge deck and pylon of a road traffic bridge ('Papendorpse brug') have been performed to establish wind induced vibration characteristics.

Computational Fluid Dynamics and Basic Aerodynamic Research

CFD Solvers and Systems based on RANS Equations

In the framework of the NIVR Basic Research Programme, the ENFLOW CFD system, based on multi-block structured grids, has been upgraded. In order to satisfy higher demands on the numerical accuracy, for example for accurate drag predictions, the numerical algorithm underpinning the ENSOLV flow solver was upgraded to improve the interfacing between the blocks of the grid. The generation of multi-block structured grids was further facilitated by an algorithm for the semi-automatic decomposition of the flow domain into blocks, based on potential theory. This ENDOMO/ENGRID method has contributed to improving grid quality for the same turn-around time of the complete flow simulation.

Hybrid grid based CFD technology, combining prismatic grid generation near aerodynamic surfaces with automatic tetrahedral volume grid generation, has become an important tool for aerodynamic analysis because it allows a higher level of automation than the more conventional multi-block type CFD. In the EU project FASTFLO II (Fully Automatic System for Three-dimensional Flow Simulations), which has been co-ordinated by NLR, a viscous flow capability has been introduced. Main focus of the FASTFLO II project has been to achieve a short CFD problem-turnaround time for viscous flow analysis of complex aircraft configurations and to realize sufficient accuracy of the computed aerodynamic entities such as pressure distributions, and lift, drag and moment coefficients. A short CFD problem turnaround time for complex aircraft configurations has been realized through the judicious introduction of hybrid grid generation techniques that allow a higher level of automation than the more commonly used, multi-block grid generation techniques. Through the introduction of turbulence modelling in the CFD system a spectrum of fluid flow problems for complete aircraft configurations can be analysed, such as for example: (i) Turbulent flow analysis for high-lift configurations at wind tunnel and flight conditions (at a high Reynolds number) with engines installed and flaps and slats deployed, (ii) Turbulent flow analysis at highly

loaded flow conditions (e.g. high angle of attack) for complex fighter aircraft configurations involving pylons, pods, stores and fuel tanks, (iii) Turbulent flow analysis for engine/airframe integration studies to minimize engine/airframe interference for new Ultra-High Bypass Ratio engines.

NLR and DLR continued their collaboration in the 'CFD for complete aircraft' project incorporating a unified grid approach consisting of tetrahedral, hexahedral, prismatic and pyramidal elements. Grid partitioning is used for parallel computing where the MPI library is used to accommodate distributed memory architectures. The flow solver has shown a scalability of about 90% per processor on the NEC-SX5 shared-memory supercomputer.

NLR participates in the EU Fifth Framework projectAEROSHAPE (multi-point aerodynamic optimization methodology). The objective of this project is centred on the advancement of aerodynamic optimization techniques that will eventually support real-life industrial multi-disciplinary design. NLR contributes to the project with the development of an efficient optimization method applying variational methods, in which adjoint equations derived from the RANS (Reynolds-Averaged Navier-Stokes) equations are formulated and solved for the computation of design sensitivities. Using NLR's ENFLOW CFD system, the optimization method will be demonstrated by means of multi-point optimization of an aerofoil at transonic speeds.

Turbulence Modelling

Turbulence models of the ENFLOW CFD system were improved and extended. The ENFLOW system is capable of computing steady and time-accurate turbulent flows around aerodynamic configurations based on the Reynolds-Averaged Navier-Stokes equations. Currently, it employs two-equation turbulence models. Work has been done on increasing the level of turbulence modelling to explicit algebraic Reynolds-stress models, aiming at an improved physical accuracy for, among other things, boundary layers with strong adverse pressure gradients and flows near the buffet boundary of aircraft.
At the same time, work has been done on Reynolds-stress transport models, which also have more potential than two-equation (k-omega) turbulence models with respect to describing the turbulence in vortex-dominated flows. The latter play an important role in the aerodynamics of combat aircraft. An extensive literature study on suitable Reynolds-stress transport models has been performed to facilitate near-future decision-making regarding the next generation of turbulence models for vortical flows. This study has been performed partly in the framework of WEAO Thales JP12.15 and partly in the framework of the EREA Joint Activity on 'Transition and Turbulence Modelling'.

In the framework of the EU project AVTAC (Advanced Viscous flow simulation Tools for complete civil AirCraft design), a (re)validation of the flow simulation tools of the respective partners has been performed using the new turbulence modelling functionality implemented within the project. In this context, the ENFLOW system, using the k-omega turbulence model with the new, so-called turbulent-non-turbulent (TNT) coefficients, has been used to simulate the flow around a wing/body configuration (AS28G), including pylon and flow-through nacelle. The TNT coefficients resolve the free-stream dependency inconsistency of the k-omega model.

NLR participates in the GARTEUR Action Group (AD) AG-29 on the validation of turbulence models for the three-dimensional turbulent flow around the so-called GARTEUR wing of the former Action Group (AD) AG-07. Detailed experimental data, including mean velocity profiles and Reynolds-stress components inside the shear layers, are available for this wing. As a first step, computations have been performed with the ENFLOW system, using the TNT k-omega model, on an initial grid delivered by ONERA. The aim is to carefully assess the correct boundary conditions, the tunnel-wall effects, and the grid quality, before performing detailed CFD simulations and comparisons with experimental data from the DNW-LST and ONERA-F2 wind tunnels.

NLR also participated in GARTEUR Action Group (AD) AG 35 'Application of transition criteria in Navier Stokes computations'. The AS 'B'-aerofoil has been used as a test case, with both fixed and predicted transition locations. Compari-

son of the results from the different partners showed that boundary layer quantities obtained from RANS solutions, which form the basis for transition criteria based on the application of linear instability theory, tend to be inaccurate. The (tentative) conclusion is that a completely coupled approach integrating stability modelling into the RANS flow solver seems to be called for.

Euler Methods

The time-accurate Euler solver HEXADAP has been extended to the flow about helicopter rotors in forward flight. A major achievement was the simulation of a two-bladed, so-called Operational Loads Survey helicopter rotor. Local grid refinement was combined with a space-time Arbitrary Lagrangian-Eulerian (ALE) formulation. The space-time formulation allows the simulation of flows about independently moving bodies using a single deforming mesh. Local grid refinement ensures accurate vortex capturing. Numerical experiments have shown the importance of satisfying the Courant-Friedrichs-Levy (CFL) condition for the physical CFL number. Too large time steps result in numerical dispersion of the vortex structures. The efficiency of the space-time algorithm has been significantly improved by a more efficient quadrature rule for the fluxes through cell faces. Combination of this and other improvements yielded a significant increase in computational performance, demonstrating the maturation of the present method for time-accurate flow simulations on deforming meshes.

The collaboration with the University of Twente on the analysis of discontinuous Galerkin methods continued. Fourier analysis of the discretized operator has resulted in an improved Runge-Kutta iterative scheme. The space-time discretization has been validated for its shock-capturing capabilities through application to a model problem ('Sod's shock tube'). A proposal for the development of a Large-Eddy Simulation method for vortex flows based on the space-time discontinuous Galerkin method was submitted to STW.

NLR is participating in GARTEUR Exploratory Group (AD) EG-31 'Time Accurate Methods'. This group has the objective to increase the understanding of advantages and disadvantages of different time accurate simulation methods based on the Euler equations. NLR has participated in the establishment of an Action Group that is to perform by code-to-code comparisons for a series of test cases with different frequency spectra.

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. NLR started manufacturing the cryogenic rear fuselage model for the tests in the ETW and the DNW-HST wind tunnels.

Scale Effects

NLR participates in the EU project HiReTT (High Reynolds number Tools and Techniques for civil transport aircraft design). The project is targeted towards providing industry with the tools and techniques to predict aerodynamic performance and control surface efficiency for very large transonic transport aircraft operating at high Reynolds numbers. The project centres on measurements in the ETW wind tunnel with an existing cryogenic wind tunnel model representative for the A380 aircraft. The model is tested under various conditions such that a large envelope of Reynolds numbers, boundary layer transition conditions, and elastic wing shape deformations are covered. Wind tunnel wall and sting interference effects are quantified and corrected for.

NLR contributes to the HiReTT project by designing and manufacturing a twin-sting balance that will be used to measure the sting interference effects and through the analysis of the wind tunnel measurements. NLR also explores the feasibility of quantifying the effects of elastic deformation of the wind tunnel model theoretically, using CFD codes with an aeroelastic coupling. The codes applied range from a full-potential method coupled to a boundary layer code (NLR's MATRICS-V system) to a block-structured Navier-Stokes solver (NLR's ENFLOW system).

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 research relies heavily on the infrastructure for CFD at NLR. The hybrid prediction technique that combines high-frequency approximations, as in physical optics, with the exact Electric Field Integral Equation (EFIE) method was applied to a rectangular wave guide. The EFIE method has been applied to a cylindrical wave guide for validation. Effects of the quality of computational surface grids on predicted RCS values have been investigated for this wave guide. Results of computations are being compared with measured data produced by TNO-FEL. These comparisons have led to renewed appreciation of the subtleties of electromagnetic scattering at high frequencies. The work was mainly funded by the Ministry of Defence.

Computational surface grid on a fighter configuration for Radar Cross Section prediction

Aeroelasticity and Vibration Research

Air Vehicle Operations Aeroelastic Support

The RNLAF has been supported with the analysis of (static) aerodynamic characteristics relevant to aeroelastic aspects, and with the analysis of limit loads for the assessment of F-16 fatigue life consumption. This support is enabled by a database that comprises F-16 aircraft CAD-models and CAD models for many different types of underwing stores that are operated by the RNLAF. The database is used for example in the context of an F-16 outer wing fatigue life consumption study. Computational work has been performed related to the static deformation of the aircraft at limit load conditions. The deformation has been obtained on the basis of CFD solutions and an elastomechanical model of the F-16. The procedure consists of iterative computations of the flow solution and the structural deformation under aerodynamic load until a final converged deformation state has been encountered. The deformations obtained in this way are delivered as input for a detailed analysis of structural stresses in relation to the fatigue life of F-16 structural parts, using a more detailed finite-element model of the outer wing.

Another activity in support of the RNLAF concerned the unsteady aerodynamic analysis of fighter aircraft (F-16) configurations for the purpose of investigating the dynamic aeroelastic effects of the presence of underwing stores and of wing tip missiles, and the effect of flap settings. This investigation is directed toward the understanding and modelling of the nonlinear, dynamic aeroelastic phenomenon at the flutter boundary known as limit cycle oscillations (LCO). The results of unsteady wind-tunnel measurements on F-16 models under forced oscillation were analysed to identify non-linear features of transonic flow and to provide a selected set of test cases to be used for CFD/CAS validation purposes.

In support of Fokker Services, wind tunnel tests in the DNW-LST, on site, full scale vibration tests and flight tests have been performed for one aircraft type.

Computational Aeroelastics

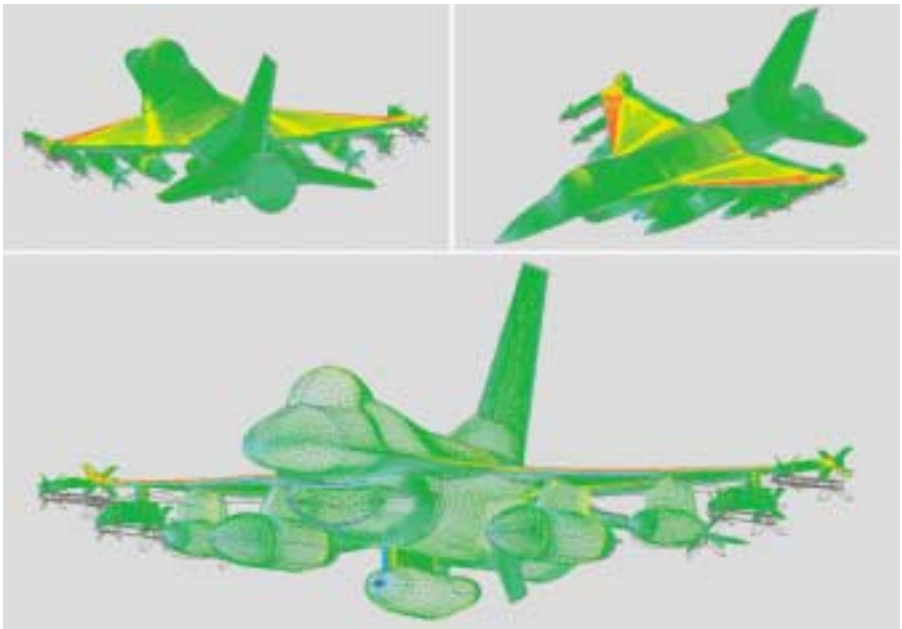
In the framework of the NIVR Basic Research Programme, a study has been continued to validate the applicability of modern viscous CFD methods for the reliable computation of static aerodynamic loads on flexible aircraft structures, such as T-tails. This study is motivated by the interest of the Stork Aerospace Group in current and future participation in the development and manufacture of aircraft components. For this purpose, a fluid-structure interaction methodology and a grid deformation routine, developed in synergy with other civil and military projects, have been integrated with Navier-Stokes CFD technology.

Under contract to the Ministry of Defence, similar developments for dynamic loads in military applications are taking place in theAESIM-Mil

project. The development of the fluid/structure interaction algorithm, which enables flow models based on time-accurate Reynolds-Averaged Navier-Stokes equations to be combined with structural dynamics, elastomechanical models, is a longer term effort with the availability of a new, advanced ComputationalAeroelastic Simulation (CAS) system as the objective. It embodies modification of the current time-accurate CFD method to enable the treatment deforming grids, the development of a fluid/structure interpolation method for the transfer of displacements and forces between the structures and aerodynamic 'solution spaces', the development of time integration methods for the aeroelastic system as a whole and the development of interfaces with elastomechanical models derived from finite element codes, such as NASTRAN. The activities in 2000 have been concentrated on studies exploring algorithmic components of the CAS system and testing of elements of the system for standard test cases.

To enhance the capabilities for routine aeroelastic predictions, the available computational aeroelastic systemAESIM-BASIC, based on full potential theory, has been extended by embedding linear lifting surface methodology for subsonic and supersonic flows and a classical flutter analysis method. This has been done in such a way that the geometrical and elastomechanical input data, needed for performing the conventional analysis, is compatible with the requirements already established for AESIM-BASIC. The method features a geometry/data-manipulator to extract surface grids for aeroelastic analysis, and a grid generator to generate single-block standard grids. Special attention has been paid to facilitate routine calculations involving large sequences of cases. This enables users to carry out predictions and analyses of the aeroelastic behaviour of flexible aircraft in transonic flight by time-accurate simulation. Although meant primarily to predict transonic flutter of the aircraft in various phases of the design process, the code also has the potential to predict loads in subsonic, transonic and supersonic flight.

The capabilities ofAESIM-BASIC for predicting flutter margins of aircraft with problem turn-around times meeting the requirements of the aircraft industry, was demonstrated for a new generation jet trainer, capable of transonic cruise. This jet trainer is equipped with a reprogrammable flight control system and with multiple control surfaces on the wing leading and trailing edges. AESIM has been used to calculate generalized aerodynamic forces on mode shapes, in NASTRAN format, provided by industry. A database of generalized aerodynamic forces has been calculated for a Mach range of 0.6 through 0.95, enabling the extension of linear flow results, obtained by industry, into the nonlinear speed regime.



Simulation of an aeroelastically deformed fully loaded fighter aircraft

A preliminary aeroelastic analysis of a twin fuselage aircraft configuration has been started as part of NLR participation in the EREA 'new aircraft configurations' project. The main purpose of this analysis is to explore the aeroelastic constraints of such configurations. This exploratory study includes the definition and analysis of a structural dynamics finite element model, static and dynamic aeroelastic (flutter) stability characteristic calculation and sensitivity analysis of the structural dynamic and aeroelastic stability behaviour as a function of structural stiffness and mass properties.

AESIM-BASIC surface grid around a modern fighter configuration

Aeroelastic Investigations for Space Vehicles

The results of wind tunnel tests in the DNW-HST and -SST, executed in 1999 under contracted to ESA/Aerospatiale, with the objective 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, were analysed. Preparations were made for a follow-up test campaign to be executed in early 2001.

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

An important step was taken in the development of better tools for the measurement and analysis of fly-over noise of aircraft around airports by demonstrating, at Schiphol Airport, the technology readiness of acoustic array measurements applied to moving aircraft.

Turbofan Engine Source Noise and Duct Acoustics

The research on aeroacoustics was dominated by the participation in five EU projects addressing the problem of noise reduction of turbofan-powered aircraft. NLR contributed to the co-ordination of this research through the X-NOISE Thematic Network.

The DUCAT (Basic Research on Duct Acoustics and Radiation) project, co-ordinated by NLR, focuses on the development and validation of computational tools for the propagation of sound in engine ducts. The experimental results of a test with a model turbofan in the DNW-LLF, carried out in 1999, were analysed and reported.

In the RESOUND project (Reduction of Engine Source Noise through Understanding and Novel Design), NLR has performed acoustic measurements in the Rolls-Royce test facility at Ansty, UK. Mode measurements were carried out in the intake of an engine test rig, with a specially designed ring of 100 microphones. These microphones were spaced irregularly, in order to extend the range of acoustic modes to be measured. With the new data-acquisition system, so-called 'sweep measurements', i.e., comprehensive measurements at a large number of slowly varying engine speeds, were carried out. This provided valuable information for further research.

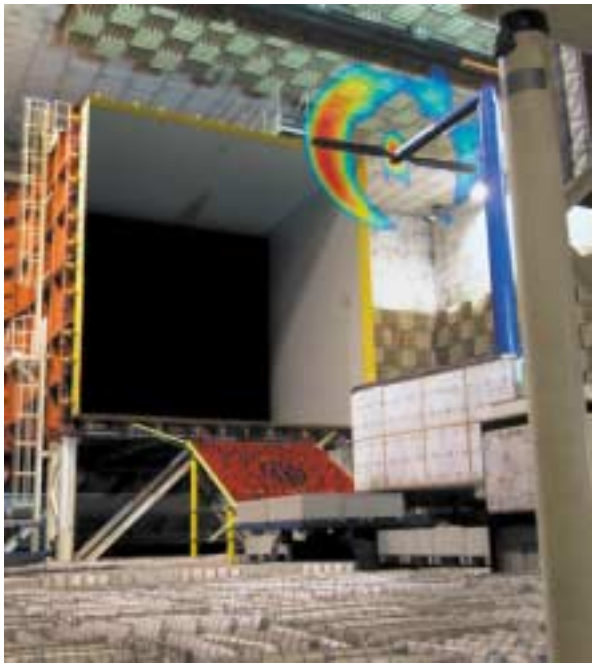
NLR's participation in the RANNTAC project (Reduction of Aircraft Noise by Nacelle Treatment and Active Control) consisted of liner tests in the Acoustic Flow Duct Facility and the validation of a duct acoustics model for non-locally reacting liners. In-situ acoustic impedance measurements on various innovative liners were carried out. A mathematical model for two non-locally reacting liners, a liner with a layer of porous material ('bulk-absorber') and a liner with helical wave-guides, was formulated and validated with results previously obtained from an experiment with a model turbofan in the Small Anechoic Wind Tunnel of NLR. The agreement between predicted

and experimental results is good. A parametric study for a full-size engine shows that the liner consisting of helical wave-guides can attenuate the so-called 'rotor alone noise' by an additional 3 dB compared to a conventional liner.

The TurboNoiseCFD project (Turbomachinery noise source CFD models for low noise aircraft design) was started. The objective of this project is to assess the capability of existing CFD codes to compute turbomachinery noise. NLR provides a wide range of benchmark results against which the CFD codes are to be tested. A start was made with the generation of the benchmark results. Most results were produced using NLR's lifting surface programs for noise radiation from rotor blades or stator vanes. Other results were obtained by a new method for the calculation of sound propagation in ducted swirling flows. This method was successfully developed at NLR within the project.

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 Aeronautics Company (LMAero). 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 parts of the aircraft on the acoustic loads on parts of the aircraft structure. The flow field in and around several weapons bay configurations of a JSF aircraft model has been computed in great detail by means of the RANS-based ENFLOW and FASTFLO CFD systems. The results have been used by TNO-TPD as input for CAA computations based on the linearized Euler equations. For the validation of this method, an acoustic test was carried out in the DNW-HST and -SST on a 1:15-scale JSF model, in co-operation with Lockheed Martin. Surface pressure measurements in the instrumented bay yielded the unsteady aerodynamic loads in the bay and on the weapons. The comparison of experimental data with computed acoustic pressures indicates a potential for a significantly improved spatial resolution capability by combining experimental and computational techniques.

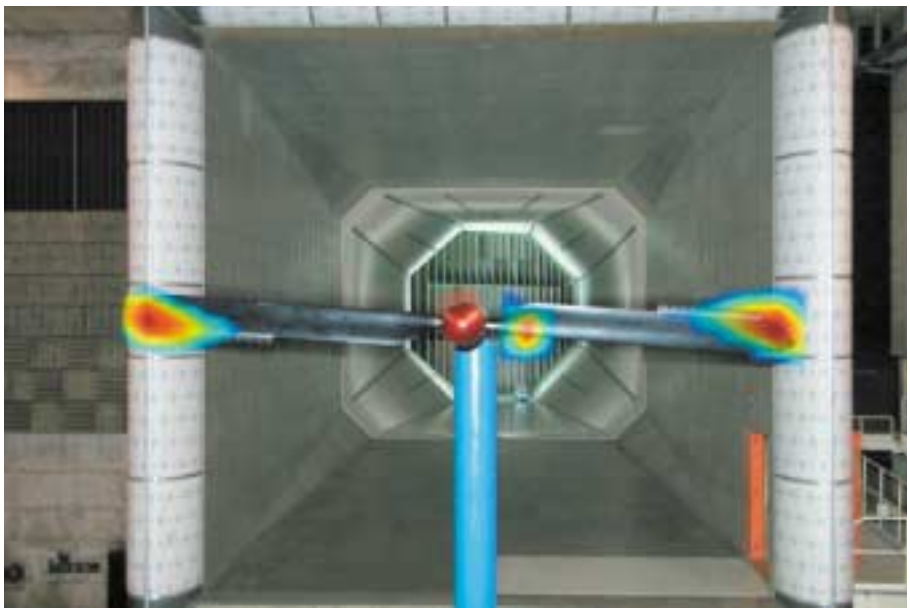


Test set-up in LLF with out-of-flow-acoustic array and noise sources in rotor plane

Research on the flow-induced noise of the extended trailing-edge flaps of a civil aircraft model was continued by the analysis and reporting of wind tunnel test performed earlier in the DNW-LST. As part of the NIVR Basic Research Programme, the measured effect of thickening the trailing edge of the flap on airframe noise was reported. The effect of the application of so-called flap tip devices on noise was also analysed and reported. The results indicate that the effect on airframe noise of thickening the flap trailing edge is not significant, 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 up to 7 dB over the relevant range of frequencies.

Propeller Noise

Besides the research on turbofan noise, the research on propeller noise was also continued in a BRITE/EURAM project, APIAN (Advanced Propulsion Integration Aerodynamics and Noise), in which the sound field of installed propellers is investigated. The NLR contribution to this project consists mainly of the computer program SCATREF for the calculation of the scattering of propeller noise by a fuselage of non-circular cross-



Noise sources on rotating blades on a wind turbine

section, with incorporation of the boundary layer. An extensive set of computations was carried out, in co-operation with other partners in the project.

Noise Propagation

In the EU project RAIN (Reduction of Airframe and Installation Noise) NLR is responsible for the subtask Fan Noise Installation Effects. The results of a sound refraction experiment in the NLR Small Anechoic Wind Tunnel, carried out in 1999 were reported. The results from this experiment are used for the validation of a ray acoustics method for sound propagation, also developed by NLR within this project. The considerable scatter of the measured flow field data turned out to be a significant obstacle to apply the ray acoustics method. Advanced spatial filtering and the construction of a very high order, three-dimensional interpolation technique made application of the computation method feasible.

Non-aerospace Acoustic Research

In the field of wind turbine noise, the EU project DATA (Design and Testing of Acoustically Optimized Airfoils for Wind Turbines) was continued with the testing of newly designed blades on a model scale wind turbine in the DNW-LLF. Besides the localization of noise sources in the stationary rotor plane, a new acoustic array processing method was applied to identify noise sources on the rotating blades. This technique enables leading- and trailing-edge noise sources on individual blades to be distinguished. With the optimized aerofoil design significant noise reductions were achieved, without loss of aerodynamic performance. The radiated noise could be further reduced through the application of trailing edge serrations.

Other activities in non-aerospace acoustic research included an experimental investigation, under contract, of the pressure waves generated by a high-speed train entering a tunnel and acoustic measurements in the DNW-LST also under contract, on a model of a truck road vehicle.

Facilities and Equipment

Wind Tunnels (DNW Support)

The investigations into the possibilities for reduction of model vibrations in vertical direction in the DNW-HST were continued. A new cone-adapter, including damping elements, was used in two wind tunnel tests for HST clients, with good results. Another test was less successful because of incorrect mounting of the damping elements. The underlying aerodynamic-mechanical model were analysed in detail. Further wind tunnel tests were envisaged.

Following a major overhaul of the supersonic wind tunnel DNW-SST in 1999, functional testing of all its systems was carried out and the SST was put into operation again.

In parallel with this work the characteristics of the Pressure Regulating Valve Control System were determined by measuring a number of signals and parameters relevant for its physical behaviour. These characteristics were then used for the design of a replacement for the existing, but degrading, Electronic Control Subsystem. The new system, which is PLC/PC-based, has now been designed, assembled and programmed, and installed, with the old system remaining active. By the end of the year testing of the new system's hardware and software was in progress.

Wind Tunnel Testing Techniques

As part of the DNW Research Support Programme several research support projects were started during the second half of the year:

- analysis of an existing database of transonic wall interference experimental data;
- definition of a wall interference correction algorithm using the measured wall pressure signature of a wind tunnel model;
- comparison of several methods used for boundary layer transition tripping.

In the area of the Pressure Sensitive Paint technique NLR contributed to GARTEUR Exploratory Group (AD) EG-40 'Application of PSP, Phase II' which is defining a follow-up of an earlier Action Group on the subject.

Instrumentation and Measurement Systems

The status of the development of new calibration software for strain gauge balances, based on the concept of transfinite interpolation, was evaluated, and the effort needed for completion was identified. The specific advantage of this new concept is in the ability to handle relatively large component interactions, common to modern type, mono-bloc balances. A proposal for the finalisation of this development in the framework of DNW Research Support is in preparation.

The equipment for unsteady aerodynamic and vibration measurements was extended with 24 channels to a 152-channel data acquisition system. The extended system was put in operation and utilized in several vibration tests, both on-site and in wind tunnels.

A new data acquisition system for acoustic measurements was delivered to NLR. The system is fully compatible with a similar system delivered to DNW-LLF. These systems significantly improve the data acquisition performance, as required for the latest developments in measurement techniques based on microphone arrays. The microphone array measurement technique was also extended with the possibility of focusing on moving acoustic sources. This technique was successfully applied to the rotating blades of a wind turbine model in the DNW-LLF and to arriving and departing aeroplanes at Amsterdam Airport Schiphol.

Infrastructure for Computational Fluid Dynamics

The ICEM-CFD system has been used extensively for 'CAD repair' and 'CAD preparation' in the framework of various CFD projects. Configurations varied from geometrically simple to complex, and were related to various civil aircraft and fighter aircraft. Short-turnaround-time CAD preparation was demonstrated for a complete fighter configuration.

A program repository at NLR containing validated CFD-systems is kept up-to-date. For the purpose of keeping CFD systems available for direct application within research and development projects, this repository is continuously updated to comply with changes in the NLR computer hardware and systems software environment.

Visualisation serves a dual role as a provider of exploration and exposition of results of numerical flow simulations. The drive to study flows with ever increasing physical and geometrical complexity has resulted in unstructured CFD applications with grid sizes above 10 million points. In order to facilitate the visualisation of the very large data sets involved, the infrastructure for visualisation is enhanced. The data-communication capacity between the high-end visualisation workstations and the NEC SX-5 supercomputer has been increased by a factor 10. An additional high-end workstation equipped with a large memory has been acquired for the memory intensive visualisations involved with employing unstructured grids.

3.2 Flight

Summary

In the area of aircraft systems design and evaluation, studies and experiments were performed to improve the operability, safety and efficiency of various types of aircraft and their operations.
All categories of aircraft are being equipped with an increasing number of add-on warning systems for all kinds of hazards. In fact so many, that the crew sometimes experience difficulties in analysing the situation. The objective of the EU project 'Increasing Safety through collisionAvoidanceWARning intEgration' (ISAWARE) was to develop a more Integrated SituationalAwareness System (ISAS). ISAS aims at providing more strategic information for protection against terrain, traffic and weather phenomena. Technical-scientific support was provided to a series of national and international industrial developments. One of them is the FOCUS (Future Operations Concepts for Utility Systems) project, aimed at the development and evaluation of new technologies for system control.

UninhabitedAerial Vehicles are not used exclusively for military operators, but are now also considered for many types of civilian applications. NLR, together with various European partners addresses the airborne andATM issues concerning such applications.

In the area of aircraft procurement and assessment, work focused on providing policy and technical information for national programmes for the replacement and/or updating of both fixed wing and rotary wing category aircraft. Support in data collection and analysis was provided to the F-16 MLU tape 2 Operational Test and Evaluation Testing that was carried out by the F-16 MLU nations at LeeuwardenAirbase.

The RNLAF (Royal Netherlands Air Force) and the RNLN (Royal Netherlands Navy) were assisted in the evaluation of the required self-protection equipment and weapons improvement or additions to make their aircraft more peace mission ready.

In the area of aircraft simulation, work on the next generation Research Flight Simulator (RFS) was continued. A series of acceptance tests of the prototype re-configurable cockpit and its systems was performed. Based on the test results, various modifications were initiated to achieve the required fidelity.

In the helicopter area, NLR participated in the activities of the GARTEUR Group of Responsables for Helicopters. Contributions were made to Exploratory Group (HC) EG-19 'Helicopter Flight Dynamics Modelling'. The helicopter pilot station was expanded with an out-of-the-window view.

Helicopter Pilot Station

The Gas Turbine Simulation Program (GSP) was widely used by international customers. Examples of applications are: the calculation and prediction of emissions, the assessment of gas turbines for naval applications, the prediction of life consumption for gas turbine components based on operational usage data and simulation of the TurBlow gas turbine used for blowing out tanks.

In the area of aircraft operations, work on aircraft systems is increasingly focused on airborne-based ATM systems and separation safety issues. Also, weather phenomena and threats imposed by aircraft-induced wake vortices were analysed and studied for both fixed-wing and rotary wing aircraft.

Aircraft separation responsibilities are experimentally transferred partly or even completely to the flight crew in forthcoming ATM concepts commonly denoted as Free Flight or more accurately, 'airborne separation assurance' concepts. NLR continues to be involved in a variety of types of work supporting the foundation of free flight.

The WAVENC (WAke Vortex evolution in the far wake region and wake vortex ENCounter) project has been completed. This EU project, led by NLR, was aimed at increasing the knowledge in the areas of wake vortex behaviour and wake vortex encounter simulation, to make possible safe separation during landing operations including the wake effects of heavy aircraft and the required separation distances of following aircraft.

Due to environmental requirements, the need for implementing environmentally friendly flight procedures is becomes increasingly important. Research and validation of possible procedures, decreasing the perception of aircraft noise and reducing the pollution by more effective use or non-use of engines is very expedient.

In the series of military field trials, a national trial, Catch-5, was carried out to evaluate the protection of both conventional and new types of flares for helicopters. The international trial MACE X, with the participation of many NATO countries, concerned the effectiveness of chaff and new types of ECM, and was carried out in France.

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. Support was provided in the certification process of the Netherlands AH-64D Apache and in NH90 flight testing. The work on the certification of the Sperwer UAV for the Royal Netherlands Army continued.

Work on international aviation rulemaking was continued by participating in international harmonisation efforts for human factors as part of the requirements for airworthiness of aircraft.

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. For the Prognostic Health Monitoring (PHM) project, knowledge in the domain of gas turbines was maintained, and supplied in a number of presentations.

The aviation community is increasingly concerned about the critical role of aircraft maintenance in aviation safety. For this reason, NLR continues to be deeply involved in the creation of evaluation tools to help predict human error potential during system design and in the integration of human factors into various aspects of aircraft maintenance and training.

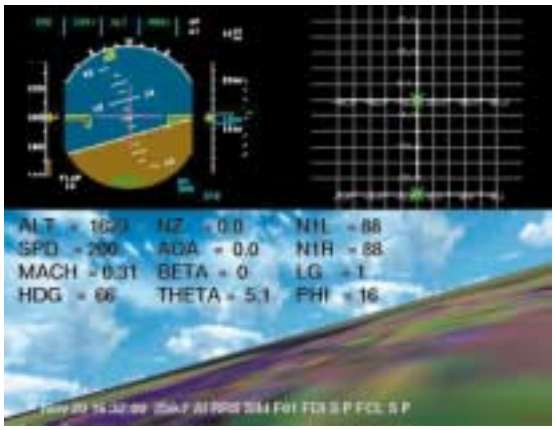
In the area of manning, work on human factors issues associated with flying under both routine and high-stress working conditions and with equipment design, training and selection was continued. Objective and quantifiable measurements on crew performance and error management are crucial in this area. The application of point-of-gaze eye tracker equipment was therefore extended, and applied in a growing number of flight deck and ATC applications, whereas the processing of measured data was accelerated by the further development of dedicated analysis software modules. NLR's unique capability was applied in many areas, such as Free Flight development, flight deck system optimisation, military training, and the assessments of workload and awareness issues for both flight crew and air traffic controllers.

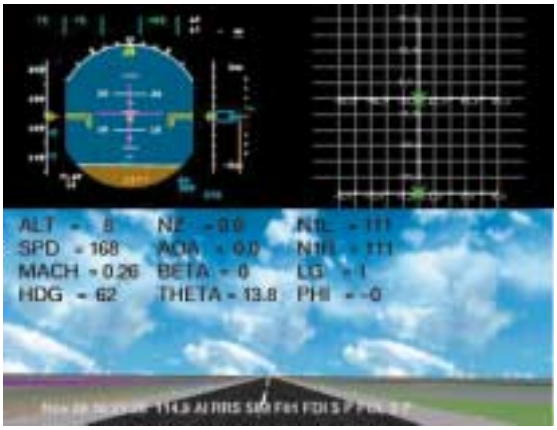
Aircraft Systems Design

In the area of aircraft systems design and evaluation, studies and experiments were performed to improve the operability, safety and efficiency of various types of aircraft and their operations. Fly-by-wire control system technologies now find their way to more types of civilian and military aircraft and the design and validation of these new systems should be robust, safe and economically achievable. The controllability of aircraft under manual flight operations is still an important factor for safe operations, especially when systems limitations are reached or under unexpected adverse weather conditions leading to close to extreme landing circumstances.

The EU project Robust and Efficient Autopilot control Laws design (REAL), was successfully completed with new design procedures and methods. The validation issues of available designs were pursued together with a GARTEUR team that addressed 'New Analysis Techniques for the Clearance of Flight Control Laws'. The application of advanced mathematical analysis techniques should assist the detection of weaknesses in flight control law designs that could jeopardise aviation safety. The application and design of modern Fly-by-wire technologies for small commercial aircraft was investigated in the EU project ADFCS (Advanced Digital Flight Control Systems).

The advent of widespread Fly-by-wire technology and also the occurrence of certain accidents with military aircraft renewed the interest in Airplane Pilot Coupling (APC), a phenomenon more commonly known as Pilot Induced Oscillations or Pilot-In-the-loop Oscillations (PIO). Based on GARTEUR Exploratory Group (FM) EG 18, Aircraft-Pilot Coupling, in which NLR participated, the Action Group (FM) AG 12 on Pilot-in-the-Loop Oscillations: 'Analysis and Test Techniques for their Prevention' was established. As part of the project's objectives, design teams work on the application of mathematical analysis tools for predicting whether or not a given pilot-vehicle system is PIO-prone or not. Pilot-in-the-loop simulations and tests are underway at NLR, CEV (Istres/France) and FFA (Sweden).





Research tools for affordable fly-by-wire digital flight control systems (ADFCS): flight visualization and analysis

All categories of aircraft are being equipped with an increasing number of add-on warning systems for all kinds of hazards. In fact so many, that the crew sometimes experience difficulties in analysing the situation. The objective of the EU project Increasing Safety through collisionAvoidance WARning intEgration (ISAWARE) was to develop a more Integrated SituationalAwareness System (ISAS) to be used in all phases of flight. ISAS aims at providing more strategical information in order to prevent situations where tactical alerting systems would trigger. Protections against terrain, traffic and weather phenomena are the key elements.

NLR was also participating in research addressing the applications of more advanced human machine interaction concepts. Part of the research programme was to assess the image performance and quality of a prototype colour-capable helmet-

mounted display (HMD) based on innovative display technology. The simulator trials provided empirical data on the image quality and human performance during simulated flight. An important tool in display work has been the NADDES (NLR Avionics Display Development and Evaluation System) software package. Significant progress was made this past year for the release of the NADDES second generation package that facilitates the rapid development and evaluation of avionics display formats throughout the complete human engineering and development process.

Technical-scientific support was provided to a series of national and international industrial developments. One of them is the FOCUS (Future Operations Concepts for Utility Systems) project, aimed at the development and evaluation of new technologies for system control. Human-machine interface concepts have been designed and evaluated by potential users. Another example of airborne systems development is the Free Flight capable FMS (3FMS) and the More Autonomous aircraft in the Future ATM System (M-AFAS). Other activities relate to helicopter programmes such as the NH90. NLR participated in the EU project Rotorcraft Handling, Interactions and Loads Predictions (RHILP). Basic goal was to develop know how, in terms of the new handling qualities specifications and dynamic models to simulate new variants of tilt rotor aircraft.

Uninhabited Aerial Vehicles are not used exclusively for military operators, but are now also considered for many types of civilian applications. NLR, together with various European partners addresses the airborne and ATM issues concerning such applications. A proposal for a co-ordinating Thematic Network was issued to the EU.

In the military field, the National Technology Project 'Self Protection Electronic Warfare Manager' was completed successfully. The project entailed the development of a demonstrator to show the possibility to automatically counter threat systems that engage the aircraft (fixed wing and helicopters) during a mission. The demonstrator was coupled to the NSF to enable evaluation in a simulated mission environment.

Aircraft Procurement and Assessment

In the area of aircraft procurement and assessment, work focused on providing policy and technical information for national programmes for the replacement and/or updating of both fixed wing and rotary wing category aircraft. The application of technologies such as helmet-mounted display systems, aircraft self-protection measures and various missiles were assessed, as were the implications of thrust vectoring. Support in data collection and analysis was provided to the F-16 MLU tape 2 Operational Test and Evaluation Testing that was carried out by the F-16 MLU nations at the airbase Leeuwarden under the direction of the RNLAF.

The RNLAF was supported with the specification and drafting of the request for information on new RECCE systems for the F-16 MLU. The replacement of this fighter aircraft was prepared by an in-depth examination of alternatives, either existing (manned/unmanned) aircraft or prototypes in the design phase. This RNLAF project is carried out in co-operation with TNO.

Work on the military application of uninhabited aerial vehicles (UAVs) was continued intensively. The first phase of the National Technology Project on 'UAV technology' was completed. This phase provided an overview of developments in the area of Observation UAVs and of Combat UAVs. Based on development histories, present programmes and projects, an initial assessment of the expected developments in the next 20 years was provided.

The RNLAF and the RNN were assisted in the evaluation of the required self-protection equipment and weapons improvement or additions to make their aircraft more peace mission ready.

Aircraft Simulation

In the area of aircraft simulation, work on the next generation Research Flight Simulator (RFS) was continued. A series of acceptance tests of the prototype re-configurable cockpit and its systems was performed. The particular design allows several flight decks of aircraft types including the Fokker, Boeing and Airbus glass types to be simulated. As a consequence, throttle systems and

pedestals have to be exchangeable in order to resemble the various cockpit philosophies. Based on the test results, various modifications were initiated to achieve the required fidelity. Work on the context simulation concept, addressing detailed simulation of both operational and environmental factors, was continued at a low pace due to the RFS work.

Performing take-offs is a thrilling part of flight training, and an extended use of simulation in this area can contribute to improving both safety and the environment. Positive and transferable skill acquisition has to be attained. The NSF was used for a collaborative effort with TNO on the human information processing of various sensory cues. The objective of the Take Off CUES experiments was to determine the range of motion stimuli that produce realistic sensations of longitudinal acceleration during a simulated take-off run in an advanced research flight simulator.

The networking of simulators provides attractive opportunities, but working with different levels of fidelity has the risk of creating a mix of simulator-dependent skills that negatively transfer to the real world. Limited experiments that address these issues were continued in the national Air Warfare demonstrator and the NLR/NASA Free Flight Internet project.

Helicopters

In the helicopter area, NLR participated in the activities of the GARTEUR Group of Responsables for Helicopters. Contributions were made to Exploratory Group (HC) EG-19 'Helicopter Flight Dynamics Modelling'. The helicopter pilot station was expanded with an out-of-the-window view.

The Gas Turbine Simulation Program (GSP) is gaining international interest. Various international customers successfully used this NLR-developed simulation. Examples of applications are: the calculation and prediction of emissions, the assessment of gas turbines for naval applications, the prediction of life consumption for gas turbine components based on operational usage data and the simulation of the TurBlow gas turbine used for blowing out tanks. Also very complex engines are now modelled such as the STOVL engine of the LMTAS JSF. The GSP programme is also used as a teaching tool by the TU Delft in the gas turbine course.

Aircraft Operations

In the area of aircraft operations, work on aircraft characteristics was increasingly focused on airborne ATM systems and separation safety issues. Also, weather phenomena and threats imposed by aircraft-induced wake vortices were analysed and studied for both fixed-wing and rotary wing aircraft.

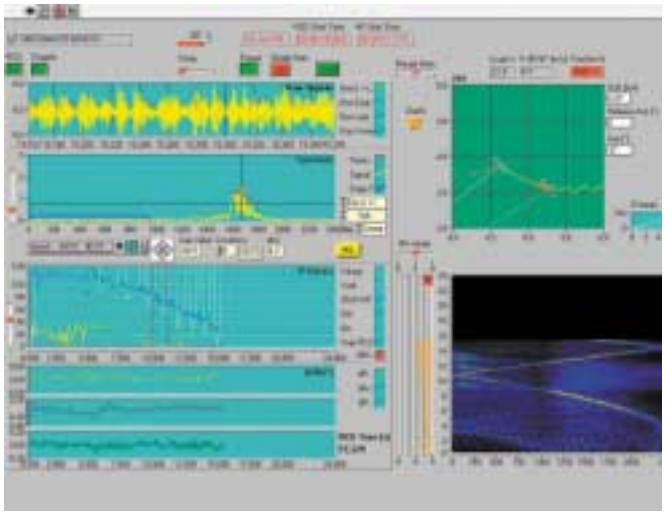
Aircraft separation responsibilities are experimentally transferred partly or even completely to the flight crew in forthcoming ATM concepts commonly denoted as 'Free Flight' or more accurate, 'airborne separation assurance 'concepts. NLR continues to be involved in a variety of types of work supporting the foundation of free flight. Simulator studies, off-line studies, as well as an internet-linked simulation have been used to refine the free flight concept, as well as to explore the human factors issues surrounding the (retro-fit) displays and systems that free flight would entail. One major recent activity of the free flight project has been the completion of the 'Human Interaction Experiment,' in which human pilots interacted in real-time via the World Wide Web. Additional work has centred on testing the conflict resolution methods for robustness, and in developing prototype HMIs for both pilots and controllers under free flight.

NLR has a close collaboration with NASA in this field, but also leads other projects in this area. An example is a two-year European project named INTENT that addresses the possible benefits of sharing aircraft INTENT information with ATC users and the possible impacts on air traffic system capacity, safety, the avionics system design, fuel burn etc.

NLR also participates in the five-year project Mediterranean Free Flight (MFF) demonstrator project that has started in March 2000. One of its objectives is to provide technical, safety and operational evaluations of integrated, interoperable new airborne-based CNS/ATM technologies and applications suitable for future ATM scenarios.

The WAVENC (WAke Vortex evolution in the far wake region and wake vortex ENCounter) project has been completed. This EU project, led by NLR, was aimed at increasing the knowledge in the areas of wake vortex behaviour and wake vortex encounter simulation, to enable safe separation including the wake effects of heavy aircraft and the required separation distances of following aircraft. The WAVENC project was succeeded by the EU Fifth Framework project S-Wake, which is led by NLR as well. S-Wake (assessment of WAKE vortex Safety) aims for developing and applying methods to quantify safety aspects with regard to wakes during the approach and landing

Due to environmental requirements, the need for implementing environmentally friendly flight procedures is becomes increasingly important. Research and validation of possible procedures, decreasing the perception of aircraft noise and reducing the pollution by more effective use and non-use use of engines, is very expedient. Funding for the development of such procedures is not matching its importance, thereby delaying practical benefits. As a result of the introduction of new systems for approach, navigation and flight management, there is a further potential for the development of new flight procedures for arrivals and departures. International collaboration takes place within the GARTEUR Exploratory Group (FM) EG-20 which was established under the leadership of NLR, on the subject 'Development of advanced noise abatement procedures'.



Quick look screen of the Catch ECM test facility showing flight path, various radar signals and Doppler history.

Military Operations

In the area of military operations, 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. The model has been demonstrated successfully in real-time mode in the Helicopter Pilot Station. A similar development was initiated for the CH-47D Chinook helicopter.

The National Technology Project 'Laser threat and protection for air crew' was continued. The project aims at the determination of laser threat and possible protective measures for aircrew and on-board sensor systems. The project is carried out in co-operation with TNO. The determination of the properties of the possible threat has been completed. In the next phase experiments on the effects of illumination by non-lethal lasers on aircrew and sensors will be carried out.

In the series of field trials, the national trial Catch-5 was carried out to evaluate the protection of conventional as well as new types of flares for helicopters. The trial was carried out with the RNLAF, the RNLN and in co-operation with DERA and TNO-FEL. The NLR's 'Catch' Seeker Test Facility (STF) was used for the trial.
Trial Catch-6 was dedicated to the Cougar. A trial installation of a chaff dispenser was tested using NLR's Catch ECM test facility (ETF) with respect to the optimum chaff ejection angle.

Sea King Helicopter of the Royal Navy lifting off HMS Rotterdam of the Royal Netherlands Navy in qualification tests

The international trial MACE X, with the participation of many NATO countries, concerned the effectiveness of chaff and new types of ECM, and was carried out in France. The RNLAF supplied the Flycatcher radar, the RNLN a PC-3 Orion aircraft. NLR provided the 'Catch' ECM test facility (ETF). Various studies with respect to self-protection system installation requirements were carried out.

The RNLAF was assisted with the analysis of the performance of its own and threat counteracting weapon systems, as well as with exercises such as Red Flag and Loftic and the preparation for employment of helicopters. Also contributions to various courses for pilots and intelligence personnel with regard tot weapon system performance and countermeasure effectiveness were provided. Other support concerned the improvement of the F-16 training simulators, the F-16 training debriefing tools, the HAWK training equipment and support of Stinger Training units.

In the area of certification, work in support of the RNLAF and the RNLN was continued. Updated navigation and targeting pods for the F-16 were tested and certified. Support was provided to the RNLN for the extension of the Westland Lynx operational life and in NH90 flight testing. The work on the certification of the Sperwer UAV for the Royal Netherlands Army continued. Sperwer was provided with a Preliminary Certificate of Airworthiness at the end of 2000. Work to achieve full certification continued, as the actual configurations of this craft have not been finalised.

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 international harmonisation efforts for human factors as part of the requirements for airworthiness of aircraft.

The certification programme for the navigation and targeting pods for the F-16 was completed successfully. The programme entailed the certification of all existing external store configurations for

Separation of a fuel tank from an F-16 during navigation pod certification flight tests

the F-16 MLU in combination with these pods. A new project, to extend the release limits for underwing fuel tanks when carried in combination with the MARS RECCE pod, was started.

The National Technology Project 'Self- Protection Electronic Warfare manager' (SPEW) concept demonstration' neared completion. This software-based manager employs available data on 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 and 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 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 of the required protection measures for aircrew. These projects are carried out in co-operation with the TNO Physics and Electronics Laboratory.

The RNLAF will replace its conventional F-16 wet film RECCE system, Orpheus, with a modern 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 at present upgrading their systems, new interoperability standards, for example on image exchange and datalinks, have been developed. NLR participated in a number of the working groups on these RECCE-related standards.

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 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 now be controlled through the Multi Function Displays. After the successful completion of the flight tests, NLR received an order for the production of eight of such units. Furthermore, one infrared line scanner system will be modified to a digital system to continue the support of special missions.

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.

Maintenance

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.

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.

The aviation community is increasingly concerned about the critical role of aircraft maintenance in aviation safety. This view has been fostered, in part, by a number of high profile incidents over the

years. Against this background, the role of the human is also being increasingly recognized as one of the most critical links in the aviation safety chain. For this reason, NLR continues to be involved in designing for greater integration of human factors into various aspects of aircraft maintenance, from designing for human factors awareness into ab initio mechanics training, to creating evaluation tools to help predict human error potential during system design.

In previous and ongoing European and national research projects, a large number of human factors issues in aircraft maintenance were identified. The Aircraft Maintenance Procedure Optimisation 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. In the area of design for maintainability, research was continued in the DESMAIN project. Its objective is to improve the error tolerance of aircraft design and system design by ensuring cognitive consistency of the maintenance task. The ongoing EU project Safety Training in the Aircraft Maintenance Industry (STAMINA) covers the training area in aircraft maintenance. A training set was developed consisting of five modules that cover the individual, task, team and organisational aspects of aircraft maintenance. A study was started into the best practices of integrating Human Factors into technical training. The resulting integrated training set up was guided by the Joint Airworthiness Requirements JAR-66.

Aircraft and Manning Issues

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 continued. 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 applied in a growing number of flight deck and ATC applications, whereas the processing of measured data was accelerated by the further development of dedicated analysis software modules. The currently 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.

NLR, together with the Royal Netherlands Navy and the former Hollandse Signaalapparaten B.V., has explored the feasibility of simultaneous registration of Eye Point-of-Gaze (EPOG) from multiple operators, in this case a team of subjects in a Defence Command and Control Environment equipped with a Large Wall Display. The demonstrations, which were carried out in Signaal's Virtual Reality Theatre, were to serve as a proof of concept for both multiple operator EPOG measurement, as well as an eye controlled cursor device.

Other innovative eye tracking techniques are being developed as part of the NLR-initiated EU VINTHEC II project, which aims to use eye tracking as a means of assessing crew co-ordination and automation awareness, on board the civil flight deck. The ultimate aim of this effort is to transfer to the aviation community, and various other domains, an objective and validated means of assessing crew interaction. Such a development could prove invaluable for training as well as operational use, in fields ranging from aviation to maritime bridge operations, to process control.

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 both 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. In response to the growing need for pilot training candidates, selection methods based on Divided Attention capabilities were updated, and are now being tested by national type rating training organisations as well as air traffic controller training centres.

In collaboration with Defence Evaluation and Research Agency (DERA), the RLNAF and TNO, the POWER (Pilot Oriented Workload Evaluation and Redistribution) programme was continued. This series of projects addresses the potential operational and functional benefits of advanced display concepts and pilot support tools.

In co-operation with EUROCONTROL, NLR has been evaluating the potential human performance impact of free routing over northern European airspace. The Free Route Airspace Project (FRAP) is using real-time, controller-in-the-loop simulations to assess how free routing is likely to influence controller workload, monitoring performance (especially for low-probability 'non-nominal' events), and recovery from error modes

NLR is also involved in various ongoing activities in the areas of training research and training development. One chief example of the former is the ESSAI (Enhanced Safety Through Situation Awareness Integration and Training) project, in which NLR is leading a team of research and industrial partners in designing and testing a training strategy for maintaining situation awareness and crisis management skills in modern day 'glass' cockpits.

NLR also developed, as part of the BETA (Operational Benefit Evaluation by Testing an A-SMGCS) project, a training package for controller of a new Surface Movement and Guidance Control System (SMGCS) under development. NLR designed and oversaw pre-evaluation testing for the project.

The ADAPT-IT (Advanced Design Approach for Personalised Training in Interactive Tools) project has been developing a methodology and tool for designing training for complex cognitive skills. Activities thus far have focused on identifying current training design practices, and from these to identify the needs for the ADAPT-IT approach. The project aims to develop actual training packages for complex cognitive skills in two domains: air traffic control, and aircraft maintenance.

The development of advanced ATC tools and displays is often seen as a critical means to accommodate future traffic levels. NLR has taken part in a number of efforts in this area, including EUROCONTROL 's Conflict Resolution Assistant (CORA) project, which ultimately aims to develop automated conflict resolution aiding. As part of this effort, NLR performed a human factors assessment of controller resolution aiding, including identifying through controller focus group discussions potential strategies for controller retraining and system development.

Flight training is expensive and a substantial burden on military costs. As part of a project, in which NLR is teamed with the Polish Air Force, a series of three studies was conducted with candidate Polish Air Force pilots, to explore the potential utility of incorporating flight data into each student's debriefing feedback. A large part of the work was focussed on the debriefing aid itself, a software tool for presenting the in-flight data during the debriefing. In order to test the debriefing concept it was applied in an experimental setting in basic training of candidate Air Force pilots. The results show that such a debriefing tool is quite useful, when applied in conjunction with observations and debriefing by the instructor. Augmented debriefing proved to be especially effective for such objective performance measures as speed, height, pitch, etc.

Thirteen major future aircraft cockpit technologies were studied in order to sketch their anticipated human factors issues in an operational context. The goal of the study was to provide the Royal Netherlands Air Force Operations and Human Factors communities with a list of anticipated human factors to deal with as they evaluate the successor to the F-16. This was done by first outlining the intended purpose and functionality of the technologies. Further, their operational impact was described, as well as their current operational status and the projected developments in 5-10 years. Based on these descriptions, the anticipated human factor issues were outlined.

3.3 Air Transport

Summary

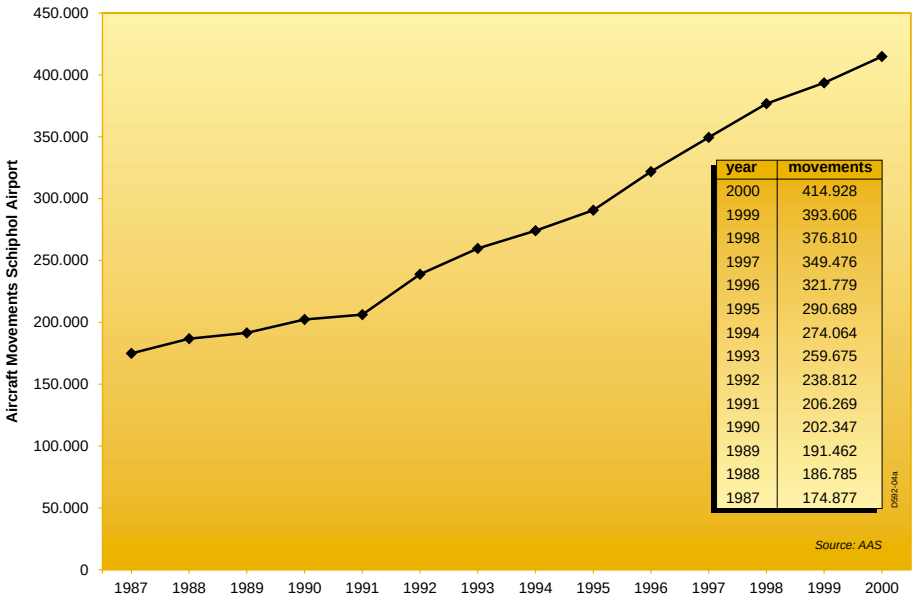
At a successful symposium 'Technology for Sustainable Growth' held at NLR, an extensive array of possible solutions for the problems related to the recent and forecasted air traffic growth on and around Amsterdam's busy airport Schiphol were discussed. Representatives of all leading organisations and governmental bodies of the Netherlands' aviation sector took part in the symposium.

During the year, national and international 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. Subjects of the research work were communications and datalink, navigation, surveillance and Air Traffic Control. Specific support was given in the area of airport and Terminal Area operations and airport automation. A separate focus was maintained on air transport safety, with research and development work on safety modelling, incident/accident databases, and flight safety. Extensive use was made of the NLR third party risk assessment methodology. In the field of environmental issues, extensive use was also made of the NLR model for the estimation of noise hindrance around airports.

An important milestone was the announcement of the Airport Scenario Analysis Package (ASAP). This package will integrate the available impact assessment models for capacity, noise and third party risk, ease the input configuration control and make the tools directly available to stakeholders over the Internet. This will significantly reduce the calendar times needed for analysis and provide better support for the policy making process.

NLR continued its international orientation and participated in many projects funded by the European Commission and by EUROCONTROL. Collaboration is pursued with EUROCONTROL, the FAA, NASA and other partner research institutes as well as the aviation industry to ensure the wide spread of R&D results and the worldwide applicability of the work.

The facilities for air transport research were maintained and upgraded, with a particular emphasis on the Tower Research Simulator, the Traffic Organization and Perturbation AnalyZer (TOPAZ) and the Third Party Risk Assessment tool.



Continuous growth of air traffic necessities innovation to avoid growth of delays

Air Traffic Management

Communications and Datalink

NLR took part in the EC and EUROCONTROL projects European pre-operational datalink applications (EOLIA) and Prototype Aeronautical Telecommunication Network (ProATN). NLR conducted flight trials in April 2000 between Amsterdam and Teesside in the UK, as well as in French and Dutch Airspace, to evaluate the pre-operational use of datalink services in a multi-centre (ground) and flight environment. Besides exchanging ATC clearances and aircraft position reports, a new service was demonstrated: Flight Plan Consistency Check (FLIPCY). Using FLIPCY, the ATC controller can request the aircraft to downlink its active flight plan and automatically compare that with the filed ground flight plan. For the ground part, NLR demonstrated the EOLIA services on the NARSIM ATC simulator which is simulating the Amsterdam Advanced ATC (AAA) system, with both datalink equipped aircraft and non-datalink-equipped aircraft.

Along with the work for EOLIA and ProATN, NLR developed the 'Platform for Research on End to End Aeronautical Telecommunications Network (ATN) data communication' (PREDACOM). PREDACOM consists of the 'Flexible Airborne ATN System' (FLAAS) focusing on the integration of the ATN with aircraft avionics and providing datalink services to the pilot, the 'NLR DataLink Server' (NDLS) providing ATN datalink services to a ground ATM system (e.g. NARSIM) and the 'NLR ATN Protocol and Performance Analyzer' (NAPPA) allowing detailed analysis of the behaviour and performance of the ATN system, both on-line and off-line. The facility is used to validate and evaluate new and existing datalink services, from both the technical (system) level to the operational (HMI) level.

NLR has contributed to the EUROCONTROL project PETAL II (Preliminary EUROCONTROL Test of Air/ground data Link) by performing test flights with the Citation II laboratory aircraft. Starting at Schiphol airport under control of NARSIM, the Citation flew towards Belgium to be 'handed over' to the PETAL II reference system at

Navigation of the aircraft is done from the experimenter's station (shown) using datalink to communicate with simulated ATC

The real research aircraft is mixed with simulated air traffic; the real aircraft is controlled through datalink, using voice as backup

the EUROCONTROL Upper Area Control Centre. Subsequently, at the French border, the aircraft was under control to Airsys ATM, simulating the Paris ATC. On the return flight to Schiphol, the reverse scenario was demonstrated. During these flights, the datalink service provided Controller-Pilot Datalink Communication (CPDLC) and Automatic Dependent Surveillance (ADS) messages to the ground. Valuable data was gathered concerning the operational use of datalink in the European airspace.

The project DADI-2 (Datalinking of Aircraft Derived Information part 2) concentrates on the initial and medium-term exploitation of downlinked aircraft data in ground ATC systems, gathered via different air/ground technologies. In this project, NLR develops and evaluates the use of Downlinked Aircraft Parameters (DAP) for an enhanced Arrival Management decision support tool, so as to support the establishment of an expeditious and efficient flow of arrival air traffic.

Navigation

For the Netherlands Civil Aviation Authority (RLD-NLA) a study has been carried out into applying minimum separations based on wake turbulence criteria during conditions of low visibility, using the Microwave Landing System (MLS). Risks have been identified for two scenarios: a single landing runway-handling MLS traffic only and a mixed ILS/MLS handling landing runway. It appeared that ground operations are the major constraint for reducing the separation distance on final approach, because of increased runway occupancy time and lower taxi speeds.

Also under contract to the NLA, NLR continued the assisting in the campaign to implement GPS-based approach procedures at airports in the Netherlands. NLR analysed radar data and workload evaluation forms from pilots in order to evaluate economic benefits, safety and environmental aspects.

In preparation for the operational validation of the European Global Navigation Overlay Service (EGNOS) for civil aviation, EUROCONTROL has contracted NLR to develop a flexible and flight ready airborne platform for demonstration and validation of EGNOS-guided approaches (PREVAIL). The PREVAIL platform collects both EGNOS navigation data and local Differential GPS data as a reference, in order to analyse the navigation performance. Furthermore, the EGNOS navigation solution can be used as a guidance input to the pilot in order to analyse the total system performance. Test flights were made with a Universal Access Transceiver (UAT) at Brétigny airport and were used to evaluate the operational validation process and to give a first impression of the dynamic performance of EGNOS in terms of accuracy, availability, integrity and continuity.

Surveillance

The objective of the Multi Sensor Fusion project, an NLR initiative, is to develop advanced data fusion algorithms for ATM applications. To this end a generic probabilistic approach is pursued through Bayesian modelling. This approach enables newly developed models and algorithms to be seamlessly integrated into advanced surveillance and automation support tools. Within this framework, research and development was carried out on multi-target tracking in situations with many closely separated targets that may perform sudden manoeuvres, accurate reconstruction of aircraft trajectories, short term conflict alerting, and mode-S environment modelling.

Under contract to ATC the Netherlands (LVNL), NLR has contributed to the specifications of the Airport Surveillance TRAcker-1 (ASTRA-1) system. The main task of the ASTRA-1 system is to provide accurate track data to its users, including the Runway Incursion Alert System Schiphol (RIASS). The ASTRA-1 system is in effect a radar data-fusion system that combines radar data from Airport Surface Detection Equipment (ASDE) systems and approach radars. As part of the ASTRA-1 specifications, NLR has specified performance requirements backed up by the analysis of live data.

Air Traffic Control

Within the framework of the European Air Traffic Management Programme (EATMP) the EUROCONTROL agency has an ongoing requirement to validate a Medium Term Conflict Detection (MTCD) function. The Amsterdam Area Control Centre (ACC) conflict detection tool (ACOD) has been the basis for the development of the European MTCD. The impact of this tool has been assessed.

Present procedures and tools are not expected to be capable of solving all problems of future Air Traffic Management (ATM) systems. Therefore, TU Delft and NLR investigate new and innovative techniques from other disciplines, such as information technology, that can help address future ATM problems. Examples of the techniques are operations research and artificial intelligence (AI). Special attention is given to the development of a new planning methodology that is able to cope with the large amount of possible ways with which an increased demand of air traffic may be handled.

Under contract to EUROCONTROL, in the AMAN feasibility study the benefits of current operational arrival management systems actually achieved and their associated costs were investigated. The results serve as decision support and reference for further development of arrival management functionality within the AMAN project. Arrival Management systems have the potential to increase the airport capacity, which can be used to increase the number of flights and/or reduce the delays. A cost/benefit analysis for the installation of an Arrival Management system turned out to be beneficial for both large and smaller airports.

NLR has participated in the European Commission's Fourth Framework project AVENUE (ATM Validation Environment for Use towards EATMS). Within this project, the European ATM industry and research institutes have built a European ATM simulator intended as a validation platform. One of the main tasks of NLR was the development of the Airborne Separation Assurance System (ASAS) module. This module allows the simulated aircraft (flight simulators and ATC-simulated aircraft) to perform airborne conflict detection and conflict resolution. The ASAS functionality is essential for the simulation of concepts such as Free Flight, where certain tasks are shifted from the ATC controller to the pilot.

The Netherlands Civil Aviation Authority (NLA) has contracted NLR to make a survey of all the factors which together dictate the maximum handling capacity in the Dutch airspace. Along with this, an overview was presented of the relevant models and simulation capabilities NLR has available to analyse how changing these factors affect the maximum handling capacity.

In the study 'Advanced conflict modelling in HIPS (Highly Interactive Problem Solver)' carried out under contract to EUROCONTROL, a comparative analysis of probabilistic detection techniques concluded that the probabilistic approach of NLR was the most promising. It was integrated in the HIPS. Results obtained using conventional

geometric conflict detection processes were compared in small-scale tests with those obtained using the probabilistic approach. Planning controllers do not need to solve all conflicts, but only filter out the likely ones. The benefit of the probabilistic approach is that it supports this 'conflict filtering process' by setting the risk threshold according to the desired level of safety. This shows the potential conflict area only if it is probable, while at the same time it will be known what level of safety this represents at the planning stage. Moreover, with the probabilistic approach it is possible to distribute safety over the different Air Traffic Control layers.

In the EUROCONTROL-funded project Testing Operational Scenarios for Concepts in ATM (TOSCA), led by NLR, the potential impact of multisector planning is considered, possibilities for improvement of the EATMS concept are studied, and accident risk of new procedures is evaluated. For the accident risk part, use is made of NLR's TOPAZ (Traffic Organization and Perturbation AnalyZer) methodology. The capacity impact was studied using the Total Airspace and Airport Model (TAAM).

The EU-funded project EMERging Technologies, opportunities, issues and impact on ATM (EMERTA) is conducted by a consortium in which NLR participates. Next Generation Satellite Systems (NGSS) and the Automatic Dependent Surveillance-Broadcast /Airborne Separation Assurance System (ADS-B/ASAS) were studied for aeronautical use, such as transition issues, cost-benefit analysis, long-term benefits, availability of data, and safety/separation modelling. Both NGSS and ADS-B/ASAS were shown to be valuable for further ATM development.

NLR supported the LVNL in the analysis of the safety, efficiency and environment effects (*Veiligheid-Efficiency-Milieu* - VEM) of a new operational concept for the Dutch regional airports Beek and Eelde. The main characteristics of the new operational concept are the automation of some of the controller tasks and the removing of all of the tasks of the assistant controllers. The work was carried out in close co-operation with LVNL during two-week stays at both Beek and Eelde airports.

A Highly Interactive Problem Solver (HIPS) equipped with NLR's probabilistic Conflict Probe eases the mental gymnastics of the air traffic contoller

Another VEM evaluation was carried out for Schiphol's Runway Incursion Alert System (RIASS), which is currently under development. RIASS supports the executive air traffic controller by detecting conflicts between taxiing, landing or departing aircraft and/or vehicles. It provides a positive contribution to the level of safety. The VEM evaluation addressed the safety and efficiency aspects.

Through a sub-contract with the ATAC Corporation, NLR collaborates with US researchers on issues in Aviation Safety Modelling to support the National Aeronautics and Space Administration's (NASA) Aviation Safety Program. In the first phase of this research, completed in 2000, a report has been produced on how an effective integration of the Man-Machine Integration Design and Analysis System (MIDAS) human performance modelling approach of NASA and the NLR TOPAZ approach could be accomplished during the next two phases.

Significant progress has been made in the development of wake-vortex-induced risk modelling, human cognition performance modelling and probabilistic conflict prediction and detection modelling. In addition, new models have been developed to allow for a systematic clustering of human related hazards as part of a qualitative safety assessment, and to extend the accident risk

decomposition theory that allows risk assessments to be performed within TOPAZ through a hierarchy of Monte Carlo simulations. These developments have found successful applications in accident risk assessment projects of the LVNL and NLA respectively.

Airports

Airport and TMA Operations

Under contract to Amsterdam Airport Schiphol assistance was given to the Project Optimisation Schiphol, an initiative of the Netherlands Air Transport Sector (several Dutch Airlines, ATC The Netherlands LVNL and Amsterdam Airport Schiphol). NLR's contribution consisted of advice and technical expertise on runway and airspace utilisation issues.

Under contract to Air Traffic Control the Netherlands (LVNL), NLR studied various technology and procedure concepts to increase the arrival capacity of Schiphol airport.

NLR participates in a long-term strategy working group called Blueprint Advanced Traffic-control Schiphol (BATS), which tries to identify trends, technological possibilities, aircraft and aircraft system developments and institutional measures that will impact Schiphol between the years 2010 and 2030. NLR activities in BATS are performed under contract to Amsterdam Airport Schiphol (AAS).

Airport Automation

In close co-operation with the Holland Institute for Traffic Technology (HITT), Marine Safety Netherlands and the Port Authority of Rotterdam, NLR takes part in a development programme for advanced traffic control systems. This programme, called Triple-I, is being co-financed by the Ministry of Economic Affairs (through Senter) and will lead to technology preparation for an Advanced Surface Movement Guidance and Control System (NLR's role) and for a new Vessel Traffic System (Marine Safety's role). The Triple-I project will show demonstrated benefits during the course of the project related to advanced surveillance, control, planning and HMI concepts.

Together with HITT, NLR developed and implemented an operational Taxiway Collision Monitoring (TCM) system for Manchester (UK) Airport. Several improvements on this TCM were carried out. A similar system is now in operation at Berlin Tegel Airport, Germany. Further applications of TCM at other airports will follow.

NLR collaborated with European partners in the Surface Airport Movement Simulator (SAMS) project, partly funded by the European Commission DG-VII. The SAMS platform was used for a demonstration on the Tower Visual Simulator at DLR Braunschweig integrated with the B-747 cockpit simulator of DERA Bedford and NLR's Tower Research Simulator (TRS) computer system in the Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Testing of Operational Procedures using Simulation (ATOPS) project. The purpose was to test procedures on simulated Amsterdam Airport Schiphol and London Heathrow Airport.

In collaboration with European partners NLR will demonstrate operational benefits of an A-SMGCS on actual airports (Hamburg and Prague) in the Benefit Evaluation of Testing an A-SMGCS (BETA) project, partly funded by the European Commission DG-VII. Continuing on the experience of the SAMS and ATOPS project, whereby benefits were shown in a simulated environment, BETA must actually perform in the operational field. NLR's activities concentrate on ATC training, through NLR's Tower Research Simulator, Human Machine Interface design and Departure Management, including start-up planning.

Airport and Airspace Analysis

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

ATC the Netherlands (LVNL) contracted NLR to study the consequences on departure capacity for the S5P runway configuration for different Standard Instrument Departure route layouts.

For the Spanish organisation AENA, studies were carried out on re-sectoring parts of the Spanish airspace, and on improved ATC operational usage for both the 'Levante' and the 'Norte Baja' (Tenerife) airspace.

Safety

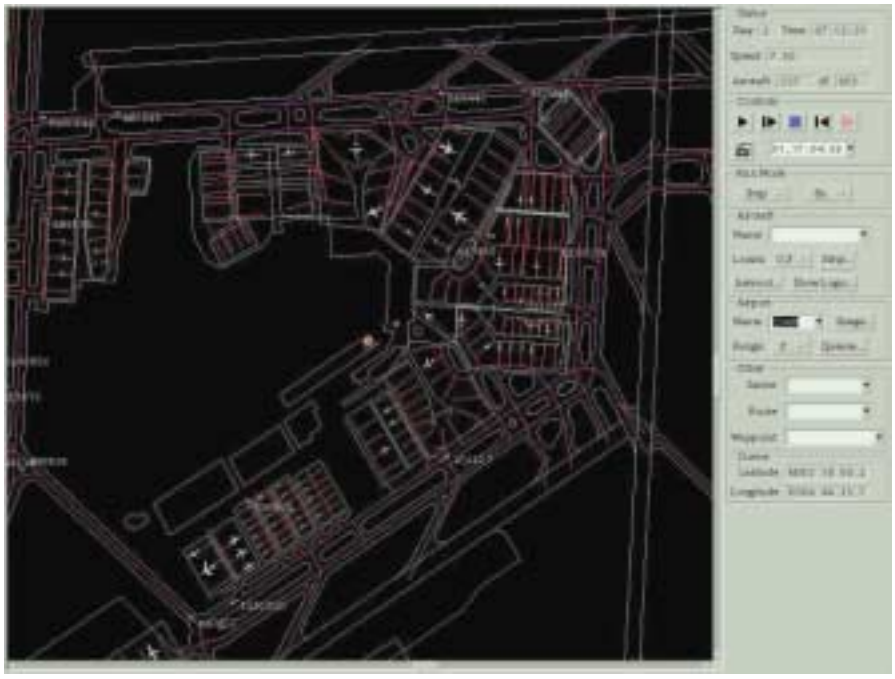
Safety Modelling and Analysis

In a co-operative effort with the Netherlands Civil Aviation Authority (RLD), accident rates of different categories of cargo operators and the factors that influence safety of air cargo operations were quantified. This information was compared with results from platform inspections performed by RLD under the Safety Assessment of Foreign Aircraft (SAFA) programme. Recommendations were given to improve the level of safety of air cargo operations, emphasizing the importance of proper functioning National Authorities in developing countries.

The EU-funded project Air Transport Safety Improvement through Quantitative Risk Analysis (DESIRE), co-ordinated by NLR, on the development of a methodology for risk assessment which allows cost-benefit analysis to be made, entered the validation phase. A protocol for the calculation of accident costs was completed and validated with a case study. The validity of the overall methodology was assessed during a workshop with airline representatives.

The EU-funded project Aviation Safety Targets for Efficient Regulation (ASTER) was launched. The objective of ASTER is to develop a methodology that enables safety targets to be set and optimized for each of the actors in the Air Transport System. The ASTER methodology is a logical development of the methodology that was explored in the DESIRE study, using quantified 'generic' accident scenarios as the core of the risk assessment method. An improved classification system for causal factors, with a reduced number of factors and a simplified structure, was developed. The cost model developed in DESIRE was also further expanded and refined to better reflect some basic methodological notions in measuring the cost of accidents.

A consortium of NEI, SAVE, TU Delft and NLR, co-ordinated by NLR, concluded the investigation on the feasibility of the development of a causal model for the analysis of third party risk around airports. Recommendations were given for the



Fast-time simulation enables bottlenecks in airport layouts to be identified quickly

development of such a model, which would combine a technical/procedural part, modelled through accident scenarios, and a management/ organizational part.

NLR participated in the EU-funded EXT-HAZ thematic network, which had the objective to analyse and explore potential synergies between different research projects dealing with external hazards to aviation, such as icing, lightning, wind shear, etc. Partners involved in the EXT-HAZ network have identified the state-of-the-art of methods for prediction, detection and protection against external hazards to aviation, and have compared this state of the art with regulation and certification requirements. This has not only been done for single hazards, but also for combinations of hazards. Areas of research that can help in further protecting the aviation system against external hazards were identified and prioritised.

Accident/Incident Data Bases and Data Mining

Under contract to Fokker Aircraft Services an analysis was conducted into accidents with aircraft similar to the Fokker 100 that occurred during automatic landings on wet runways. Searches for these accidents were conducted in the NLR Air Safety Database. Furthermore an analysis was conducted on the relation between the touchdown sink rate and the hydroplaning speed of aircraft tires.

NLR was contracted by Amsterdam Airport Schiphol to assist in the analysis of the data in the Operational Airport Safety Information System (OASIS) database. Using data from the NLR Air Safety Database, a systematic analysis of the incidents in OASIS database was conducted.

In modern aircraft many aircraft variables are recorded, by means of the Flight Data Recorder or a dedicated Quick Access Recorder. Typically these data are used to monitor exceedances of certain aircraft parameters. However, the vast amount of useful safety information hidden in these data is currently not used by most operators. The current research programme is meant to show that these data can be used to analyse routine events, and by doing so, can expose safety trends hidden within the standard operation of an operator. Both in the United States and in Europe similar initiatives are undertaken, because world-wide these analyses are considered to be essential for desired improvements in general safety levels. Several statistical analyses have been initiated in co-operation with KLM Royal Dutch Airlines, using large amounts of routine flight data. This concerned an explorative study intended to demonstrate how certain safety trends can be made visible and which statistical methodologies are most promising.

Third Party Risk Analysis for Airports

NLR completed the reassessment of model parameters and the implementation of model extensions in the third party risk analysis software. A number of risk calculations were carried out with the adjusted model.

In an ongoing project under contract to the Ministry of Defence for the development of third party risk calculation methods and models for military airbases, accident probability parameters and accident consequence parameters were derived from accident data.

Third party risk calculations were performed under contract to the RIVM as part of the environmental outlook and the annual national review by the RIVM of the state and development of the environment. In addition, third party risk calculations were performed for a major Southern European Airport, Niederrhein Airport and Zeeland Airport. A rough study on the development of third party risk was performed for Eindhoven Airport.

Under contract to the Netherlands Ministry of Housing, Physical Planning, and the Environment, NLR developed methods to visualize the development of societal risk within municipal areas. These methods are intended for use as guidance tools for land-use planning.

Under contract to the Ministry of Transport, NLR together with RIVM carried out a study into the policy options for inclusion of the Societal Risk metric in government policy regarding the third party risk around Amsterdam Airport Schiphol. The policy options defined by NLR and RIVM were presented at an international workshop of invited experts. The findings of the workshop were

used in support of the government's decision making on regulations governing current and future growth of traffic volumes at the airport.

Air Transport Safety

As a consequence of a crash at Amsterdam Airport Schiphol, on Christmas Eve 1997, and the recommendations of the ensuing accident report of the Dutch Air Transport Safety Board, a Committee was installed to review the tailwind and crosswind criteria in use for runway assignment, and to recommend on a harmonized set of criteria, taking into account not only the safety aspects, but also capacity and noise consequences. NLR in co-operation with the MITRE corporation has been contracted by the Committee to perform the study, covering all aspects mentioned. In a particularly short time this study has been carried out, using statistical data from the NLR AirSafety Database, to assess the risk involved in tailwind and crosswind operations. Special circumstances for Schiphol have been addressed, such as the specific wind climate, the runway lay-out, and noise and capacity constraints, in addition to general aspects, such as the certification of crosswind capability, the operational use of crosswind and tailwind criteria by operators, etc. Results have been reported to the Committee and were widely accepted in the international air transport sector. The review has led to the recommendation of new crosswind and tailwind criteria, which are slightly relaxed during day-time, and slightly more stringent during night-time, and which currently form the basis for runway assignment by LVNL and runway use by the operators.

As focal point for air safety issues within the co-operation of European Research Establishments, NLR contributes to the combined safety initiatives of the Commercial Aviation Safety Team (CAST) in the USA and the Joint Strategic Safety Initiative (JSSI) in Europe. In this context NLR participated in the so-called 'Loss-of-Control' Joint Safety Analysis Team (JSAT), after earlier JSATs analysed Controlled Flight into Terrain, and Approach and Landing accidents. NLR contributed by leading the analyses of several accidents, and identifying several new intervention strategies for this type of accidents. NLR participated in the final analysis effort, and contributed to the report, which was made public at the end of the year.

Other activities in the context of air transport safety were aimed at contributions to the CAST-ICAO common taxonomy working group, which is focused at defining a harmonized and generally accepted accident database taxonomy. Also, as a member of the European Advisory Committee of the Flight Safety Foundation, NLR provided assistance in the preparation of 14th European Air Safety Seminar.

Deviations from prescribed operating procedures have been a contributing factor in the majority of aircraft accidents since 1970. Together with the University of Leiden's Centre for Safety Research, a study was performed into the psychological and sociological factors influencing human behaviour towards non-adherence. A theoretical framework was developed and linked to aircraft accident data from the NLR Safety Database. In addition, non-accident data was gathered using a questionnaire filled in by a large number of airline pilots.

Accident Investigations

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

Two investigations into F-16 accidents were supported, one of which involved a mid-air collision with a general aviation aircraft. A mid-air collision involving two light aircraft from a civil flying school was investigated in support to the Dutch Transport Safety Board.

For the RNLAF studies were done into the effects of adverse weather conditions on fighter pilot survival of night-time accidents at sea, and into the perceived additional risks of transport of non-combat personnel in military aircraft.

Research Aircraft

Fairchild Metro II

In the framework of the Automatic Dependent Surveillance - Broadcast (ADS-B) Technology Assessment programme of EUROCONTROL, NLR has used both its research aircraft to conduct

flight tests with different ADS-B technologies, including SSR Mode S, Universal Access Transceiver (UAT) and VHF Data Link (VDL) Mode 4. The Metro was used in all three test programmes that included test flights in Germany, France and the Netherlands and in which many international organizations participated.

The Fairchild Metro II research aircraft continued to be used for the flight inspection of the civil radio navigation aids in the Netherlands. This activity, started in 1997, is performed under contract to Air Traffic Control the Netherlands (LVNL). In 2000 about 250 hours have been flown for this activity.

Cessna Citation

The Cessna Citation research aircraft was used, together with the Fairchild Metro, in EUROCONTROL's UAT test programme and flew test trajectories from the Brétigny airport in France. The Citation was also used in a test programme, called Research Aircraft for Data Link Investigations by comparing Alternative Links (RADIAL), conducted by the German Air Traffic Control (DFS), to obtain information on key technical parameters for different ATN technologies. For these tests the Citation was equipped with SATCOM, VDL and Mode S data link systems. In the framework of the EU project European Pre-Operational Data Link Applications (EOLIA), several flights were made in which communication with NLR's ATC simulator NARSIM was tested using the satellite communications network. In succession to the EOLIA programme, several test flights were made with the Citation for the project Flexible Airborne ATN System (FLAAS). For the EUROCONTROL project PREVAIL, the Citation was used to test the use of EGNOS position data to provide flight path guidance; the capability to fly Advanced (curved) Continuous Descent Approaches was successfully demonstrated.

A number of flights have been made with the Phased Array Universal Synthetic Aperture Radar (PHARUS) for purposes including continued testing of the interferometric mode of operation, military applications and comparison with data from the ICONOS satellite. In preparation for the S-Wake programme, in which aircraft responses to wake vortices are studied, a number of test flights were made to quantify the aircraft responses to flight control inputs.

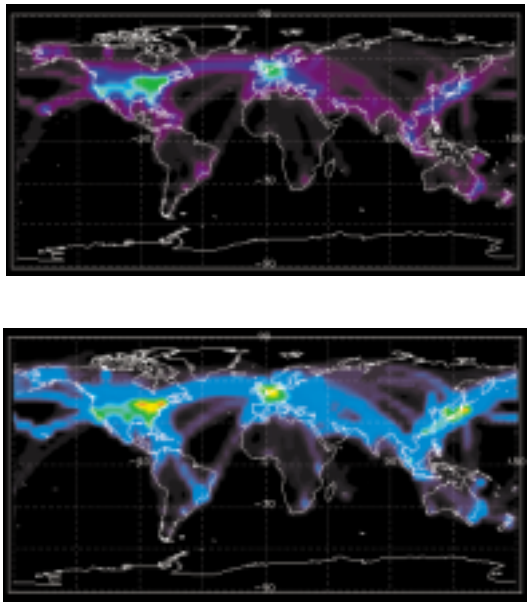
Transport and Environmental Studies

Air Pollution

For the Ministry of Transport Civil Aviation Authority, the AERO 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). NLR has contributed to the acceptation of the AERO model within the ICAO/FESG (Forecasting and Economic Sub Group).

For the Ministry of Transport, the current annual amount of CO_2 emissions by civil aviation to and from small and regional airports in the Netherlands was quantified.

Partly funded by 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. A vast amount of Flight Data Recorder (FDR) data has been processed into environmental impacts and whenever possible, related to certification criteria. AEROCERT is carried out by several European partners of which NLR is project co-ordinator.



CO_2 emission by aviation in 1992 (top) and in 2010 (bottom)

NLR contributed to the EU-funded thematic network on Identification of Aircraft Emissions Relevant for Reduction Technologies (AERONET). NLR is a member of the AERONET Management Team and co-ordinates the expert group on Operations and Forecast of Air Traffic Development.

Under contract to the International Air Transport Association (IATA), NLR continued a study into operational measures to reduce aviation emissions such as Air Traffic Management improvements and optimization of flight performance. Information and views were obtained from airlines, EUROCONTROL, and global organizations such as IATA and ICAO. On average, slightly differing from region to region, improvements of more than 10% are potentially achievable in aviation fuel efficiency and emissions reductions by the year 2010, compared to today.

On behalf of the Netherlands Ministry of Housing, Physical Planning and the Environment, NLR contributed to activities of the ICAO-CAEP working group on technical issues related to aviation emissions.

For the Royal Netherlands Air Force, the feasibility of an emissions-monitoring system was investigated. The recommendation was to set up a simple emissions-monitoring system based upon fuel usage, and with emissions numbers as output.

For Amsterdam Airport Schiphol, NLR, in co-operation with TNO, finished a comparison of models for the calculation of local emissions in the surroundings of Schiphol. Consistency in input data was found to be important for comparable model output, especially data on the number of aircraft movements and the so-called time in mode (i.e. specific flight phase).

Noise Exposure

As in earlier years, NLR calculated aircraft noise exposure for various 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. Noise exposure calculations were performed for the Environmental Impact Studies for the redesign of the configuration of Amsterdam Airport Schiphol. Noise effects were evaluated for the introduction of 3000-ft approaches for Amsterdam Airport Schiphol during daytime. The measure shows positive noise effects for specific areas close to Schiphol, and negative noise effects for areas further from the airport because of the translation of arrival routes.

An update of the aircraft noise and performance database, which is part of Dutch noise exposure calculation guidelines, was made. An inventory of aircraft data still required was made, available data were collected from several sources and processed, and requests for the remaining data were sent to aircraft manufacturers.

The re-design of the methodology of noise regulation around Amsterdam Airport Schiphol was worked out in more detail. This new regulation will become operational in 2003 with the introduction of a new, fifth, runway. NLR provided technology consultancy to the Netherlands Civil Aviation Authority (RLD-ONL) in further refinement of the noise regulations. NLR also assisted by providing noise exposure characteristics in various measurement units (Kosten Units, $LA_{eq\text{-}night}$, L_{den} and L_{night}) for transport scenarios for the year 2010.

As part of the project Inventory of Noise Control Systems and under contract to the RLD the airports of Zürich, Copenhagen and Düsseldorf were visited because of their diversity of aircraft noise control. From the visits it became obvious that both noise calculations and measurements were performed at each airport for purposes such as law enforcement, planning and noise surcharge systems. The implementation of both noise measurements and calculations does vary per airport.

In a consortium with Resource Analysis and Adviesbureau Peutz & Associés, NLR was involved in a sensitivity analysis of the calculation method for aircraft noise (Kosten units). Investigated were: differences in calculation results for forecast calculations and noise monitoring calculations, the sensitivity for changes in key assumptions within the noise calculation regulations, and the effects of operational measures.

Results of a study of the environmental benefits of Continuous DescentApproaches compared with conventional approaches were reported. The study was based on data acquired from the Flight Management System of aircraft corresponding with 54 flights. The FMS operational performance data was used in calculations of noise footprint areas. Besides, FMS data was used in order to make comparisons of the fuel consumption in the last 45 km of the approach.

In order to reduce the noise impact of airline fleets, the European Union and governments are studying possible increased noise stringencies that could be introduced by ICAO. Recent studies focus on stringency measures that propose an 8-14 dB reduction with respect to the ICAO Chapter 3 standards and phase-out of aircraft that do not comply with the new standard. The timeframe for these phase-out scenarios is 2010/2020. NLR has researched the possible impacts of these increased noise stringencies on the noise load and aircraft fleet composition at Amsterdam SchipholAirport. Only the 14-dB stringency will have a significant impact.

Monitoring of Environmental Aspects

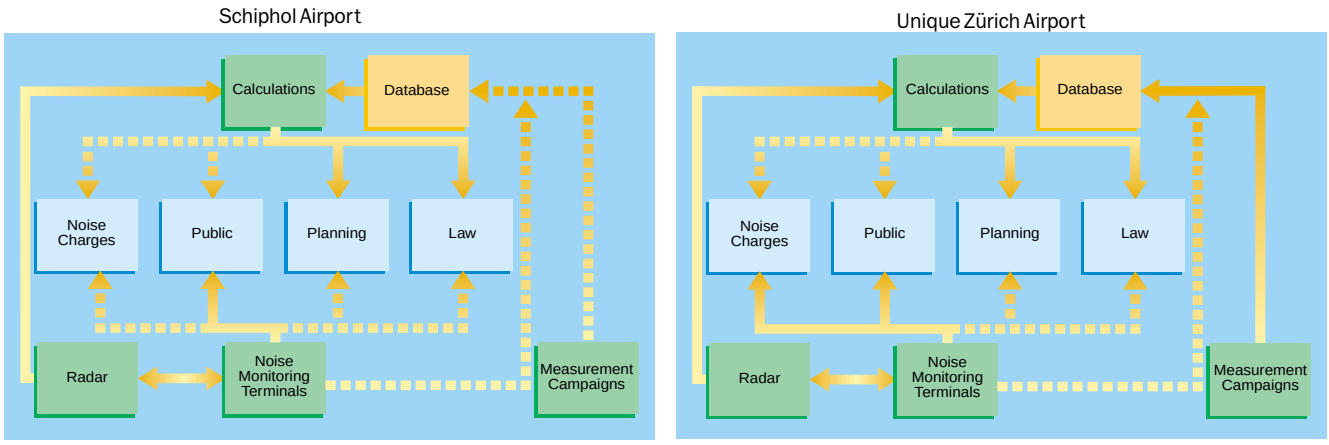
Under contract to the Netherlands Ministry of Housing, Physical Planning, and the Environment, NLR has analysed the flight tracks and the related noise exposure for the surroundings of Brüggen and GeilenkirchenAirbases.

Under contract to the Netherlands Ministry of Transport, and under contract to Air Traffic Control the Netherlands, information obtained from the Flight track andAircraft Noise Monitoring system FANOMOS was used to support several studies. Studies were related to e.g. health impact related to aircraft noise, flight track dispersion and improvements in aircraft noise exposure modelling.

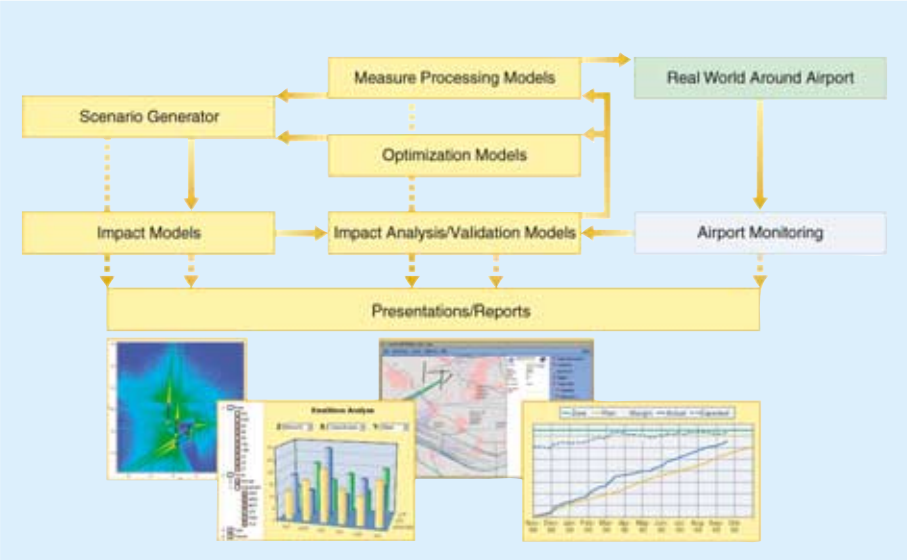
Under contract to the Netherlands Ministry of Transport a feasibility study has been conducted for a flight track and aircraft noise monitoring system around GroningenAirport Eelde.

Airport Scenario Analysis Package (ASAP)

As a result of the analysis of the developments and problems around especially AmsterdamAirport Schiphol, the ASAP initiative was started. ASAP will offer aviation parties in the Netherlands a tool to analyse quickly the impact of changes in fleet, routes, airport configuration and procedures. It can be used by stakeholders through the desktop PC, accessing the tool over the Internet network. By significantly reducing the project calendar times a strong support for the policy making process is given. It is realized by making available and integrating all relevant impact predicting models at NLR, being noise load, exhaust gas and external safety models, and, in addition, the various airport capacity models. Further models (e.g. internal safety and cost efficiency) can be added at a later stage. The development of ASAP was announced at a symposium NLR held in June 2000. During the year the full development line was selected, configured and installed. A first running system (COCKPIT version 1) is expected to be released in 2001.



Comparison of Aircraft Noise Control Activities at Amsterdam Airport Schiphol and Unique Zürich Airport; dotted lines are inoperative



The Airport Scenario Analysis Package (ASAP) will be designed to quickly identify the best possible way forward for the airport by incorporating all relevant environment modelling

Facilities and Equipment

NLR Air Traffic Control Research Simulator (NARSIM)

NLR continued to keep the NLR Air Traffic Research Simulator (NARSIM) abreast with the latest technologies. Effort was spent on the Human Machine Interface, an upgraded Airborne Separation Assurance System module and a controller display update. The facility was used to run a short introductory Air Traffic Control course.

To develop, adapt and test HMI applications using these technologies, a library of generic software has been developed. Based on this library, a replacement for the existing radar display software of NARSIM, developed in 1987-1988, was made. A preliminary version of this Air Traffic Controller Display (ATCoDis) has been used to prototype an Arrival Management HMI and in the preparation of free flight experiments. The same generic library has been used to build the Tower HMI Plan View Display of the NLR Tower Research Simulator.

Within the Free Flight Flight Management System (3FMS) project a number of enhancements were developed for NLR's ATC Simulator (NARSIM): a Distributed Interactive Simulation (DIS) server; an upgraded NLR ASAS (Airborne Separation Assurance System) module with conflict detection and resolution with 4D trajectory change points; an ATCo display update including Belgian and French airspace for the Plan View Display and a Meteo Server.

NLR developed an introductory Air Traffic Control course on NARSIM. After having been given for NLR personnel in several years, the course was given under contract to RLD.

Tower Research Simulator (TRS)

NLR develops a Tower Research Simulator to allow the Netherlands Air Transport Sector, and in particular Air Traffic Control the Netherlands (LVNL) to evaluate future airport infrastructure and/or procedural changes to Schiphol. The Tower Research Simulator was in a development phase, with teams designing and implementing specific airport software modules representing airport traffic, flight movements, procedures, tower controller systems etc. A visual system has been ordered which allows tower controllers to 'look outside' and have a realistic view of Schiphol and its operation. The visual system has a 135-degree horizontal by 40-degree vertical field-of-view surrounding the tower controller working positions. The TRS and its visual system are planned to be integrated by the end of 2001. At the end of 2000, a baseline version of the TRS became available after an extensive verification and validation procedure. Validation trials were executed in a pseudo-operational environment, encompassing various controller positions such as those for the ground controller, the tower controller and the start-up controller, as well as supporting working positions for the pseudo pilots and the experiment leader. Although not yet fully functional, the TRS has already been used in actual investigations: ATC the Netherlands (LVNL) used

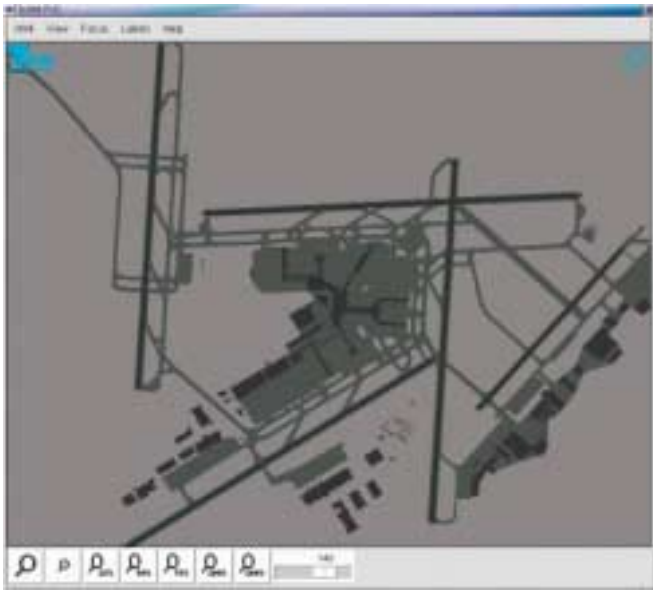
the TRS to evaluate several Runway Incursion Alert System (RIAS) variants for future use on Schiphol.

Traffic Organization and Perturbation AnalyZer (TOPAZ)

The TOPAZ facility assists safety assessment and model-based ATM concept validation studies. TOPAZ emphasises 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 safety studies on new ATM operations including Airborne Separation Assurance Systems or Aeronautical Mobile Satellite Systems. Also, safety aspects for simultaneous missed approaches on converging runways were assessed. Other activities were the exhaustive explanation of the TOPAZ validation methodology to professional safety experts and other interested parties and the collection of TOPAZ application results and know-how for inclusion in a newly developed TOPAZ Information Management System.

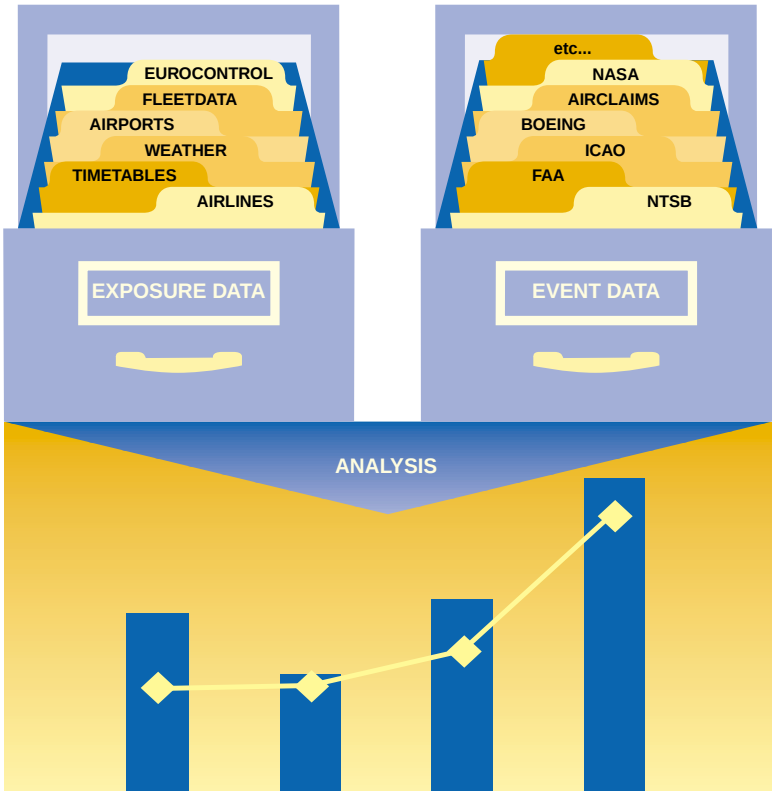
Total Airspace and Airport Modeller (TAAM)

TAAM is used by the Netherlands air transport sector to evaluate a large number of different options to increase the capacity of Schiphol while at the same time maintaining punctuality of the airlines. In a highly realistic model of Amsterdam Airport Schiphol with detailed infrastructure and procedural correlation of its current operation, the sector uses TAAM with its validated model to investigate measures that in many cases have a sector-wide impact. Efforts are being undertaken to show 'noise' contours generated by the Integrated Noise Model (INM) based on TAAM-scenarios and TAAM-output. Correlated flight tracks, noise contours, capacity and punctuality numbers can be given for a particular scenario.



Prototype of Tower Plan View Display for Tower Research Simulator

Electronic tools such as touch screens could in future assist the Tower Contoller in performing his work safety while handling more traffic



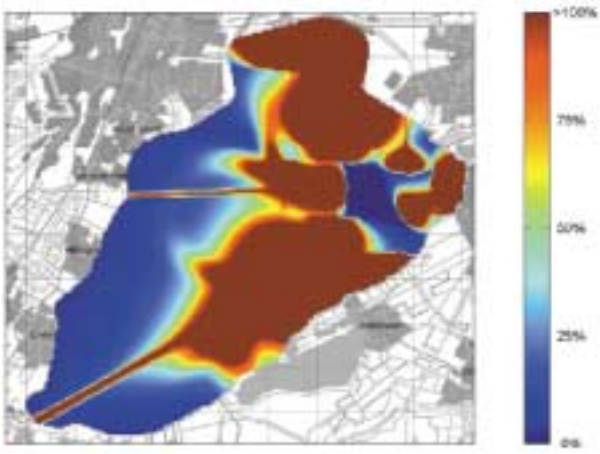
Application of NLR Safety Database for systematic safety analysis

NLR Air Safety Database

NLR maintains a comprehensive database containing air safety data. Besides accident and incident data of civil aircraft also other types of data are collected including flight exposure data (flight hours, departures), weather data, airport information, fleet and operator data. The data are updated annually. The NLR Air Safety Database was used in several projects and for ad-hoc queries both for internal and for external parties. The projects include the update of the third party risk models, a study into crosswind and tailwind limits for civil aircraft, and the writing of world-wide and national statistical aviation safety summaries for the Civil AviationAuthority (RLD).

Third Party Risk Analysis Tool

As part of theAirport Scenario Analysis Package, new third party risk analysis software is under development to enhance the capabilities of the risk analysis tool and to keep it up-to-date. The new software will become a user-friendly tool and will be accessible directly by stakeholders. Two important new features of the software are that it is fully integrated with software tools for airport capacity analysis and airport noise calculations and that it will allow risk analysis for very detailed scenarios including separate traffic mixes per arrival and departure route. The requirement analysis was finished and documented, and the concept software design and concept user interface design documents were completed. The enhanced modelling should fulfil the growing need of



Relative growth of group risk, for more than 100 fatalities, as a result of the addition of 1000 persons per hectare in the vicinity of Schiphol

governments and the air transport sector to receive objective detailed risk information, especially during decision-making processes.

Citation Future Aircraft Systems Testbed (FAST)

Several new and generic capabilities were developed for application within the Citation Aircraft Systems Testbed. The continued development process concerned, among other things, a generic display system, a generic datalink system, a generic Research Flight Management System, and the installation of a multi-purpose target computer system for interfacing and flight control functions. A major achievement is that this architecture facilitates to a great extent the re-use of software used in flight simulator and/or air traffic simulator projects. To demonstrate the achievements accomplished so far, a demonstration flight test programme with the Citation testbed has been executed. The Advanced Continuous Descent Approach (ACDA) has been selected for this demonstration. Earlier, this concept had been the subject of a simulator investigation, which provided a good opportunity to demonstrate the effort required to transfer this research to real flight test. A successful flight demonstration of the concept has been carried out at Eelde airport. The experiment demonstrated not only the ACDA concept but also the advanced 'Tunnel-In-The-Sky' guidance along the trajectory.

3.4 Structures and Materials

Summary

Research and development activities in structures and materials were executed in the areas of loads and fatigue, structures technology, and the extension and improvement of laboratory facilities. Investigations and developments in these areas were primarily aimed at issues and themes that reflect the global industrial drive for improved affordability.
Projects under the Fourth Framework Programme of the European Union were finished, and projects under the Fifth Framework Programme were started.
The technology readiness demonstration aimed at Dutch industry participation in the US Joint Strike Fighter (JSF) programme and NLR's share in the development of the fibre-metal laminate GLARE were the major contract research projects in structures and materials in 2000. The selection of GLARE as a material for the Airbus A380 fuselage has significantly increased the time pressure. The activities mentioned, together with other contract research for, amongst others, the Royal Netherlands Air Force (RNLAF), the Royal Netherlands Navy (RNLN), the Netherlands Institute for Aerospace Programmes (NIVR), the Netherlands Department of Civil Aviation (RLD) and aerospace and aero-engines industries mainly from the Netherlands, work in the area of structures and materials again increased by approximately 20 per cent compared to the previous year.

Shear test on fuselage panel of Gulfstream aircraft

Loads and Fatigue

Aircraft Loads and Certification

The one-dimensional modelling of atmospheric turbulence for gust loads analysis prescribed in the current airworthiness requirements may not be adequate for future very large aircraft. For the development of the large Airbus A380 aircraft, more realistic modelling may be required, in which spanwise variation of gust velocities is accounted for. Various investigations have therefore been carried out to judge the effects of two-dimensional modelling of vertical turbulence on gust loads on large aircraft. In a continuation of research on this subject in the early nineties, work was carried out under contract to DaimlerChrysler Aerospace Airbus.
The RLD was provided 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, the development of a computer program for the generation of load sequences for fatigue testing and analysis was completed. In this project, experience with the Fokker 100 fatigue tests carried out in the mid-eighties has been used.
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.

Together with SP Aerospace and Vehicle Systems, NLR investigated active damping control to improve the performance of aircraft landing gear.

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.

Apart from the F-16 aircraft structure, also the engine is monitored. NLR has developed models to predict the engine life consumption using monitored flight data and engine data.

For the Westland Helicopters Ltd. Lynx helicopters, a load and usage monitoring system has been developed and installed. This system monitors structure and engine parameters.

For the RNLAF, preparations of a load measuring programme for the Lockheed Martin C-130 Hercules fleet were continued. An agreement was signed with Lockheed Martin to exchange design data and measured operational data.

For the Royal Netherlands Navy and the Portuguese armed forces, load monitoring in Lockheed P3 Orion aircraft was being continued.

The Spanish armed forces awarded NLR a contract to procure and install a load monitoring system in Lockheed P3 Orion aircraft.

On behalf of the Royal Netherlands Navy, NLR participates in the Service Life Assessment Programme (SLAP) and Service Life Extension Programme (SLEP) for the Orion aircraft. SLAP/SLEP is a collaborative programme between the US Navy, the Canadian Forces, the Australian Forces and the Royal Netherlands Navy. 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.
NLR has completed a material characterization programme for new aluminium alloys that can replace the existing materials in the P3 Orion. These new materials have better corrosion resistances and the same or better strength and fatigue properties.

To reduce maintenance costs and to increase the sortie rate, 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 have been demonstrated in collaboration with the US manufacturers to the JSF Programme Office using F-16 data collected with the monitoring system FACE. The demonstrations have been completed successfully. The demonstrated capabilities of the Dutch PHM consortium have led to invitations to participate in the Engineering and Manufacturing Development (EMD) phase of the JSF starting in 2002.

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 completed. 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 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.
Two programmes dealing with advanced Thermal Barrier Coating systems and one programme dealing with an advanced sealing concept were started. In the programmes, coatings and seals are designed, manufactured and tested.
An investigation into the necessity of coating internal cooling channels in turbine blades and vanes was completed.

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 being developed and evaluated. NLR was involved in a European programme on the characterization and evaluation of TiAl and single crystal materials.

Failure Analysis

Several service failures were examined, an example being a broken rotor hub of a Lynx helicopter. A Royal Netherlands Navy (RNLN) Lynx helicopter suffered loss of a rotor blade just before take-off. The blade loss was due to failure of a rotor hub arm by fatigue. The rotor hub arm was an integral part of the monobloc forged rotor hub made from the titanium alloy Ti-6Al-4V. NLR carried out a service failure analysis in co-operation with the RNLN and GKN Westland.
The analysis included fractographic and metallographic examinations to determine the fracture mechanism and the presence or absence of metallurgical defects. The microstructural factors influencing fatigue strength and fatigue crack initiation were discussed. There was no evidence of any metallurgical defect associated with the rotor hub arm failure.

Estimates of service stress levels for the failure location could be obtained from a combination of fractographic and metallographic information, the details of full-scale and specimen fatigue test failures, and elementary fracture mechanics analyses.
It was concluded that the failure was most probably due to frequently occurring service fatigue loads and stresses higher than those used in the design safe-life estimation.

Fatigue and Damage Tolerance

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

Statistical methods have been evaluated for their applicabilities to risk assessments of cracked structures. An efficient method was implemented and used to predict the probability of failure of the F-16 augmentor duct.

The applicability of statistical methods in the design of aircraft structures in relation with the regulations is studied in the European ADMIRE project. NLR participates in this project along with all major European aircraft manufacturers.

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 ESA contracts. A fatigue crack growth model was developed for GLARE, and consultancy was provided to the Polish Air Force on the use of the NASGRO computer code.

Space

To support the Dutch industry in the design of spacecraft components, the properties of Planesee PM1000 and Inconel MA754 were investigated and compared. A brazing procedure to join these materials is under development for the production of honeycomb panels.

Structures Technology

Materials

Metallic, composite and hybrid materials were being evaluated and characterized at NLR with respect to their mechanical or corrosion properties, which may include the effect of various surface, environmental and heat treatments. Also, several fabrication technologies for the production or joining of metallic structural components were being investigated.

Materials Engineering

Under contract to the NIVR, the effect of Electron Discharge Machining (EDM) on the fatigue properties of new, high strength steel alloys has been investigated. EDM is a technique used by SP Aerospace and Vehicle Systems to generate high precision slits in landing gear components. For the same customer, the feasibility of using the phosphoric-sulphuric acid anodising process, which is environmentally friendlier than traditional chromium-based anodising, was investigated. Anodis-

ing is a treatment or pre-treatment for corrosion protection, adhesive bonding or painting of aluminium components. Under contract to the RNLAF, chromate-free paint systems have been evaluated with respect to the more severe regulations that will be imposed in the near future. The effects of new, environmentally friendly replacements for cadmium plating and chromate-free paint systems on the fatigue and corrosion properties of steel and aluminium have also been investigated for Fokker Aerostructures, with regard to possible participation in the development of the JSF.

Under contract to the NIVR, several projects are being carried out to support the development of GLARE in co-operation with Fokker Aerostructures, Structural Laminates Industries and Delft University of Technology. GLARE is a fibre-metal laminate, to be used as skin material for certain sections of the fuselage of the Airbus A380. NLR contributed with qualification testing of GLARE laminates in co-operation with Airbus partners and Fokker Aerostructures. A large test programme was carried out to investigate the environmental durability of GLARE. In addition, the corrosion behaviour of GLARE and its resistance against several paint removal techniques were investigated.
The characteristics of fracture surfaces of composite materials were studied in GARTEUR Action Group (SM) AG-20, and a follow-on action group was defined.

Fabrication

Friction StirWelding (FSW) is a promising fabrication technique to weld aluminium alloys that cannot otherwise be welded. Under contract to the NIVR, process parameters were determined to obtain optimum material properties with respect to strength and fracture strain, and the feasibility of the technique has been demonstrated at the level of stiffened wing panels. Several fabrication technologies were being investigated for Fokker Aerostructures, focused on a possible participation in the development of the JSF. The feasibility of friction stir welding was being investigated for thin sheets and for the joining of heavy lugs to structural components.
Process parameters for high speed machining of steels were being investigated, in particular with respect to the residual stress state. A numerical simulation of the process of metal sheet forming has been developed. In-house research projects to investigate advanced welding techniques were carried out in co-operation with DLR and TNO. Within the framework of an IOP programme, and in co-operation with the universities of Delft and Eindhoven, NLR contributed to the investigation of adhesive bonding techniques for non-aerospace aluminium structures.

Stiffened panel made using friction stir welding

Composite component for F-16 landing gear

Composites Technology

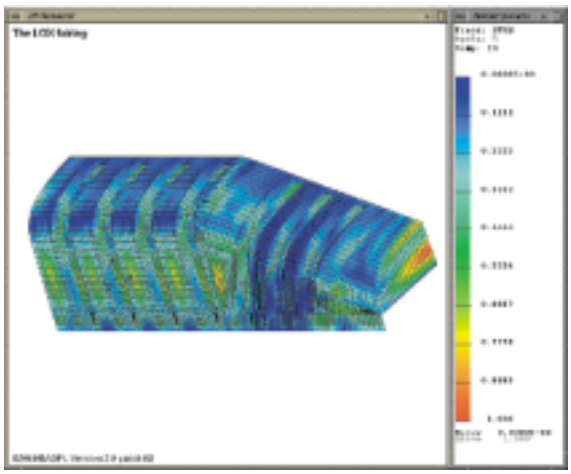
The development of fabrication technology for structures made of composite materials has been continued in national programmes, in co-operation with Fokker Aerostructures and SP Aerospace and Vehicle Systems, as well as in the framework of European EUCLID and Brite/Euram programmes. This is a multi-disciplinary activity, combining the selection of materials and process parameters, and includes design, design optimization, numerical analysis, and experimental validation.

Resin Transfer Moulding

Resin Transfer Moulding (RTM) is a relatively young technology with great potential to produce high quality, cost-efficient composite components, because it can be automated to a large extent. To develop the capabilities for the automation of the RTM technique, an extensive co-operation was initiated with the Department of Applied Mechanics and Composites of the Faculty of Mechanical Engineering of Twente University. Under contract to the NIVR, the resin film infusion technique was being evaluated for the production of stiffened skin panels. Within EUCLID RTP 3.15, focused on the RTM-fabrication of a military fin box, a method to monitor the process parameters of the RTM process inside the mould was being developed. In co-operation with SP Aerospace and Vehicle Systems, heavy landing gear components were being developed with the RTM technique based on current 'metal' designs for the NH90 helicopter, a national CODEMA programme, and the F-16, as a technology demonstrator. Within the framework of EU project TANGO (Technology Application to the Near-Term Business Goals and Objectives of the Aerospace Industry), NLR has started the fabrication of fuselage frames for the full-scale composite fuselage 'barrel' section, to be made using RTM. Several beams are being fabricated by RTM for the JSF programme of Fokker Aerostructures. Within the framework of the NIVR Space Programme (NRT), the design of a composite LOX fairing for the Ariane 5 launch vehicle was optimized, using NLR's code B2OPT, for Fokker Space.

Thermoplastics, Low Cost Manufacturing Technology

Apart from RTM and similar techniques, NLR also developed or applied other techniques to manufacture composite structures. In co-operation with Fokker Special Products, new thermoplastic matrix materials for higher service temperatures were being investigated. In order to qualify PPS/Carbon for usage up to 105 degrees C, an extended qualification programme has been initiated. Adhesive bonding of PPS and the effect of Corona surface treatment were also investigated. Consultation with respect to low cost manufacturing techniques has been provided to a regional cluster of composite manufacturers, an activity funded by the Ministry of Economic Affairs. Royal Huisman Shipyard was supported in the design and production of composite masts.



Finite Element model of LOX fairing for Ariane 5 launcher

Structural Design

Design methods were being developed for the aerospace industry, and design optimization methodologies were being developed within the framework of national and international programmes. Also, explicit structural designs and modifications of these were validated, either experimentally or numerically, for the industry and the RNLAF. NLR has upgraded Fokker's software to UNIX standard, and is subsequently providing support regarding maintenance and quality control.

Design Methods

Under contract to the NIVR, a design method has been developed for metal corrugated ribs, in accordance with the fabrication process used by Fokker Aerostructures. Several design methods and related philosophies were being developed for Fokker Aerostructures, focused on a possible participation in the development of the JSF. Design methods have been developed for composite corrugated ribs, for the configuration of sandwich run-outs, for shear webs with holes, and for bolted joints in composite parts. An optimization method for stiffened panels was developed on the basis of B2OPT, as well as a method to generate load sequences for crack growth calculation. Also, the influence of the simplification of fatigue spectra for composites, and the feasibility to integrate material qualification and structural certification programmes for composites have been investigated.

To support the GLARE development, a method to generate stress-strain curves, based on the constitutive properties was developed. The capabilities to predict buckling of GLARE panels were evaluated by testing and analysing stiffened panels, loaded in shear or by a combination of shear and compression. Analysis methods were developed to predict crack initiation and fatigue crack growth. Several design methods were developed in international co-operation. Failure criteria for skin-stiffener interfaces and for delaminated zones were developed in EU project EDAVCOS (Efficient Design and Certification of Composite Aircraft Structures) and failure criteria for bolted joints were being developed in the project BOJCAS (Bolted Joints in Composite Aircraft Structures). Under contract to EADS of Hamburg, tests and analyses were carried out to support its composites damage assessment methodology.

Optimization and Structural Synthesis

Numerical optimization is a key element of the structural design development at NLR. New applications and developments were pioneered with the versatile in-house code B2000/B2OPT. The EU project named MOB (Multi-disciplinary Optimization of a Blended Wing Body) was initiated. In this project, B2000 will be used to size the structure. The design will include piezo-electric devices to deform the aircraft shape in a controlled way, in order to allow the regular steering devices to be eliminated. Under contract to the NIVR, a programme to develop a computer-assisted structural design environment was initiated. The objective of this programme is to integrate design and analysis tools with an optimization capability, for which B2OPT is the testbed. Under contract to Fokker Aerostructures, a fuselage panel optimization code for the Airbus A380 was enhanced.

Design Validation

The final evaluation of a structural design, and of newly developed design methodology, requires full scale component testing. For URENCO Aerospace a technology project to develop a composite helicopter drive shaft was being carried out. In this project, full-scale components were tested in torsion under environmental conditions and with ballistic impact damage. The design was supported with finite element analysis. Under contract to EADS of Toulouse, an Airbus A340 fuselage panel was tested in NLR's specially developed Multi-axial Fuselage Panel Test Set-up. The panel was subjected to circumferential loads, transverse pressure and axial loads, representative of cabin pressure and fuselage bending (due to taxiing and gust loading). For the same customer, bi-axial lap joint tests were carried out.

Structural Mechanics

The ability to model structural response by computational methods is of great importance to speed up the design process, to reduce the technical risk of a selected solution, and to reduce the extent of time consuming and costly experimental programmes. Numerical solutions for the structural response are sometimes the only solutions possible, for instance in the analysis of crash and impact events. Further benefits of computational methods are achieved with the simulation of fabrication

processes, to generate *first-time-right* designs, which will significantly reduce financial risk.

Stability Analysis

The influence of damage and delaminations on the stability of composite structures was studied in the framework of EU project EDAVCOS, and in GARTEUR Action Group (SM) AG-22, Design Methodology for Damage Tolerant Composite Wing Panels. In Garteur Action Group (SM) AG-25, Postbuckling and Collapse, the effect of plasticity, mode-jumping and skin-stiffener separation on buckling and postbuckling behaviour are addressed. The capability to compute the buckling behaviour of stiffened GLARE panels, including the occurrence of plasticity, was evaluated.

Under contract to Jansens en Dieperink Company, the influence of the content of silos on their buckling behaviour has been investigated.

Vibration Analysis

The topic of active damping of vibrating structures is of interest for space applications and for equipment isolation in military aircraft and helicopters, and was addressed in GARTEUR Action Group (SM) AG-23. The interest of the Ministry of Defence in the subject has resulted in NLR's participation in EUCLID programme VIBRANT (Vibration Reduction by Active Control Technology). For this programme an evaluation was made of end-user requirements for Commercial-Off-The-Shelf equipment. Furthermore, an inventory of possible applications in helicopters of the RNLAF and the RNLN has been made, to define an equipment vibration isolation system to be used as a demonstrator. For Fokker Aerostructures, acoustic fatigue analyses of structures excited by a random acoustic loading were carried out. For the USAF and DWA, a manufacturer of metal matrix composites (MMC), stress analyses were carried out of the F-16 engine access cover with ventral fins, based on dynamic loading conditions, which were measured in-flight. This project has resulted in a proposal for design modifications. Within the framework of CODEMA project CLAAS, dynamic analyses of an F-16 wing pod were carried out to analyse the effect of vibrations on the characteristics of patch antennas.

Impact Dynamics

Crash and impact are load cases for which structural concepts are developed to achieve improved safety of aircraft and operations. EU programmes CRASURV (Crash Survivability of Composite Aircraft Structures) and HICAS (High Velocity Impacts of Composite Aircraft Structures) were focused on the development of structural concepts and computer codes for structures made of composite materials, including the case of bird strike. NLR's contribution to EU programme CAST (Crashworthiness of Helicopters on Water, Design of Structures using Advanced Simulation Tools) is the development of a fuselage bottom skin panel concept, aimed to resist the water pressure upon a forced landing, in order to extend the time for evacuation. The EU programme CRAHVI, Crashworthiness of Aircraft for High Velocity Impact, was defined to develop design methodology and both deterministic and stochastic analysis capabilities for composite leading edges of horizontal stabilizers. For the RLD, a computer code was being developed to model the collision of an aircraft with approach light structures near runways, in co-operation with Twente University. The code has been validated by comparisons with test data obtained from wing sections hitting approach light structures at 140 km/h. The test data were made available by manufacturers in Finland and Canada.

Fatigue and Damage Tolerance

The expertise of NLR in the area of fatigue and damage tolerance has been applied in contracts from ESA. Within the framework of GARTEUR Action Group (SM) AG-26, NLR participated in the development of life prediction based on of equivalent initial flaw size distributions. Under contract to NIVR, the Strip-Yield model of plastic deformations near cracks was improved by refining the description of constraint effects. Initiation and growth of cracks in GLARE material were studied, and models for the description of the observed behaviour were formulated.

Materials Modelling

The analysis of the structural response for the case of complicated loads caused by impact and crash loads, or the simulation of fabrication processes which involve large displacements of material, for instance, require modelling of non-linear material

properties. Under contract to the NIVR, a model based on momentum and energy conservation considerations was developed to simulate the high-rate plastic deformation of aluminium in the friction stir welding process. Stress and temperature distributions were also computed, and compared with experimental data. A simulation method to compute plastic deformations was being developed for sheet forming technology.

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 NIVR Space Technology programme (NRT), a new design concept for the hot structure of a rudder for the X38 re-entry vehicle has been developed.

Computational Science

New developments in the area of structural mechanics and computational science were introduced in 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 TU Delft and Twente University both operate and contribute to the code. The aeronautical research institutes DLR of Germany and CIRA of Italy also use the code, which accommodates the exchange of software developments.

The optimization module B2OPT has been extended with dynamic constraints to solve complex, non-symmetric frequency response design problems. Public domain iterative solvers were implemented and tested, which allows large volume element based problems, with over 150,000 degrees of freedom, to be analysed on cost-effective PC-hardware. A dedicated solver was made, and tested, to solve even larger problems, with 10,000,000 degrees of freedom, by means of NLR's SX-5 supercomputer, for steady state temperature analyses. The development and implementation of piezo-electric overlay elements was completed in a project conducted in the framework of the NIVR Space Programme. This enables structures with piezo-electric layers to be analysed and optimized. Within the framework of the EU project HICAS, material models for composites under high strain-rate impact loading were validated.

Certification Tests

Certification tests on materials and design concepts for the J-nose of the Airbus A340 500/600 were performed under contract to Fokker Aerostructures. Based on these results and preliminary tests on the materials and design concepts for the J-nose of the Airbus A380, BAe Systems has chosen the Fokker Aerostructures concept for this aircraft.

The certification tests on the main spar and the wing panels of the Fokker 60 were completed.

For Aerospatiale, biaxial tests were carried out on lap joints.

Fatigue test on fuse pin of Airbus A340 300/ 600 main landing gear

Field Emission Scanning electron microscope combined with energy dispersive material analysis equipment that became operational

In close co-operation with Fokker Aerostructures and EADS, the Mega-barrel programme of the Airbus A380 was started. During this programme, Glare material will be tested as a fuselage material.

Both static and dynamic certification tests were being carried out on the main landing gear break pin of the Airbus A340 500/600, under contract to Fokker Aerostructures.

Service Support

In conjunction with Fokker Services a modification of the overhead panel of the Fokker 100 was carried out for Korean Airlines.

An evaluation of the maintenance requirements and regulations for small aircraft was performed under contract to the RLD.

For TA under contract to Fokker Services, AAA radomes were designed, manufactured and tested after wind-tunnel tests performed by NLR.

Facilities and Equipment

Test House

The control systems and data loggers of the static and dynamic test facilities were modernized.
The creep test facilities and the furnaces were further extended.
For non-destructive testing, an acoustic Emission Inspection System (Mistras 2000) was purchased; the evaluation phase was started.

Material Research Equipment

A field emission scanning electron microscope has become operational in combination with a new energy dispersive material analysis system.
A new climate room of 4 by 3 by 2.5 metres has been installed for environmental testing.
A fully digitized light microscope has been purchased.

Manufacturing of Fibre Reinforced Material

A data acquisition system was installed for the RTM and autoclave processes.

Newly installed large climate test chamber

3.5 Space

Summary

In 2000 NLR space activities have been focussed on both technological developments and application oriented research. Some of the projects constitute further development of work initiated in the past, while some others are new and explore new areas of interest, following the emerging needs of customers.

Examples of new work include the activities in support of the development of the Global Navigation Satellite System (GNSS) with the following elements: support to system design and analysis, design and realization of specific measurement, simulation and evaluation equipment, operational validation of applications such as aviation, and safety analysis. Projects carried out include an EGNOS non-European user assessment (ECUREV) and support to the definition of Galileo in the GALA (Galileo Achitecture Definition Study) and GalileoSat projects.
Also new initiatives were undertaken to further increase the co-operation with the value adding industry to enhance the operational use of remote sensing data in commercial applications. NLR is focusing its activities on the development of necessary ground and data infrastructure such as the RAPIDS mobile groundstation and the NEONET data infrastructure.

Other emerging research activities in the technological developments include the development of new test and verification technology in preparation of the Gravity Field and Steady-State Ocean Circulation (GOCE) and First/Planck missions of the European Space Agency (ESA) and the development of a new cooling concept for high-density electronics, the Flat Swinging Heat Pipe.

Examples of further development of work initiated in the past are the Mission Preparation and Training Equipment (MPTE) for the European Robot Arm where an initial delivery has been installed at ESTEC in Noordwijk. Good progress has been made in the development of Sloshsat FLEVO, a mini satellite for the study of liquid dynamics and liquid management problems in space. Testing has been completed successfully, with only the combined vibration test with the system that ejects the satellite from the Space Shuttle remaining to be executed.

NLR has further developed and strengthened its expertise acquired over the past few years in various domains such as the International Space Station utilization activities, microgravity payload development, thermal control and many remote sensing application projects.

It is recognized by NLR that small satellites and/or constellations of small satellites are of increasing importance in different space application programmes. NLR participated in various projects in this field.

Global Navigation Satellite System

In the ECUREV project, led by the Spanish company GMV, NLR is responsible for the identification of non-European (multi-modal) user groups which benefit from a potential European Geostationary Navigation Overlay Service (EGNOS) extension. Within this framework a demonstration facility has been developed, to be tested by NLR in a remote location. The facility consists of a monitoring station and a transportable Receiver Integrity Monitoring System connected to the EGNOS System Test Bed.
NLR has been involved in the GalileoSat Definition Study project of ESA as a subcontractor of Alenia Spazio of Italy for dependability and safety (or RAMS) analysis of the GalileoSat System, the Space Segment and the Ground Segment. Consequently considerable insight has been developed in the functionality, architecture and performance aspects of Galileo and associated service performance in terms of accuracy, availability, continuity and integrity. NLR has also acted as subcontractor of Astrium Ltd. of the United Kingdom for the definition of site requirements for part of the Ground Segment elements.

NLR has contributed to the Galileo Architecture Definition Study (GALA) for the European Commission (EC) as a subcontractor of GMV for the specification of validation tools required for the Galileo system. This included the specification of tools for system analysis, system simulation at different levels of detail and tools to support measurement campaigns.
NLR experts have been members of the GALA Support Team, a consultant in the definition of the verification and validation methodology to be applied for Galileo.

Utilization of the International Space Station

In co-operation with Atos-Origin, NLR has contributed to the development of a demonstrator of the Advanced Crew Terminal (ACT) in support of a Protein Crystal Growth drawer experiment. ACT supports the crew in space laboratory operations with a set of generic tools, e.g. procedures, multi-media support and virtual control panels. The ACT development makes use of the latest Internet and 'Web' technology. Preparations have been started to ensure that mini-satellite Sloshsat FLEVO will be able to use the ACT user interface and data storage service on-board the Space Shuttle.

The set-up of a European Drawer Rack Facility Responsible Centre (EDR-FRC) was investigated as part of the ESA definition study for the European decentralised operations ground segment. NLR represents the Dutch Utilisation Centre (DUC) in this multilateral project, focusing with Belgian co-partner SAS on the EDR-FRC definition activities. Various definition documents have been developed that allow for an operational scenario encompassing an EDR-FRC at ESTEC supported by Belgian USOC (User Support and Operations Center) and the NLR-DUC.

The Lidar Performance Analysis Simulator (LIPAS) simulates the Doppler Wind Lidar (DWL) when accommodated on the International Space Station (ISS). This simulation has been developed under ESA-contract in co-operation with the Royal Netherlands Meteorological Institute (KNMI). The LIPAS software has been upgraded for general use and updated to allow for a new system configuration at ESTEC. A CD-ROM containing a user manual, software and presentation material completed the project.

In 1999 the Erasmus User Centre (EUC) at ESTEC had been upgraded for the promotion of the International Space Station. In 2000 further progress was discussed with ESA, especially the transition activities at EUC towards integration with a Facility Responsible Centre for the European Drawer Rack, a payload contribution to the ISS. A major part of the ESA television transmissions from the EUC about the International Space Station could be followed at NLR using a satellite dish originally intended for receiving ERS-1 data.

Antenna for dissemination of ERS data also capable of receiving transmissions from the Erasmus User Centre

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 ISS. Preparation and mission support will take place at the Mission Control Centre and Rocket and Space Corporation 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 instructor training and support tasks such as software maintenance.
The initial, or Pre-Flight, delivery of the ERA MPTE has been installed at ESTEC in Noordwijk. After a year of integration and testing at NLR, a pre-shipment test is carried out to demonstrate to the prime contractor Fokker Space and customer ESA the user-required functionality. After shipment to ESA these tests were repeated and, in a collaborative effort with Fokker Space, some fine-tunings and minor updates were implemented.

Sloshsat FLEVO

NLR is the main contractor for Sloshsat FLEVO, a mini satellite for the study of liquid dynamics and liquid management problems in space. The

behaviour of water in an instrumented tank in the satellite will be monitored to help understand how sloshing affects the attitude and orbit control of space vehicles. The micro-gravity disturbance by liquid in a tank is determined as well. Of the total mass of 129 kg of Sloshsat FLEVO, 33.5 kg is liquid water in a smooth 87-liter tank. Sloshsat FLEVO is to be launched from the Space Shuttle, and operated for two weeks from the ground via the Space Shuttle communication channels.

Most spacecraft system level tests have been performed, such as thermal-vacuum tests, metrology and alignment measurements, end-to-end functional tests, and EMC testing. The determination of the centre of mass and moment of inertia required special attention because of the stringent experiment accuracy requirements. A torsion wire test set-up was developed, a concept already proven successful in an earlier project. Sloshsat FLEVO testing has been completed, except for the combined vibration test with ESAJECT, the system that ejects the satellite from the Space Shuttle. After this final test the spacecraft will be ready for integration on the Shuttle Hitchhiker Bridge, 7-8 months before launch. At present a launch opportunity has not yet manifested itself.

Preparations were started to support the Sloshsat FLEVO project with the Advanced Crew Terminal user interface and data storage service on-board the Space Shuttle.

Sloshsat FLEVO mini satellite in flight configuration

Thermal Control

Convective Interfacial Mass Experiment (CIMEX)

In the framework of the ESA Microgravity Application Promotion (MAP) project, NLR together with a European team of experts, has started the Convective Interfacial Mass Experiment (CIMEX), which consists of four different experiments to be carried out in the Fluid Science Laboratory (FSL) aboard the International Space Station (ISS). One of the constituents is CIMEX-3, NLR's Versatile Two-Phase Loop Experiment, a multi-purpose loop with mechanically and capillary pumped option, different types of evaporators (capillary and swirl), and the possibility to operate using different fluids.

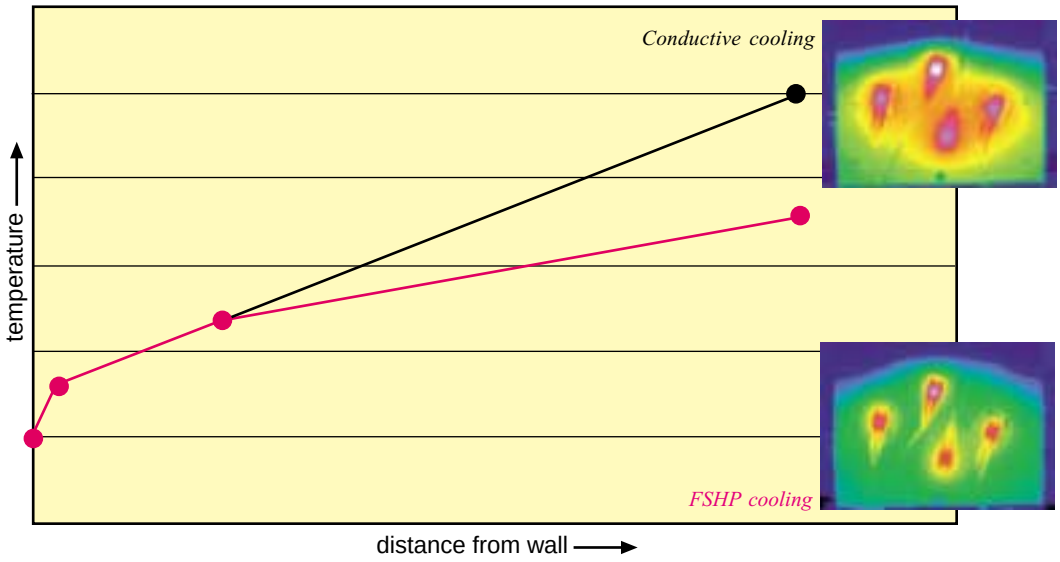
Primary objectives of the CIMEX-3 experiments are to study micro-g two-phase flow and heat transfer issues. To allow optical measurements of two-phase heat transfer to be made, transparent (swirl) evaporators and high efficiency low pressure drop condensers have been developed and incorporated. Furthermore the void/mass fractions in the adiabatic line can be measured, so that the NLR vapour quality sensor (VQS) can be calibrated in orbit using several working fluids. The observations of the flow inside the transparent components and the VQS data are used for flow pattern characterisation and creation of flow pattern maps.

Another important objective is the viability demonstration of mechanically and capillary pumped two-phase loops operating with different fluids or mixtures.

The actual breadboarding and building of the loop will be done in close co-operation with Bradford Engineering B.V.

Thermal Control of AMS

In co-operation with NIKHEF (Netherlands Institute for Nuclear and High-Energy Physics, Amsterdam) NLR is involved in the thermal design of the Alpha Magnetic Spectrometer (AMS). AMS is a particle physics detector, aiming at measuring the mass, charge sign, momentum, and energy of particles and antiparticles in order to establish their identity. It will be installed on the ISS late in 2003,



Typical temperature predictions for a conductive plate and a Flat Swinging Heat Pipe (FSHP) and corresponding infrared images

for the duration of three to five years. AMS is being built by collaboration headed by Nobel Prize laureate S.C.C. Ting, from the Massachusetts Institute of Technology.

NLR and NIKHEF are working together with Carlo Gavazi Space (Italy) and OHB Systems GmbH (Germany) for the overall thermal design of the AMS, where NLR is responsible for all two-phase thermal control technology required for efficient heat removal. The baseline is to minimise thermal hardware and costs, and to avoid active loops where possible. For the thermal control of one of the detectors, the AMS Tracker, NLR is designing a mechanically pumped carbon dioxide two-phase loop. The Tracker, located inside the vacuum case, is surrounded by the cryogenic magnet, which must not receive any heat from inside. Moreover, the Tracker has rather severe requirements regarding spatial and temporal temperature gradients. This and the existing complicated three-dimensional configuration require that the power dissipated in the Tracker (136 W) must be removed by means of an active two-phase loop.

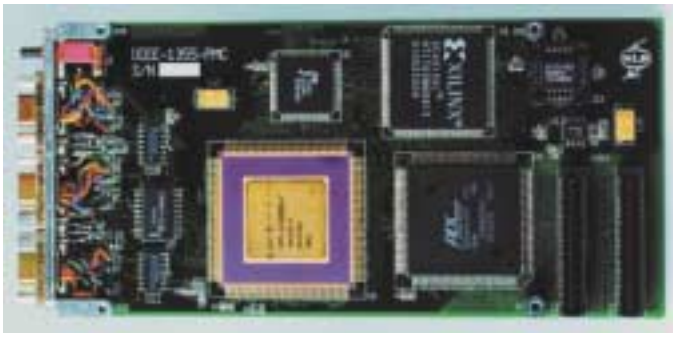
Design issues include the space qualification of a mechanical pump, the temperature requirements during the full spectrum of ISS operational attitudes, and the operational lifetime of 3-5 years.

Flat Swinging Heat Pipe

A new cooling concept for high-density electronics, the Flat Swinging Heat Pipe, has been developed in co-operation with Bradford Engineering B.V. of the Netherlands. The Flat Swinging Heat Pipe is suited for application in satellites and aircraft. This passive cooling concept does not have the drawbacks of pumped systems and has a much better performance than other passive cooling systems, such as pure conductive systems, because it combines the advantages of two-phase heat exchangers, a small amount of working fluid and high performance, with those of passive systems. Passive systems do not require moving parts or electric power, have low masses and small volumes, and make possible flexible design and micro-g to high-g operation.

Test and Simulation

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, and based on experience with the development, production and use of test equipment for scientific satellites such as XMM-Newton and INTEGRAL, NLR is developing a next generation of Test and Verification Equipment (TVE) for spacecraft avionics systems, such as the Attitude and Orbit Control Subsystem (AOCS). Starting points for the developments are the



A 1355 PMC module with three DS-DE links for the SpaceWire VME interface for on-board links

application of existing relevant technologies, modularity, scalability, and re-use of tools, equipment and results during the various phases of the spacecraft life cycle.

The next generation Test and Verification Equipment under development by NLR will offer: a real-time simulation environment based on EuroSim, a checkout environment based on SCOS-2000 and a modular VME Front End. This Front End will provide interfaces to the spacecraft data buses inluding existing test interfaces for MACS and OBDH bus and new ones for the MIL-1553 bus, the new PSS-04-256 standard OBDH bus, and the SpaceWire (upgraded IEEE-1355) data link. It will also provide analogue and digital stimulation and monitoring interfaces to spacecraft hardware required for hardware-in-the-loop closed loop testing, and an interface of the real-time simulation environment with the SHAM OBC emulation equipment.

SpaceWire/IEEE1355

The new SpaceWire serial high speed on-board data link (derived from the IEEE 1355 standard) has been promoted by ESA and CCSDS. The real time front-end system of the Test and Verification Equipment (TVE) (see above) has been extended to communicate with this new spacecraft on-board data bus/link and the AOCS unit electronics.

Presentations on the development of the IEEE1355/SpaceWire VME interface and obtained data rate characteristics have been given at the ESA SpaceWire workshop and the project final presentation at ESTEC. The commercialisation of the IEEE1355/SpaceWire VME interface will be done by Satellite Services B.V.

Turbidity Sensor

At NLR a sensor has been developed for real-time, on-line measurements of turbidity in liquid media. The sensor is suitable for the measurement of the biomass of bacteria growing in a liquid medium. At present the interest in the application of bacterial metabolism as part of conversion processes, e.g. wastewater purification, biological air filtering (BAF), is increasing rapidly. Especially for an enclosed environment such as the International Space Station, understanding such conversion processes is of vital importance. The turbidity sensor has successfully been used for measuring bacteria growth at the Bioclear B.V. premises in Groningen. The use of the sensor in the future experiments of Bioclear under microgravity conditions has been investigated.

In addition to space applications, various designs based on the same principle can be developed for earthbound applications where the observation of particle suspensions or dispersions is involved.

Remote Sensing

Operational Ground Systems

The mobile ground receiving station for remote sensing satellite data, RAPIDS, has successfully and rapidly been deployed in Bulgaria in the framework of the Dutch Ministry of Defence programme for co-operation with middle and east European countries. Steps are taken to set up long lasting co-operation between NLR and Bulgarian institutes.

RNLAF personnel unloads RAPIDS antenna for a demonstration in Bulgaria

In the framework of the military development project EUCLID RTP 9.8 on data processing and handling for military satellite surveillance systems, the RAPIDS mobile satellite receiving station was upgraded for the reception of data from the Indian Remote sensing Satellite (IRS) and the Advanced Synthetic Aperture Radar (ASAR). ASAR is an imaging radar sensor on board Envisat. Software was developed for automatic geocoding of received SPOT images, for distributed processing of SAR and optical data and for the development of a user interface for the visualisation and manipulation of image information. A series of three demonstrations will be given to European armed forces. These activities include participation in exercise JPOW-6 (Sicily, Italy) and demonstrations at the Western European Union Satellite Centre (Torrejon, Spain).

Satellite Remote Sensing

Constellations of small satellites are of increasing importance in earth observation. In relation to this development, NLR participated in various projects and programmes.

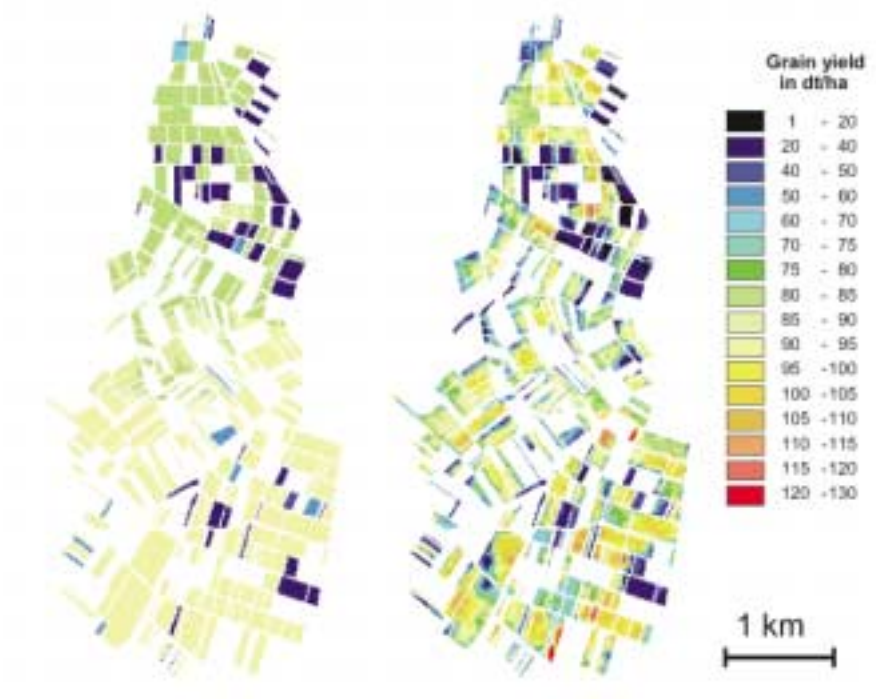
NLR started co-operating with Surrey Space Centre Ltd. in the framework of the Disaster Monitoring Constellation Programme. This constellation comprises five small earth observation satellites providing daily imaging of any area on the globe. NLR will be responsible for the realization of the data processing facilities on the ground.

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

The EUCLID RTP 9.6 programme is focussed to a large extent on the application of small satellite technologies in military earth observation. Within this programme NLR co-ordinates the research into cloud sensing, i.e. imaging performance improvement based on the use of real-time cloud cover information. In addition, NLR is responsible for the specification of the baseline of a geostationary cloud mapper mission.

Optical Remote Sensing Observation Models

The models OSCAR and SAIL, developed at NLR in the past to simulate the observation of vegetated surfaces by means of optical remote sensing, have been applied in two ESA studies. The OSCAR study was aimed at investigating the potentials of the future earth explorer land mission (LSPIM) for the advanced retrieval of biophysical



Improving the estimation of crop yields using a combination of crop growth models and remote sensing images. Left: crop yield map predicted from crop growth map only; right: improved and more detailed crop yield map by combination with remote sensing data.

land surface parameters by means of a hyperspectral and directional imaging spectrometer. With the use of numerical experiments it was shown that by model inversion of hyperspectral and directional data a large number of surface parameters could be retrieved.

In the ESA study GeoBIRD and in collaboration with VISTA GmbH, of Munich, a special two-layer version of the SAIL model has been developed in order to facilitate the combination of optical Remote Sensing data from the operational satellites Landsat and SPOT with a vegetation growth model. In this site-oriented approach, simulated images, based on SAIL computations and growth model outputs, were compared to actual images. The differences were fed back to adjust the driving parameters of the object model (leaf area index, fraction dead leaves and soil moisture) until they matched. From the results spatially distributed maps of local crop yield and plant density could be derived. The conclusion has been drawn that this advanced assimilation of remote sensing data in a geographic modelling environment appears very promising.

Remote Sensing Applications

For the Photo Interpretation Section of the RNLAF 311 Squadron, the DIRECD image processing system was upgraded and extended with an additional mode for the exploitation of data coming from the digitized Infra Red Line Scanner (IRLS) sensor of Orpheus.

For the UNMEE mission NLR together with TNO-FEL produced both paper and digital satellite image maps of the area of operation.

Work on the use of remote sensing for precision agriculture was continued with Wageningen Agricultural University, and the developed techniques were used in a study for the Dutch Gasunie on crop damage assessment as a consequence of pipeline presence.

Support was given to the Dutch Police in investigations on the firework explosion in Enschede, by generating a three-dimensional model of the explosion area and assisting in the analyses of the observations by witnesses.

The European Space Agency (ESA) has awarded the Sarcom consortium a contract to distribute data world wide from the ERS and Envisat radar satellites. The consortium, formed by Spot Image, has brought together eight major players in the Earth observation market, all of whom distribute SPOT, ERS and RADARSAT data. NLR with Geoserve are both part of Sarcom consortium. NLR started the distribution of Ikonos high resolution optical data.

Data Infrastructure

The Internet implementation of the Netherlands Earth Observation Network (NEONET) was completed by NLR. With this major achievement, an important information network is offered to national users of earth observation data. Topical Nodes installed at recognized centres of expertise offer thematic information and span up a network providing pointers to earth observation resources. Currently, Topical Nodes are installed at the Royal Netherlands Meteorological Institute (KNMI, Sciamachy Data Centre), Rijkswaterstaat (Dutch Coastal Net and Waternet), TU Delft (TU D, DEOS) and the Geomatics Business park. The main node, called Apex, in the hierarchy of nodes has been installed at NLR.

NEONET was built on the in-house developed software tool Clubs. Clubs is a generic tool for exchanging metadata between different platforms and different databases. Clubs has been developed using state-of-the-art technologies and standards such as Java, Java Servlets, XML and XSL. It can be easily adapted to support a wider or other range of metadata. Based on this concept NEONET will be able to exchange information with the European earth observation information infrastructure, which will be based at ESA/ESRIN (Italy). Interest was expressed by ESA/ESRIN to use the NEONET/Clubs software as part of this European system.

As part of the ESA project SatCast (Satellite multicast for web applications), NEONET successfully demonstrated its capabilities to synchronise information networks using satellite communication links.

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 in which NLR continued its ICT and mathematics support were air traffic management; consultation, command and control in military environments; process, product and service 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 airport support research and technology development tools and facilities at DERA, DLR and NLR.

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.

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. The analysis of health and usage data using on-line analytical processing and neural networks was set up.

In the area of simulation, training, visualization and virtual environments, NLR continued the development and testing of the Mission Preparation and Training Environment (MPTE).

NLR supports customers in process, product and service improvement. With the use of ICT, computer-based working environments are created that support the conservation, accumulation and re-use of know-how and products. Tools were developed that make it possible for NLR to act as Application Service Provider by giving customers access to working environments.

In the area of robotics NLR continued participation in the development of the European Robot Arm (ERA) at Fokker Space. This concerned exception handling and software architecture, development and testing for the Mission Preparation and Training Equipment (MPTE). The first version of the MPTE software was developed and tested, meant for supporting the preparation, simulation, validation, verification and on-earth monitoring of ERA missions.

In the area of surveillance, NLR continued the development and maintenance of sensor data processing systems for civil and military use. This concerned the ARTAS tracker for EUROCONTROL application, its military version MARTAS and radar quality monitoring tools. Industry was assisted in R&D with respect to a management system for air and vessel traffic.

In the context of European R&D programmes NLR contributed to the development of several virtual environments for engineering support. This work concerned software, mathematical methods and organizational aspects of the use of advanced information and communication technology.

System simulation and control engineering were supported by contributing to the development of the configurable simulator tool EuroSim and an automatic model transfer tool between EuroSim and commercial model generation products. Results of the developments were integrated in the working environment for computer aided control engineering for optimal usability.

In the area of computational physics attention was paid to numerical and modelling aspects of a multi-block Navier-Stokes solver and a space-time Euler solver.

The development and operational support of NLR's Information and Communication Infrastructure was continued. The further adaptation on requirements in the field of Virtual Enterprises, including Application Service Provision was directed to information storage, security, reliability and information exchange with national and international customers. NLR started the innovative integration of IT tools for European Virtual or Extended Enterprises. In this context attention was

paid to tools for Secured Networking, for Multi-company Workflow Management and for Navigation through distributed, heterogeneous Product Data Models.

Air Traffic Decision Support Systems

Registration and Analysis

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 information on noise to recordings of actual flight tracks, complaints and flight plan information. FANOMOS is operational at Amsterdam Airport Schiphol, Rotterdam Airport and Maastricht-Aachen Airport.
Under contract to the Netherlands Ministry of Transport, and under contract to Air Traffic Control the Netherlands, improvements and extensions to the functionality of FANOMOS have been realized. Data acquisition systems located at the Air Traffic Control site at Maastricht-Aachen Airport and the RLD site at Schiphol were dismantled and replaced by the new FANOMOS Input Processor system. The new system has been installed at the Netherlands Ministry of Transport / RLD and proved to be stable throughout the year, enabling flight data to be processed continuously.
Under contract to Deutsche Flugsicherung (DFS), the latest version of the FANOMOS server system has been made available to DFS. It has been installed turnkey in Offenbach am Main, Germany.

Monitoring

For Amsterdam Airport Schiphol, NLR was responsible for the life cycle support of the Runway Use Inspection System (*Baangebruiks Controle Systeem*, BGCS).

Airport Planning and Decision Support

One of the focal points of research on decision support systems is planning in complex environments where incomplete information, uncertainty and time constraints play important roles. A new approach was added to the methods and tools already in use: the representation of planning problems in a constraint-reasoning environment. NLR has created a basis for the specification and implementation of constraint relaxation problems, which are a special type of constraint reasoning problems. The results of this research have been conserved in NLR's Decision Support Facility, in which all results of decision support research projects are integrated. This facility provides a working environment for decision support research and software development.

Departure Sequencing

Collaborative Decision-Making (CDM) has been defined as a key concept for the ATM2000+ strategy of EUROCONTROL, aimed at improving information exchange between the actors in air traffic – air traffic service providers, airspace users and airports – to enhance the way they work together at the operational level. In the framework of ATM applications for CDM, NLR has investigated a departure-sequencing algorithm that computes optimal take-off times for a given take-off order of aircraft. This algotithm is based on an algorithm earlier designed for arrival sequencing.

Consultation, Command and Control

Decision Support, Planning and Tasking

In co-operation with DERA, the Pilot-oriented Workload evaluation and Redistribution (PoWeR) project was continued. 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 completed. In the first experiment, predicting airborne target manoeuvres using real-time case-based reasoning was investigated. The second experiment concerned a Self-Protection Electronic Warfare manager, in which scheduling and execution of counter measures against threats have been investigated. Finally, research was started into the feasibility of real-time Bayesian Belief networks to deal with uncertainty in on-board tasks. Together with TNO-TPD's three-dimensional sounds experiment, these experiments were being integrated into the final demonstrator of the project.

NLR has successfully finished its contribution to EUCLID RTP 6.1 'Advanced Information Processing for a Command and Control

Workstation'. The goal of this programme, carried out by eighteen participants from seven countries, has been to accelerate the application of artificial intelligence (AI) and advanced software engineering methods, such as agent-based and object-oriented approaches, in Command, Control, Communications and Intelligence (C3I) systems. NLR has participated in the area of decision support, planning and tasking, with research focussed on artificial intelligence techniques for time-critical planning and re-planning. Research results have been implemented in a demonstration system for the allocation of sorties and artillery to prioritised targets in a military peace enforcement scenario. This demonstration system also incorporates the results of the other participants in the project, and forms the basis for an integrated Decision Support Facility capable to support air, army and navy commanders.

Military Databases

A number of developments in civil database research appear to be promising for military information systems as well. Multi-media databases form one such development. Under contract to the Royal Netherlands Navy, NLR has carried out research into an architecture that facilitates the storage of and access to different types of media servers in an integrated manner. The main properties of the architecture are modularity and extensibility. The results are expected to be relevant for integrated storage and use of military images, video, text and other media.

Interoperability in Command and Control

In the future, more and more military operations may have to be conducted by coalitions of NATO nations. This places new and more important requirements with respect to interoperability on the Command and Control (C2) systems in use by the various NATO nations. These systems must have the capability to exchange information. In 2000, NLR participated in two NATO projects related to interoperability: JWID, JointWarrior Interoperability Demonstration, and NIETI, NATO C3 Interoperability EnvironmentTesting Infrastructure.

JWID is an annual event where experts from the industry, public sector and warfighters are brought together to witness demonstrations of off-the-shelf and new and evolving technologies that solve Command and Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) interoperability issues for joint and combined warfighters.
At JWID, NLR, in close co-operation with the Netherlands Ministry of Defence and the Royal NetherlandsAir Force, demonstrated the interoperability of ICC and OMIS-2. ICC is the initial CAOC capability, developed by NC3A and in use at ICAOCs (Interim CombinedAir Operations Centers) as the predecessor ofACCS. OMIS-2 is the modernised Operations Management Information System, developed by NLR and operational at Volkel Air Force Base. The systems were connected via a prototype interface, which has successfully been demonstrated during the JWID2000 demonstration period at SHAPE (Mons, Belgium) against an operational scenario as a background.

The mission of the NIETI is to provide an integrated multi-national testing capability making maximum use of existing NATO and national testing facilities, with a management structure to employ the capability. Within NIETI, NLR participated in the project team and took part in discussions related to interoperability testing environments.

Reliability, Availability, Maintainability, Safety and Certifiability

Health and Usage Monitoring Support

NLR has participated in research aimed at the development of an aircraft prognostics and health management (PHM) system.A general architecture for such a system has been developed based on a cycle of on-board measuring and off-board learning and improving. The main goals of a prognostics and health management system are to find relations between aircraft operational performance data and aircraft component status, and to predict aircraft component degradation or failure based on these relations. PHM enables scheduled maintenance to be replaced by on-condition maintenance, which reduces the overall aircraft lifecycle costs.
In this context, NLR has also performed research on neural networks to find relations between aircraft operational parameters and strain gauges

for structure fatigue monitoring. The results are promising and may lead to the replacement of strain gauges by software (virtual sensors). This research has been performed by ICT specialists and structures specialists of NLR in close co-operation with maintenance experts from the Royal Netherlands Air Force.

Assessment of Wake Vortex Safety

A probabilistic safety assessment is being carried out as a work package of the collaborative European research project S-Wake, in close co-operation with NATS, DFS, ONERA, and Sofreavia. The overall objective of this work package is to extend the WAVIR methodology that includes an independent risk criteria framework for wake vortex induced accident risk and a toolkit. The methodology and toolkit are applied to a number of scenarios in order to quantify the safety levels under current practice flight regulations, considering different classes of weather and a matrix of different aircraft weight classes. Modified concepts (e.g. aircraft design changes, operational improvements, or weather type specific safe separation distances) that could allow a larger airport capacity are evaluated as well. To validate the probabilistic wake vortex safety assessment model, data from Flight Data Recording (FDR) analysis will be compared with safety assessment results obtained for Heathrow airport. Up to 80,000 flights will be analysed and approximately 250 to 300 wake vortex encounters are expected to be identified.

Risk Analysis of Simultaneous Missed Approaches

The increase in air traffic has necessitated the development of new and advanced Air Traffic Management (ATM) procedures for busy airports such as Schiphol. For some proposed ATM procedures, ICAO regulations do not yet exist, and a thorough safety assessment that incorporates the roles of Air Traffic Control (ATC) and pilots is required.

A risk analysis of simultaneous missed approaches on Schiphol converging runways 19R and 22, where the Obstacle Clearance Altitude (OCA) of runway 22 is proposed to be reduced from 350 ft to values below 200 ft, has been made. This allows runway 22 to be used during actual CAT-I weather conditions, which will support the optimisation of the arrival scheduling.

Schiphol Runway Lay-out

Guidelines for the adoption of a risk criteria framework to judge the acceptability of collision risk were given. Based on the integration of three NLR facilities – Information System for Safety and Risk analysis (ISTaR), Traffic Organisation and Perturbation AnalyZer (TOPAZ) and Flight Track and Aircraft Noise Monitoring System (FANOMOS) – an existing risk model is extended to enable the collision risk of the proposed ATM procedure to be determined.

Numerical evaluations show that the collision risk may attain an unacceptably high level under certain conditions, especially when approaching aircraft on runways 19R and 22 both make straight missed approaches, and ATC does not intervene. For trying to maintain the collision risk at a low and acceptable level, some risk reducing measures are identified. In particular, ATC monitoring and instructing – turn right! or climb to! – to aircraft, conducting a missed approach on runway 19R in case of a previous straight missed approach on runway 22 is required.

Provided that the identified measures are applied, the proposed reduction of the OCA of runway 22 to values below 200 ft is risk neutral within a broad spectrum of missed approach procedural aspects, and may be judged adequately safe. This conclusion is also valid for the possible future situation where the final missed approach altitude is raised from 2000 to 3000 ft and/or the wind criteria for the use of runway combination 19R / 22 is changed to 20/7 knots.

Reduced 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. The emphasis was on specifications for the development of software for the modelling of Altimetry System Error (ASE), Flight Technical Error (FTE) and Total Vertical Error (TVE) probability distributions. These distributions are used to estimate the probability of vertical overlap for aircraft at adjacent flight levels, a main parameter of the vertical collision risk model. 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. In that context, the revision of the ICAO Manual on the implementation of a 1000-ftVertical Separation Minimum was finalised.

South Atlantic Airspace Collision Risk Assessment SASAR

Under contract toARINC, two safety assessments were conducted for AENA. The first one concerned the feasibility of the implementation of a 50NM lateral separation minimum in a proposed new route structure in the EUR/SAM corridor between Europe and South America on the assumption that the airspace is RNP10 (Required Navigation Performance of 10 nautical miles). The second one concerned the feasibility of the implementation of the ReducedVertical Separation Minimum (RVSM) in the same route structure, assuming that the pertinent aircraft population will be MASPS (MinimumAircraft System Performance Specification) certified. The implementation of RVSM is expected to concur with the implementation of RVSM in Europe.

Safety Related to GPS NPA Approaches

Under contract to the RLD, a data collection programme to verify the accuracy of Global Positioning System (GPS) Non-PrecisionApproach (NPA) procedures was continued. Radar data on approaches to Beek runway 22 were collected using the FANOMOS flight registration system. These data are analysed and modelled by appropriate probability distributions. The obtained distributions have been 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 was compared with existing accuracy criteria as established by the ICAO OCP.

Process, Product and Service Improvement

Tool Kit and Middleware for Working Environments

NLR continued the development of SPINEware, under contract to NEC. SPINEware provides tools and middleware software to support the construction and application of working environments on top of computer networks. Such working environments provide the user with access to the computing capabilities of the computer network as if they were available from a single, easy-to-operate computer that may be customised for particular users, application areas, and projects. Details emerging from the use of different and usually heterogeneous computer systems are hidden from the end user, who therefore may concentrate on the actual computing job.

SPINEware was further enhanced and extended to meet demands from users and projects. The 'tool chaining' facility was enhanced to support the construction and usage of workflows, which are building blocks for the definition and application of business processes. The SPINEware middleware, which is based on the CORBA standard, was further developed in order to deal with firewalls, which contributes to the construction of working environments that may span several networks and enterprises. To support web-based access (i.e., via Internet, using a web browser only) to a working environment, as required in several national as well as international projects, the development of a graphical user interface based on Java was started. To support the marketing and application of SPINEware, a help desk is being set up. The help desk comprises several elements of user support, such as handling of service requests, set up and maintenance of product information and a web site, and training courses.

NLR has been using SPINEware to realize several working environments for the preservation, application, and even accumulation of knowledge – in the forms of tools, data, and documentation – in specific areas.

Working Environment for Safety and Risk Analysis: ISTaR

The SPINEware-based working environment for Safety and Risk Analysis ISTaR has been used in safety projects. ISTaR's graphical user interface provides developers and analysts easy access to risk analysis and safety information, models, and tools. Experience shows that the implemented workflows enable up to fifty times more simulation cases to be executed in up to four times shorter turn around times.

User interface of the working environment for safety and risk analysis

The main field of application is air transport, in particular accident risk models and tools for the evaluation of safety aspects of existing and proposed new Air Traffic Management (ATM) procedures. Models and tools were being integrated to assess collision risk between aircraft, wake vortex induced risk, navigation performance, external safety around airports, and causal safety.

Architecture for Airport Scenario Analysis Package

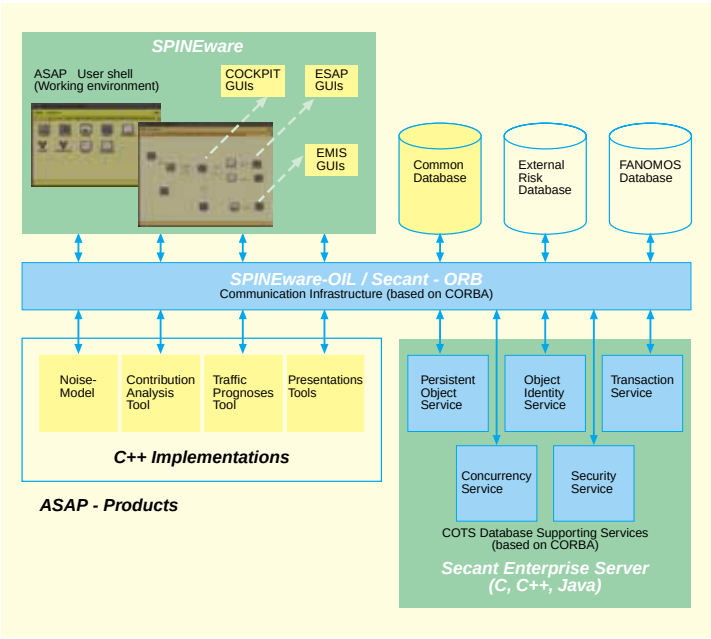
The software architecture of the Airport Scenario Analysis Package (ASAP) was developed. ASAP is a competence management system for air transport investigations that integrates specific domain competence by modelling it as distributed application components. These components reside in a distributed computing environment that uses the state-of-art Common Object Request Broker Architecture (CORBA), SPINEware and Enterprise technology (such as Java). The architecture facilitates access via Web browsers as described below.

Web Browser Access to NLR Resources

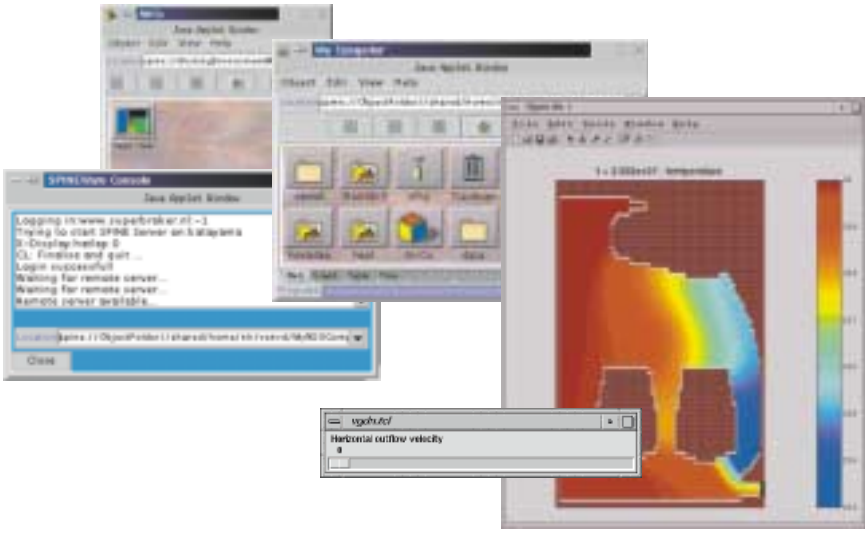
Tools were being developed that enable NLR to act as Application Service Provider by giving customers access to working environments of NLR. One of the tools is Superbroker, which facilitates access to NLR resources via a common Web browser. Superbroker has been used successfully for a real-time simulation including computational steering of an air curtain air conditioning system. Using superbroker such complex simulations can be made available to anyone with access to the Internet.

Information Processing for Design Modelling and Optimisation

Support was being given to the national 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.



Architecture for Airport Scenario Analysis Package software



Ilustration of the use of a Web browser applied for simulation on NLR's supercomputer

For the European aircraft industry, technology development and demonstration work was carried out in the area of design modelling, using the STEP Express Language. Subsequently, a working environment was developed in which control engineers can perform computer-aided engineering of new vehicle control systems highly efficiently, while managing system complexity effectively. This environment has been integrated into a larger prize-winning aeronautics design environment.
As a member of EvoNet, the ESPRIT Network of Excellence on Evolutionary Computing, NLR has been leading the Aerospace Working Group. In this group, information is exchanged of specific aerospace-related requirements for evolutionary computation, of current and future application areas, and of available tools. NLR has organized a first workshop in which co-operative research and technology development activities will be detailed. NLR's own focus is on evolutionary multi-objective optimisation.

In the area of data mining, domain expertise and data mining technology and tools were being used to identify new relationships, which enable design, and maintenance and logistics to be improved.

Working Environment for Computer Aided Control Engineering: ISMuS
NLR has further developed the virtual working environment ISMuS for ComputerAided Control Engineering (CACE). ISMuS (Information System for the development of Multibody Systems) facilitates the exchange of knowledge between various people and their CACE projects. Within ISMuS the model developer has access to several CACE tools and behaviour and control models of dynamical systems. ISMuS acts in part as a model repository. It appears to the user as a single virtual computer. A graphical user interface provides file manipulation, tool chaining and easy program activation through point-and-click and drag-and-drop operations on icons.

ISMuS is a so-called instantiation of SPINEware, a tool developed at NLR to create applications area working environments. ISMuS is an open environment for model development enabling new CACE tools and models to be incorporated easily.

An important ingredient of ISMuS is the Model-Oriented Software Automatic Interface Converter (MOSAIC). MOSAIC naturally fits into the virtual CACE working environment. Integration of the model transfer process into an automatically executable workflow reduces time and effort. It eliminates repeating and boring jobs that require the same actions time and again, and saves time in the transfer of model files from one system to another.

Working Environment for Software Engineering: ISEnS
The SPINEware-based working environment for software engineering ISEnS has been further

enhanced by the integration of tools for software development following the Unified Process and tools for the implementation of Capability Maturity Model (CMM) Level 2 key process areas, such as requirements management and software configuration management. Together with procedures and guidelines developed, these tools provide an integrated, cost-effective software development environment for producing the systems that current and future customers demand. The integrated software-engineering environment is being applied in, among other applications, the development of a new system for external safety analysis in the vicinity of large airports and a system for the analysis and control of noise limits around Amsterdam Airport Schiphol.

Optimizing the Management of Transport Services

A thematic network for optimising the management of intermodel transport services, THEMIS, was being developed under the Fifth Framework Programme of the European Commission, DG Energy and Transport. THEMIS addresses ongoing research and development in the field of ICT in multimodal freight transport, with the main objectives to understand and define the position of freight transport within the future European Intelligent Transport System (ITS). THEMIS also aims to organize the freight ITS components in an architecture that will achieve the most effective result for the users. One activity in the THEMIS project is the co-ordination of European Research and Technology Development projects in the field of multimodal freight transport by grouping them in clusters according to broad subjects. A member of the THEMIS thematic network, NLR contributes to the co-ordination of the clustering activities in the area of the European Air Traffic Management System. NLR also contributes to the activities on the synthesis of a common intermodal architecture framework taking into account traffic management systems.

Human Computer Interaction

Within the framework of the Intra-Active Inter-Action project (I2), studies are being carried out on a number of Human Computer Interaction technology topics. In close co-operation with Thales (formerly Signaal) and SARA, research is being done in the fields of Intelligent User Interfaces, Multi-Modal Interfaces, Virtual Reality and Distributed User Environments. The result of this project will be a demonstration platform showing the applicability and importance of these techniques within the aerospace domain.

Robotics

Operations

The specification of the Exception Handling (or Failure Detection Isolation and Recovery (FDIR) system) of ERA was modified due to changes in the ERA design and due to additional restrictions imposed by the ERA subsystems. All remaining threshold values were determined for the checks, and some other threshold values were updated due to test results with the real hardware. The FDIR system was further tested on the ERA simulator. About two-thirds of the tests were done, and no major problems were found. Requirements that could be verified by means of Review of Design or Analysis were considered verified by ESA.
In the framework of ERA Operations, diagnosis and recovery procedures were written, as were a number of test specifications to verify these procedures. The operations verification plan has been updated due to changes in the Flight Operations Manual. System engineering support was provided to solve problems found during general ERA testing.
In the framework of ERA Evolution, research was completed towards the use of closed-loop identification techniques using linear models for a predictive maintenance facility, which will aid in the determination of what and when maintenance (both hardware and software) should be performed. Research into the application of Kalman Filter based FDIR, taking into account the sensitivity for some non-linear characteristics of the ERA, was completed.

Simulation and Control Operations

Under contract to Fokker Space, NLR has developed the first version, the so-called Pre-Flight version, of the Mission Preparation and Training Equipment (MPTE) for the International Space Station (ISS) European Robotic Arm (ERA). The MPTE is a ground-based information system (hardware and software), supporting the preparation, simulation, validation, verification and on-earth monitoring of ERA missions. MPTE also

supports the training of cosmonauts in the execution of ERA missions and the evaluation of executed ERA missions.
The MPTE pre-flight version of the software component Mission Preparation has been finalised. This component supports the preparation and validation of ERA missions in a data format suitable for uplinking to the ISS. Support for mission verification will be added in the final version. By the end of 2000, approximately 60% of this software had been submitted to extensive white-box and black-box unit testing according to the baseline approach described in the ESA Software Engineering Standards PSS-05. For the Final version all code will be unit tested. The unit test approach was successfully demonstrated to ESA/ESTEC and Fokker Space. After the integration of the Mission Preparation component with the other MPTE software components and hardware the MPTE was submitted to integration testing and system testing in the NLR space laboratory.
The MPTE pre-flight version was delivered to ESA/ESTEC. NLR assisted ESA/ESTEC and Fokker Space during hardware and software installation and took part in the Post Delivery Inspection. NLR has provided maintenance support since.
Preparations were made for the Russian Instructor Training of the Mission Preparation component expected to take place early 2001.

Surveillance

ATM suRveillance Tracker and Server (ARTAS)

The ARTAS tracker was extended to process Mode-S elementary surveillance data, i.e. unique aircraft addresses and improved pressure altitude measurements (25-ft resolution). The extended so-called ARTAS V6 release constitutes the next major upgrade of the currently operational systems. ARTAS V6 was extensively tested and validated, both by NLR and the ARTAS main contractor AIRSYS ATM. Meanwhile, the ARTAS Users Group decided to incorporate some features of the non-released V5 tracker into V6; in particular the use of a height versus groundspeed profile for altitude estimation and the use of an outlier model for altitude measurements. Both features improve the performance of the ARTAS tracker under special circumstances. This second, V6B version, of the tracker was again extensively tested and formally accepted by EUROCONTROL.
NLR was also responsible for the correction of problems and the implementation of change proposals for the operational V4 version of the tracker in the scope of pre-CAMOS (Centralised ARTAS Maintenance and Operational Support). Pre-CAMOS is intended to ensure ARTAS support until the full CAMOS will be in operation, expected for mid-2001.
NLR contributed to the ARTAS course from INSTILUX by presenting the Tracker module.

Quality of Service Requirements for ADS in Europe (QoS)

The QoS study is a continuation of the work done for ARTAS2. ARTAS2 considers the benefits of using aircraft-derived data, such as Mode-S enhanced surveillance or ADS-B, together with data from classical radar sensors. The QoS study addresses the benefits from an extended multisensor environment assessment. To that end, the ARTAS systematic error estimation function was extended to incorporate ADS-B data, and a sensor accuracy estimator was developed. Both of these were tested using simulated data sets.

SASS-C User Requirements, Validation and Extension

ATC providers and industry use SASS-C (Surveillance Analysis and Support System - Centre) to evaluate radar and tracker performance, and for quality monitoring and incident investigation. In the face of new surveillance technologies, such as Mode-S and ADS, SASS-C needs to be extended. For the next major release, the objective is to incorporate the handling of Mode-S elementary surveillance data. User requirements were collected and drafts User Requirements Documents were delivered for the modules surveillance data collection, tracker analysis, surveillance sensor simulation and the user interface.

Tracker for Military Aircraft

NLR and HITT under contract to the Royal Netherlands Air Force (RNLAF) carry out the project MARTAS, 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. NC3A, with the help of NLR, has

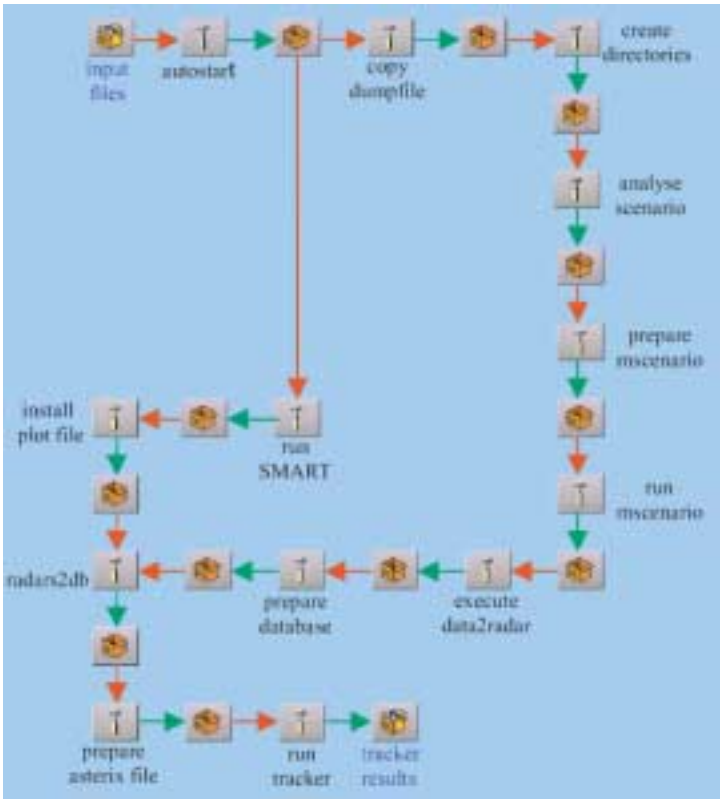
tested MARTAS using simulated scenarios, containing specific military manoeuvres. These tests have been performed before and after making modifications to the MARTAS tracker. This enabled NLR to show where the tracker algorithms (initially being developed for tracking mainly civil aircraft) could be improved to follow military aircraft as well. It also enabled NLR to show the benefits of the adaptations after the re-testing had been performed. The results of the test of NC3A, the NLR adaptations to the MARTAS tracker and the NLR analysis of the results have been presented, in co-operation with RNLAF, NC3A and HITT, to representatives of military and civil aviation authorities (including LVNL, RNLAF and EUROCONTROL).

In the mean time, NLR has started to prepare for the third and last phase of the MARTAS project; the validation of the adapted tracker against the EUROCONTROL standards as used for the acceptance testing of the ARTAS tracker. A validation test environment has been created, using SPINEware v3.0, that will automate the running of MARTAS validation tests.

Radar Quality Monitoring Tools

Air Traffic Control the Netherlands (LVNL) has asked NLR to assist in providing the LNVL Air Traffic Controllers with accurate estimates of the actual radar quality. To that purpose, NLR has assisted with the installation of a Radar Quality Monitoring (RQM) tool. The tool has been integrated with the SASS-C tool already in use by the LVNL, which automatically monitors the quality of the classical radars on a daily basis, under responsibility of the LVNL. Anomalies in the established quality figures are automatically reported via the internal LVNL email system.

NLR has also developed a number of tools for the LVNL to facilitate the quality assessment and monitoring of ASDE (Airport Surface Detection Equipment) radars. Again, these tools have been integrated with the SASS-C tool. Using these tools, the performance of both the current and the future ASDE radar (to be installed at Schiphol airport) can be monitored. The results from these tools will be used in the introduction of the fifth runway.



SPINEware-based workflow for the MARTAS evaluation environment

Virtual Environments for Engineering Support

Virtual Environment for Enhanced Aeronautical Concurrent Engineering

For several decades, European aeronautics companies have recognised the benefits of multi-national collaboration. New aircraft programmes are becoming increasingly complex and expensive. For competitiveness European companies are investing in the re-engineering of their processes, and have started to implement Concurrent Engineering techniques and, along with that, the concepts of Virtual or Extended Enterprises. The major European players in the aeronautics industry have decided to collaborate in the EU ENHANCE project (ENHancedAeroNautical Concurrent Engineering), a consortium of 14 contractors, including NLR, and 39 subcontractors.

NLR is leader of two of the nine workpackages, namely Information Technology and Support, and is Task Leader for four ENHANCE Tasks: COMITIF (Common principles for IT Infrastructure), Innovative IT, Concurrent Engineering and Support. Also, contributions are provided to scientific calculations and to Business Cases.

The often rather different IT environments of the participating companies have to be standardized and integrated into one targeted Common IT infrastructure for the Extended Enterprise. COMITIF defines such a Common IT infrastructure (hardware, software, protocols, networking services, database services, collaborative services, etc.).

Whereas the COMITIF task focuses on standard, off-the-shelf products, the objective of the Innovative IT task is to assess innovative IT technologies for Concurrent Engineering in Aeronautics. The industry has selected three major industrial topics for further research and development, i.e. Secured networking, Multi-company workflow systems and Navigation in distributed heterogeneous product data models. For each of these topics, illustrators are developed that will show the possibilities and advantages.

The objective of the secured networking illustrator is to enable reliable, flexible, secured business quality communications to take place between partners of the Virtual Enterprise over the Internet. The secured networking illustrator focuses on the implementation of Virtual Private Networks (VPN). A VPN typically uses the Internet as the transport backbone to establish secure links between business partners and extends communications to regional and isolated offices, significantly decreasing the cost of communications for an increasingly mobile workforce.

The objective of the workflow illustrator is to illustrate how partners with different workflow management systems can co-operate on a common, but distributed business process. Information Technology, and more specifically, workflow technology will aid to control and monitor the Concurrent Engineering (CE) business process. As participating companies intend to continue using their own workflow management systems, interoperability of workflow systems is a critical IT issue for interconnecting business processes.

The objective of the navigation illustrator is to illustrate a secured, standards-based, collaborative environment in which geographically dispersed members of a virtual enterprise will interact with heterogeneous data, which may have originated from other parts of the enterprise. End users will be enabled to simultaneously share ideas, resolve problems and evaluate and exchange information as well as contributing to product development by adding value to product data according to their roles.
An end-user of the system needs to transparently obtain, work with and return data to the Product Data Management (PDM) systems; he should not concern himself with the details of where the data is actually stored or how the system manages the data. Furthermore, access is required to structurally dissimilar data originating from a variety of disciplines.

In ENHANCE, NLR is also involved in supporting the implementation and application of Concurrent Engineering (CE) methodology in aeronautical industry and in the development of common principles for design calculation. In the CE support area reference models according to CE principles for the organization of aeronautical industries, and guidelines for implementation of such organisation are being developed. In the area of Common

principles for design calculation the recommended ways of working with respect to calculation in an aeronautical CE environment are being developed.

Air Management Simulation for Aircraft Cabins (ASICA)

ASICA (Air management simulation for aircraft cabin) is a Fifth Framework EU project that is carried out by a consortium consisting of 11 leading European industries and research laboratories. Led by NLR, it aims to improve the Environmental Control System (ECS) on board of aircraft such that air quality is increased. In this way the passenger's perception of comfort and the crew working conditions are improved. In addition, ASICA aims to diminish the fuel consumption due to ECS. Besides NLR, principal contractors are Liebherr Aerospace, EADS Hamburg, Nord-Micro, Lhotellier, and CERFACS.
ASICA was started by the identification of requirements and the analysis of existing ECS components to find root causes for failure to meet the requirements. NLR contributed with an analysis of the link between the ECS and avionics.

Models will be developed for software-based simulation of the steady state and time-dependent behaviours of the components of the ECS. These models will be integrated into a steady-state simulation model and a time-dependent model for the whole ECS system, including the cabin. NLR contributes to the development of the integrated ECS models. The state-of-the-art with respect to the generic problem of numerical integration of black-box models for steady state behaviour has been described, and recommendations for further approach have been made. The models developed will be validated in various hardware facilities at the ASICA partners' sites.

New concepts for ECS components will be developed on the basis of the root causes identified for not meeting the requirements. For the design and selection of the new concepts, the models developed in ASICA will be used. NLR will focus on an integrated modular architecture and on the development of controllers, that presents an alternative for current ECS control. The selection of alternative controllers focuses on multi-variable control methods, which can cope with the physical dependencies in the ECS system and which fit with an integrated modular architecture. The concepts selected will be validated in the hardware facilities.

To support the simulation of the integrated ECS model (and other models developed in ASICA) by the ASICA partners, NLR develops a Distributed Simulation Framework (DSF). The DSF will comprise NLR's computing facilities in the De-Militarised Zone and facilities to enable the ASICA partners to simulate efficiently on NLR's computing facilities. These facilities will be based on NEC's SPINEware middleware package. User requirements on the DSF have been agreed with the ASICA partners and an initial design for the DSF has been made.

Optimization of Airports, Including Landside (OPAL)

The project OPAL, a research and technology development project of the EU Fifth Framework Programme, was started. A consortium consisting of 16 partners, for whom NLR is the project co-ordinator, conducts the activities.

The objective of OPAL is to develop a facility for total airport performance analysis, where 'total airport' is used to indicate the complete airport operation as a combination of airside and landside operations. Major stakeholders, such as airlines, airport operators, and air traffic service providers, expressed the need for such a facility at workshops held at the European Commission. The ever-increasing growth in traffic demand shows the vulnerability of the entire air transport infrastructure: the airports are becoming the prime and foremost choking points within the system. One the difficulties experienced by the stakeholders is the lack of insight in the integrated set of airport processes and the individual process interdependencies.

To achieve the objective several existing simulator/tools for modeling certain parts of total airports and for addressing certain performance measures (e.g., capacity, delay, safety, cost-efficiency, and environment) will be connected by the facility. A selection of simulator/tool combinations will be tested and evaluated for one or more of the airports of Amsterdam, Athens, Barcelona, Frankfurt, Madrid, and Toulouse.

The OPAL facility then makes accessible geographically distributed simulators/tools; enables simulator/tool combinations to be selected for testing and validation for one or more airports; and enables these simulator/tool combinations to be operated for evaluation, what-if analysis and optimization. The added value of this facility is that it can enhance the ability of existing simulators/tools to co-operate; provides a unified and integrated platform for modelling and evaluating total airports (at different sides of an airport, at different levels of detail, and with respect to the interaction between landside and airside), can examine trade-offs between different kind of problems; and can support the choice of simulator/tool for specific types of analysis.

NLR will participate in all phases of the development of the OPAL facility. In particular it will contribute through its knowledge and experience in distributed simulation and middleware technology. Furthermore, NLR will provide various simulators/tools to the facility for modelling and evaluating scenarios for Amsterdam Airport Schiphol. The user requirements and operational concept were completed, and the design of the facility was begun.

Interaction Processes in Multi-Disciplinary Design and Optimization

A Computational Design Engine (CDE) incorporating multi-disciplinary design and optimisation (MOB) will be developed and applied to the design of a Blended Wing Body (BWB) aircraft configuration. The primary focus of the project is the development of tools and methods of working that facilitate the design of large scale and complex aeronautical products by distributed teams employing a variety of discipline-based programmes and approaches. The secondary focus is to demonstrate a CDE by the application to a problem of intrinsic interest, namely a blended wing body (BWB) aircraft that is a potential competitor to the A380 with some relevance to military aircraft design. One of the main roles of NLR in the MOB project is to facilitate the interaction processes among the different disciplines and the different partners in the project. This is being achieved by setting up an ICT infrastructure, the CDE based on SPINEware middleware, such that convenient and appropriate exchange of information and tools among the different players in the project is made possible.

System Simulation and Control Engineering

Configurable Simulator Tool EuroSim

The EuroSim consortium further develops EuroSim to access and support the international simulation community with state-of the-art simulation support. EuroSim developments are partly funded by NIVR.

NLR has conducted a EuroSim Model Interface Study to identify the types of simulation models the Simulator Development Environment must be able to handle. Investigations were carried out on the simulation model interfaces of the current EuroSim Mk2 system, the new requirements for the simulation model interfaces of the EuroSim Mk3 system, the Simulation Model Portability standard of ESA/ESTEC, the High-Level Architecture standard of the US DoD, and object-oriented technology. The study has been targeted at increasing the compatibility, interoperability, applicability, and portability of the coming EuroSim versions and its simulation models with respect to the international architectures, standards, and technologies for simulation systems, preserving the distinctive qualities of the EuroSim system itself.
At NLR, EuroSim has been integrated in the working environment for support of control engineering ISMuS, increasing the efficiency and quality of engineering activities. NLR also set up a Configuration Management Plan to support product development.

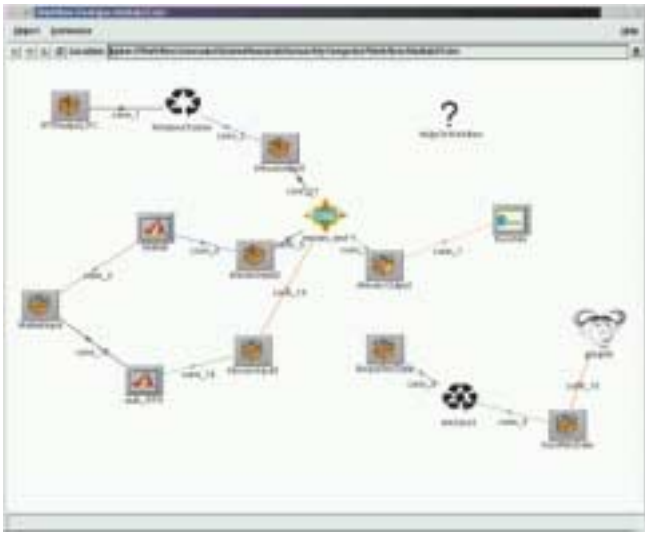
Automatic Simulation Model Transfer via MOSAIC

Under contract to ESA, NLR has further developed the Model-Oriented Software Automatic Interface Converter (MOSAIC). The MOSAIC tool automates simulation model transfer from MATLAB/Simulink to EuroSim. NLR has started work on automating transfer from MATLAB/Simulink/Stateflow to EuroSim. The Stateflow enhancement to MOSAIC will enable model and simulator developers to take advantage of Stateflow's state transition capabilities in the real-time environment of EuroSim. After completion of the Stateflow work, MOSAIC will be made suitable for model transfer from MATLAB/Simulink/Stateflow to ESA's Simulation Model Portability (SMP) standard.

MOSAIC is used in the aerospace industry. NLR has applied MOSAIC in several simulation projects, for instance for model development in the Affordable Digital Fly By Wire Flight Control System (ADFCS) project for NLR's Research Flight Simulator. The goal of this project is to develop architecture for affordable fly-by-wire (FBW) digital flight control systems for small commercial aircraft. ADFCS partners create models of flight control systems all over Europe with MATLAB/Simulink. NLR transfers the MATLAB/Simulink models of the aircraft with MOSAIC and implements them in the simulator. It has been experienced that automatic model transfer with MOSAIC significantly reduces time, cost, effort and error-prone source code editing. A feature of MOSAIC is that it does not in any way affect the mathematical logic of a model. Simulation results before and after a transfer with MOSAIC are identical up to machine level.
As demonstrated in NLR's working environment ISMuS, MOSAIC fits in the virtual CACE working environment. Integration of the model transfer process into an automatically executable workflow reduces time and effort even more.

Middleware for Man-in-the-Loop Simulators

NLR develops and maintains a number of real-time man-in-the-loop distributed simulators, such as NARSIM and TRS. Real-time man-in-the-loop simulators require complex software systems that can only be developed and maintained by dividing them into several relatively simple functional components. For these simulators a proprietary middleware suite has been developed. This suite, called GEAR (General Environment for ATM Research), supports software quality control and re-use of software components. In practice the simulation software components are distributed over several computers and are implemented in multiple programming languages. The GEAR middleware is a layer of distributed software that resides between the simulation software components and the operating system network services. GEAR enables all components to work together as a single, high-performance and flexible system, combining the flexibility of a middleware-based software system with the high performance required for real-time simulation. GEAR releases developed in 2000 provide support for the JAVA programming language.



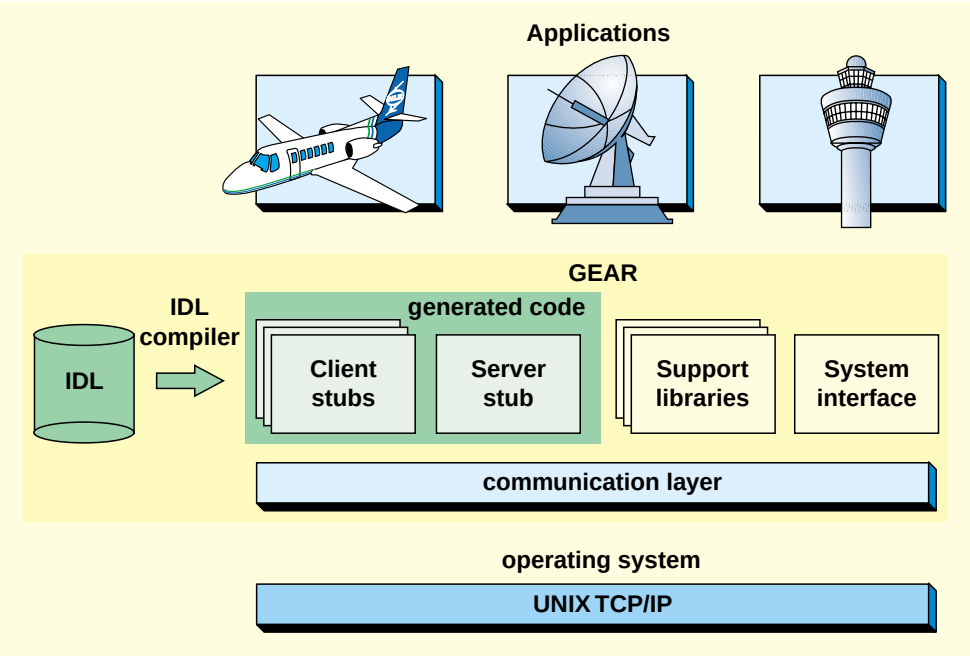
Workflow in ISMuS associated with simulation model transfer from Matlab to EuroSim

Automatic Debiting Systems

NLR has been supporting the Ministry of Transport in the process of selecting consortia for the delivery of automatic tolling systems. NLR supported simulations showing that with the right choice of system parameters the requirements on reliability of electronic fee collection could be met.
Additionally, NLR contributed to the realization, execution and analysis of tests with prototypes of the ADS systems. This concerned the testing of detection and registration systems along the A12 motorway, and the testing of the electronic fee collection system on the test track in Lelystad. Finally, systems for automatic license plate recognition have been compared and evaluated. The detailed simulations have provided insight in the critical points of the proposed systems, which proved to be very valuable for the definition of the experiments in practice.

Multi-disciplinary Design and Optimization

Progress has been made in the application of genetic algorithms and Pareto-front evaluation of multi-objective design optimization problems. These techniques have been applied successfully in an aerodynamic design study of an airfoil in which the objectives based on the lift and drag coefficients were treated in parallel but independently.



Architecture of man-in-the-loop simulators based on GEAR (General Environment for ATM Research)

Computational physics

The Multi-block Navier-Stokes Solver ENFLOW

The numerical accuracy of the flow solver ENSOLV in the NLR simulation system ENFLOW for viscous, turbulent flows around complex aerodynamic configurations was further improved. This system is based on the Reynolds-averaged Navier-Stokes equations and employs multi-block structured grids. In order to improve the prediction of the aerodynamic forces, the numerical accuracy of the flow solver was increased at the interfaces between the blocks of the grid. To improve the physical accuracy of the flow solver, work has been done on increasing the level of turbulence modeling from two-equation models to explicit algebraic Reynolds-stress models.

The Space-Time Euler Solver HEXADAP

The efficiency of the space-time algorithm of the space-time Euler solver HEXADAP was significantly improved by a more efficient quadrature rule for the face fluxes. This quadrature rule exploits the specific features of the discontinuous Galerkin method. The flow variations are used to expand the flux integrand into a Taylor series, of which the first terms are calculated exactly. Furthermore, the HLLC approximate Riemann solver has replaced the Osher scheme. Combination of these two improvements yielded a performance increase of a factor four. This increase demonstrates the maturation of the present method that is based on a discontinuous Galerkin finite element method, for time-accurate flow simulations on deforming meshes.

Based on a Fourier analysis of the discretized differential operator, the Runge-Kutta time integration method has been optimized for this particular finite element method. The optimized method allows local time steps two to three times larger than the previous method to be applied.

The space-time discretization has been validated for its shock-capturing capabilities for Sod's shock tube problem.

The NLR Information and Communication Infrastructure

The NLR Information and Communication Infrastructure (ICI) has continued to be put at the disposal of internal and external customers, and has been adapted to a growing need for information handling and exchange. Facilities for use as a Virtual Enterprise, including Application Service Provisions, have been installed and made accessible in the De-Militarized Zone. The upgrade of the Firewall system for more security levels has been started. A Product Data Management system, Windchill, for information management and exchange has been ordered.

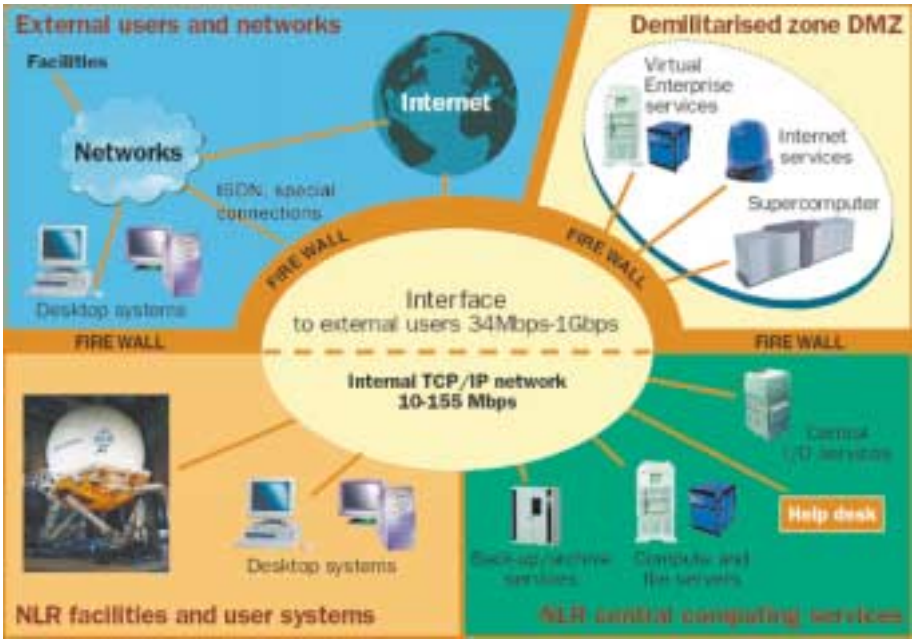
The ICI consists of a high-speed communication network and a variety of facilities, including a supercomputer, several other UNIX-based servers and several PC servers. The network connects the facilities to workstations, X-terminals, PCs and terminal equipment for research facilities. The number of stations connected was increased from 1941 to 2175. Two facilities of NLR located at Schiphol have been integrated by means of ISDN connections.

For compute-intensive simulations, NLR operates an NEC SX-5 supercomputer, a shared-memory supercomputer with 64Gbyte main memory and with eight processors. Each processor has a processing speed of 8 Gflops.

For further improvement of the availability, the backbone link between the two main sites, the least reliable part of the ICI, has been replaced with a redundant connection. The bandwidth of the connection can be varied, based on the operational need, up to 155 Mbits per second.

A firewall system has been selected on the basis of the security requirements of NLR, and ordered.

Data storage at NLR is by central data storage servers, so that data can be shared between staff working on the same project. The total size of the data stored on the central file servers having UNIX or Windows operating systems has increased from 963 Gbyte to 1500 Gbyte (1.5 Tbyte). The total number of files on these servers increased from 4,281,000 files to 6,850,000. In order to cope with the continuous growth of data, the implementation of a Storage Area Network (SAN) system has been started. During nights and weekends, the UNIX fileserver facility is used for data-backup. Backups can be made of all servers at NLR automatically. During the weekends a full dump is made. The total size of all full dumps during a weekend increased from 1 Tbyte to 2.7 Tbyte.



The Information and Communication Infrastructure of NLR

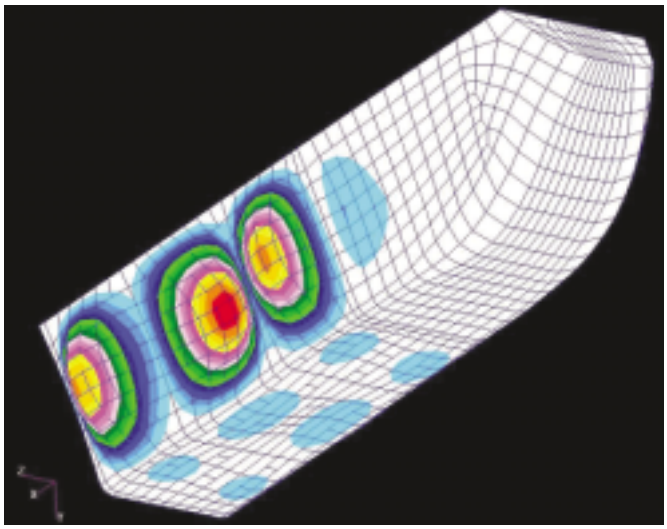
3.7 Avionics

Summary

The main areas of activities in the field of avionics were 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 the development of an extensive infrastructure of partly computer-based tools , for avionics systems performance assessment, virtual prototyping, systems design, electronics design, and computational electromagnetics.An extensive inventory of facilities for avionics flight testing provide the means for conducting flight trials for in-house and external customers operating aircraft in the Netherlands and abroad.

NLR has been involved in various aspects of future avionics systems for both civil and military use. In the field of civil avionics technology, NLR performed a case study for the Netherlands Department of Civil Aviation (RLD) related to the incremental certification of Integrated Modular Avionics (IMA), and, under contract to the NIVR, NLR continued its activities of a computer-based development infrastructure for avionics, including flight critical avionics.

In the field of military avionics, NLR continued to provide support to the Royal Netherlands Air Force (RNLAF), in particular on the evaluation of the mission avionics systems of the candidates for the replacement of the F-16. NLR continued its activities in the EUCLID project Avionics Architecture Evaluation Tool. With this tool, avionics architectures can be modelled, and their performances analysed. NLR continued the development of Embedded Training (ET) technology for fighter aircraft. ET provides the ability to train fighter missions in a virtual environment in actual flight. Together with seven international companies, NLR is involved in a EUCLID programme aimed at the development of an ET demonstrator for the AerMacchi MB 339 CD trainer aircraft. NLR participates in the design and development of the Nato Frigate Helicopter (NFH) Mission System of the NH90 helicopter. NLR develops a software module that performs track-to-track associations of tracks generated from surface and subsurface vessels, using information from sensors. The design of the algorithm for comparing tracks has been completed, and the development of the software was started. Activities in the development of the Avionics System Integration Rig (ASIR), focused on the development of the avionics mock-up for the NFH, were continued.



Above: reconnaissance pod on F-16 fighter; right: calculation of the deformation, caused by aerodynamic loads, of the surface of a reconnaissance pod to be used as a conformal antenna

In the field of sensor technology, NLR continued work on Phased Array Universal SAR (PHARUS), an airborne imaging full polarimetric SyntheticAperture Radar for remote sensing. PHARUS has made a number of flights on NLR's Citation II research aircraft. The EUCLID project New Technologies for Lightweight SAR (Synthetic Aperture Radar) was continued. The SAR antenna is composed of a number of identical tiles, each equipped with a number of Transmit/Receive Modules. NLR is responsible for the development of the digital control module that distributes the antenna beam steering data and gathers housekeeping data.

In the field of avionics computational electromagnetics (CEM), NLR was involved in several projects concerning antenna performance prediction and actual antenna measurements. NLR participated in the project Conformal Load-bearing Antennas on Aircraft Structures (CLAAS) for the assessment of the effects of surface vibrations and deformations (resulting from aerodynamics loads) on the performance of conformal antennas. Investigations in Electromagnetic Compatibility (EMC) problems included support to ESTEC on planned Radio Frequency Compatibility (RFC) tests on the ENVISAT-1 and support to the Dutch Radio communication Agency (RDR) on the measurement of field strengths near antennas.

Testing for environmental qualification increased strongly. For a number of customers, a variety of environmental qualification programmes were carried out, in which prototypes, ranging from avionics systems to cable harnesses, were subjected to various hostile environments.

In the field of electronics, NLR continued supporting Dutch industries preparing for participation in the development of the JSF. A major item is the application of Commercial- Off-The-Shelf (COTS) components. Participation in the development of avionics equipment for the NH90 helicopter was continued. Under contract to NIVR, the evaluation of new concepts for electrical power distribution has been continued. Under contract to EUROCONTROL, NLR continued its support of the design and development of Advanced Data Link Processor (ADLP) units.

NLR was awarded a contract for the development and delivery of the Service Electronics System for European Space Agency's Cells In Space (CIS-6) micro-gravity experiment. Under contract to the European Space Research and Technology Centre (ESTEC), NLR delivered two Data Collection Units (DCU), to be used in thermal testing in the Large Space Simulator (LSS) at Noordwijk. Under contract to ESA/ASTRIUM, support to Dutch industries in the design and qualification of non-volatile mass memory for use in the International Space Station (ISS) was continued.

In the field of wind tunnel instrumentation, NLR continued the development of the Facility Management System for the future Italian Icing Wind Tunnel. Research into advanced facility management systems for wind tunnels was also continued, as was research into Wind Tunnel Instrumentation and Signal Conditioning.

Research was carried out in the application of COTS components and obsolescence management.

The largest customer in the field of flight test instrumentation was the RNLAF. The instrumentation system installed in an F-16 MLU aircraft was adapted to new requirements. An important improvement was the installation of a high-speed camera system used for separation tests. Other projects were vibration tests for Stork Aerospace and Air Data System measurements for the Belgian Air Force. Experience gained in the development and operation of flight test instrumentation in extensive flight test programmes proved to be valuable for testing high voltage cargo train power systems.

Work for reconnaissance by the RNLAF was continued. Existing F-16 capabilities were adapted to the F-16 MLU. The first production models of an interface developed to adapt the new generic reconnaissance interface of the F-16 MLU to the ORPHEUS reconnaissance system were delivered. All four Medium Altitude Reconnaissance Systems

were delivered to the RNLAF after modification to MLU standards. A demonstrator of a digital data system for the ORPHEUS I/R line scanner was built and flight-tested.

For EUROCONTROL, data link trials were executed with experimental digital data link equipment for ADS-B applications installed on board NLR research aircraft. The Prototype Aeronautical Telecommunications Network (ProATN) project was concluded.

Involvement in GNSS navigation projects consisted of three parts. Evaluations of modern GPS receivers for accurate flight path measurements were performed, NLR participated in the EU ECUREV programme aimed at developing tools to demonstrate the EGNOS system in outer European regions, and the EU SHINE integrated GPS/AHARS receiver development programme was started.

Avionics systems

Civil Avionics Technology

Support to the Netherlands Department of Civil Aviation

A case study was performed for the Netherlands Department of Civil Aviation (RLD) related to incremental certification of Integrated Modular Avionics (IMA). The IMA concept provides the possibility to make changes to the configuration of the software applications. For example, applications can be added, or updates of applications can be installed without the necessity of overall re-certification. The case study was aimed at analysing the impact on certification activity. The specification data of the IMA-based Generic Avionics Scaleable Computer Architecture (GASCA), an EU Fourth Framework project, were used. A certification plan was prepared including the required data to obtain a so-called Technical Standard Order (TSO) approval for the Avionics Computing Resource (ACR) module and its applications.

Development of Infrastructure for Flight Critical Avionics

Under contract to the NIVR, NLR continued its activities for the development of a computer-based development infrastructure aimed at cost effective development of flight critical avionics. Activities concentrated on tools for requirements traceability and management.

Military Avionics Technology

Support to the Royal Netherlands Air Force (RNLAF)

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 the modelling of avionics systems and associated architectures. Especially, much attention was given to the evaluation of the mission avionics systems of the candidates for the possible replacement of the F-16.

Avionics Architecture Evaluation Tool (A^2ET)

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. With this tool, avionics architectures can be modelled, and their performances analysed.

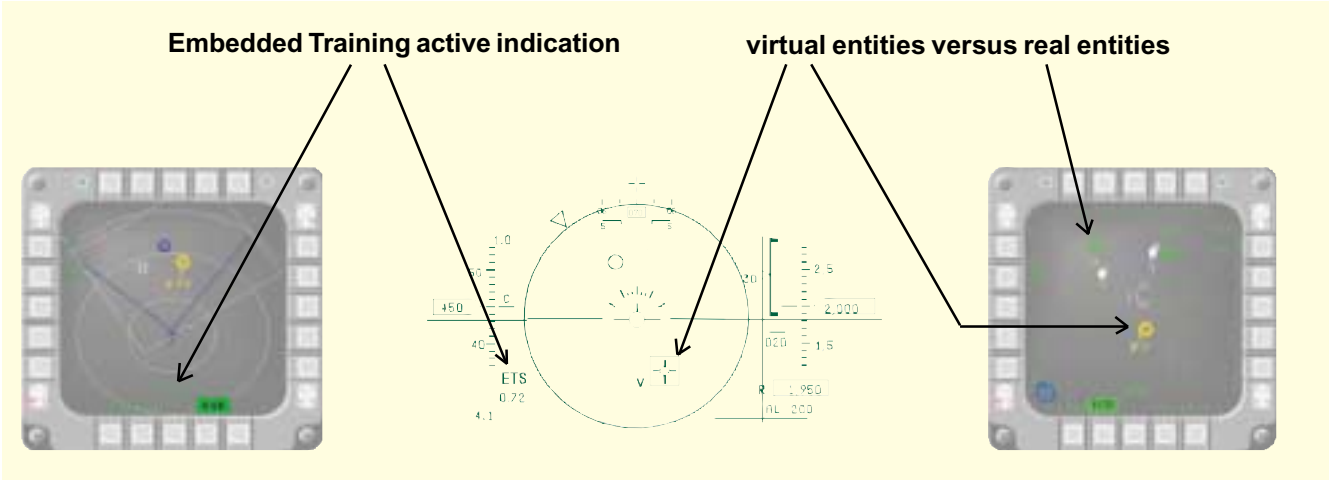
The tool consists of a 'Blueprint Manager', which provides a means to describe a complex avionics architecture. NLR has implemented a plug-in that evaluates the performance of the defined architecture. The plug-in contains a so-called 'Blueprint Interpreter' that fetches the required data from the blueprint repository and provides it to the performance models, implemented with SES/Workbench. Using the plug-in, NLR implemented a library of complex performance models of Integrated Modular Avionics (IMA) components. The application models use a standardised Application Programming Interface (API), and contain functional source code from an avionics application that normally runs on the target. The performance models for the avionics computer resource have the same API and process the service requests

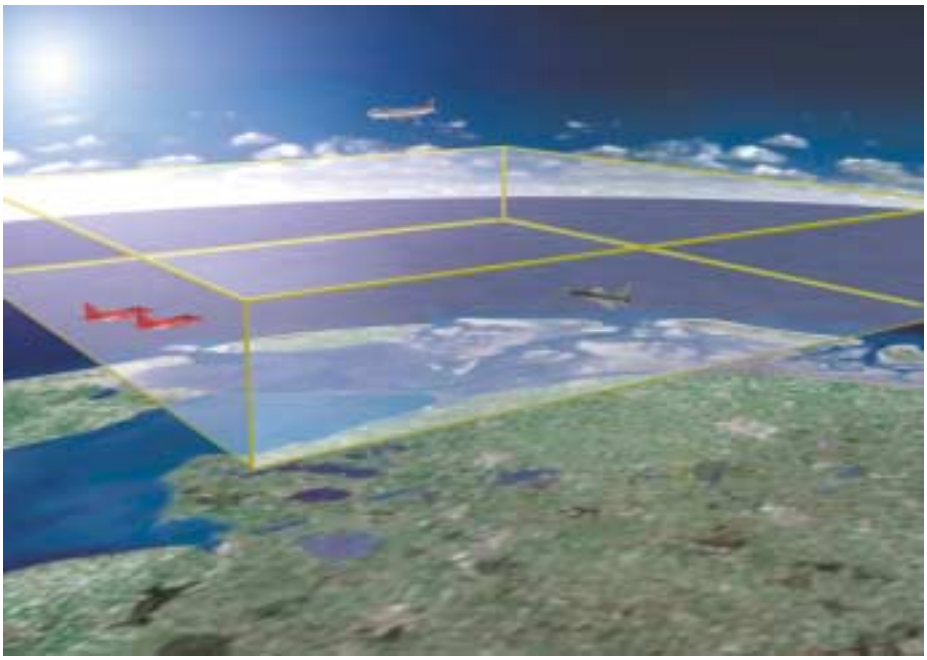
coming from the hosted applications. All details of the functionality are incorporated, including the emission of messages through I/O ports. Other models describe the network (avionics Ethernet), sensors, displays and actuators.

Embedded Training

NLR is involved in the development of Embedded Training (ET) technology for fighter aircraft, in close co-operation with Netherlands industry. ET has the ability to train fighter missions in a virtual environment provided to the fighter pilot. It allows the pilot to engage a 'training mode' during flight, presenting a training simulation on cockpit displays, which will enhance the effectivity of the training proces. Compared to ground-based training simulators, ET increases training fidelity since the pilot experiences the actual stresses and environment of flight manoeuvres, as well as alleviating the dependence on specific training areas.

Activities were focused towards system development followed by a successful evaluation using NLR's ground based National Simulation Facility (NSF). In addition NLR, together with seven companies, is involved in the EUCLID RTP 11.12 programme, which is aimed at the development of





Embedded training: F-16 MFD and HUD displaying simulated and real-world information (top), virtual training area mapped onto the real world (bottom, left) and ET mainpage scenario selection alpha to echo (bottom, right)

NH90 NFH Avionics Rig and flight deck

an ET demonstrator for the AerMacchi MB 339 CD trainer aircraft. NLR is responsible for the system and architectural design.

Interfacing and integrating an ET system with the aircraft's avionics, without compromising the safety of flight and the operational capabilities, poses a technical challenge. Imposing a virtual world on the pilot in flight requires the addition of functions to ensure safety of flight. A safety function must terminate the simulation in case of any flight hazard or equipment failure that could jeopardise the pilot, the aircraft or the surrounding environment.

During mission preparation an instructor is able to set-up a training mission for the pilot. After the ET mission a debriefing function replays the scenario, allowing 'post-flight' assessment of the pilot's performance and movement, a feature that will reduce reliance on highly instrumented training ranges. As indicated on the Multi Function Display (MFD), the pilot can select a specific training scenario. (Scenarios *Alpha* through *Echo* are available.)

ET reduces the dependence on training ranges by enabling mission simulations to be conducted in any suitable airspace. The technology under development enables the pilot to be made aware of both the real world and the virtual targets by indications on his MFDs and Head-up Display (HUD).

NH90 Mission System Development

NLR participates in the design and development of the Nato Frigate Helicopter (NFH) Mission System of the NH90 helicopter. NLR develops a software module that performs track-to-track associations of tracks generated from surface and subsurface vessels, using information from sensors such as radar, Forward Looking Infra-Red (FLIR), Electronics Support Measures, and sonar. The main goal of the module is to reduce operator workload. Currently, track associations of this kind are performed manually. Using the new software module, the operator confirms or rejects suggestions, and is relieved from the task of comparing tracks in detail. The design of the algorithm for comparing tracks has been completed, and the development of the software has been started.

Avionics System Integration Rig (ASIR)

Activities on the development of the Avionics System Integration Rig (ASIR) continued, and focused on the development of the avionics mock-up for the naval variant of the NH90, the NFH. The NFH is to enter into the operational service of the Royal Netherlands Navy in 2007. NLR participates in the design and development of the Mission System. By having a part of the hardware and software structure available, NLR is able to serve as point of contact, for both the Navy and the consortium building the NFH, where it comes to modifications and further development work.

Providing the pilot interface to visualise the effects of changes in the systems architecture is considered necessary.

Sensor Technology

Phased Array Universal SAR (PHARUS)

NLR continued work on PHARUS (Phased Array Universal SAR), an airborne imaging full polarimetric SyntheticAperture Radar for remote sensing, developed, built, and operated in co-operation between NLR, TNO-FEL, and TU Delft. In 2000, PHARUS has made a number of flights on NLR's Citation II laboratory aircraft. During these flights, new operating modes were investigated resulting in high quality imagery.

Lightweight Synthetic Aperture Radar (SAR)

The EUCLID project RTP 9.7 'New Technologies for Lightweight SAR (SyntheticAperture Radar)' was continued. The SAR antenna is composed of a number of identical tiles, each equipped with a number ofTransmit/Receive Modules. NLR is responsible for the development of the digital control module that distributes the antenna beam steering data, and gathers housekeeping data. The overall antenna command architecture was earlier developed by NLR in the RTP 9.3 project. It consists of a centralisedAntenna Control Unit, which controls the distributed, antenna mounted, Tile Control Electronics (TCE) units.

A detailed design and breadboard of the TCE was made, including the definition of the command and telemetry protocols between TCE andAntenna Controller. The TCE is a complex device performing many functions, and is implemented using FPGA technology.

Avionics Computational Electro Magnetics (CEM)

Antenna Technology

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

In order to assess the effects of surface vibrations and deformations (resulting from aerodynamics loads) on the performance of conformal antennas, NLR is involved in the project CLAAS (Conformal Load-bearingAntennas onAircraft Structures). Conformal antennas on aircraft allow non-conventional antenna locations such as the skin of the aircraft to be used. Antennas installed at these locations are, however, subject to steady and unsteady aerodynamic loads. The inertial forces and these aerodynamic loads will cause deformations and vibrations of the total antenna surface, having a negative effect on the antenna performance. The effect of these distortions on antenna performance will be most significant on highly directional antennas.As a pilot project, the technology is applied to a Side-LookingAirborne Radar (SLAR) antenna mounted on a reconnaissance pod mounted under a fighter type aircraft.

PHARUS image of Amsterdam Airport Schiphol; PHARE data by TNO, NLR and TU Delft

This generic SLAR antenna is a phased array antenna covering two faces of the pod: one part on the vertical side face and one part on the lower face of the pod. Radiation patterns are computed for distorted antenna surfaces.

Electromagnetic Compatibility (EMC)

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

NLR provided support to ESTEC with regard to the planned Radio Frequency Compatibility (RFC) tests on the ENVISAT-1, an advanced polar orbiting earth observation satellite that will provide measurements of the atmosphere, ocean, land, and ice over a five-year period. The satellite's payload consists of a set of instruments for measuring the atmosphere and instruments for measuring the surface through the atmosphere. The support by NLR's EMC laboratory consisted of providing information for the granting of a license by the Dutch Radio Communication Agency (RDR), looking into the aspects of human safety of ESTEC staff and visitors, assessing the Electromagnetic Interference (EMI) to ESTEC equipment, and reviewing the test procedures with respect to safety.

The growing number of antennas, especially those for mobile communication, has raised some fear for potential influence on human health. Local authorities have to issue permits to install these systems on the roofs of apartment blocks and near houses. In some cases disputes arise about the actual field strengths experienced by humans near the antennas. In support of the Dutch Radio Communication Agency (RDR), NLR derived a procedure for the measurement of field strengths near antennas. This procedure not only addresses the antenna masts for mobile communication, but also antennas for broadcasting, antennas for fixed radio links, and antennas of radio amateurs. This procedure was validated by the KEMA by carrying out measurements near a number of antenna configurations.

Environmental Qualification

A large increase in activities in the field of environmental testing occurred. For a number of customers a variety of environmental qualification programmes were carried out, in which prototypes, ranging from avionics systems to cable harnesses, were subjected to various hostile environments (temperature, altitude, vibration, EMC, fluid contamination, humidity, etc.).

Smoke Generation and Arc Tracking in Flight Deck Wiring

In recent years, aircraft wiring has been implicated in incidents involving smoke in the passenger cabin and on the flight deck of commercial aircraft. The Smoke generation and Arc tracking in flight deck Wiring (SAW) project sets out a series of test cases designed to address implications and consequences of over-current and insulation faults within flight deck wiring. A smoke test facility that enables the temperatures on the inside and outside of wire bundles, the degree of light obscuration, and the signals on 50 different wires as a function of time to be measured while a DC or AC overload current is applied, has been built. For visualization purposes, the process is recorded using a digital video camera. Different types of wire bundles and different compositions have been compared with respect to heat dissipation, smoke generation, and disruptions of the signals.

Electronics

Instrumentation and control

Wind Tunnel Facility Management Systems

Under contract to Turbo Luft Technik (TLT) of Germany, NLR together with its sub-contractor REACT of Canada, continued the development of the newest generation of Facility Management Systems 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 based on PCs with Windows NT operating systems. Important characteristics of the facility management system are: real-time behaviour, flexibility and easy extension of functionality. The system provides among other things tunnel control, model-control, high-level subsystem control, data

handling, data manipulation, visualization and video control. This icing wind tunnel will be equipped with a very extensive video system, intended for visual observation of icing conditions. All cameras and recorders will be remote controlled by the facility management system. Research into advanced facility management systems for wind tunnels was continued.

Wind Tunnel Instrumentation and Signal Conditioning

Under contract to DNW, NLR develops a new Data Acquisition System (DAS) interface for the DNW Data Acquisition System. The minicomputers with UNIX operating systems currently used for data acquisition tasks will become obsolete within the next two years. For the DNW, powerful PCs with Windows NT operating systems will replace them. The DAS interface will be realized using commercially available hardware and software (using the COTS approach) to the maximum possible extent.

Positioning System for Borehole Radar

In co-operation with T&A RADAR and TNO-FEL, NLR continued its involvement in the development of an advanced borehole radar instrument. Activities of NLR are in the field of mechatronics.

European Transonic Wind tunnel (ETW)

Under contract to ETW, NLR updated the Inclinometer Interfaces that are part of the measurement equipment for ETW wind tunnel data acquisition system.

Aviation

NH90 Remote Frequency Indicator

NLR continued its support to Dutch industries in the design and development of avionics for the European NH90 helicopter. Under contract to Schreiner Components 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, development and qualification.

Electrical Power Distribution

Under contract to the NIVR, the evaluation of new concepts for electrical power distribution and for switching/fusing have been continued. The aims are: enhancing system reliability by removing electromechanical parts, energy conservation and mass savings. To prove the new concept, prototypes have been built and functional and environmental tests have been performed.

Advanced Data Link Processor

Under contract to EUROCONTROL, activities were continued to support the design and development of the Advanced Data Link Processor (ADLP) units. The ADLP provides communication functions and application in conjunction with a Mode S Transponder.

Space

Sounding Rocket Instrumentation

As a sub-contractor to Fokker Space, NLR was awarded a contract for the development and delivery of the Service Electronics System for the European Space Agency Cells In Space (CIS-6) micro-gravity experiment. This experiment will be launched on a Swedish Maser sounding rocket. The service electronics system for CIS-6 is based on many of the elements previously developed for the Cells In Space (CIS) programme, including the Cosmic Dust Aggregation AG module launched in 1999.

Temperature Data Acquisition System

Under contract to the European Space Agency, NLR delivered two Data Collection Units (DCU). Two partners of ESTEC, IABG of Germany and Interspace of France are also involved in the project. This DCU is part of a new Temperature Data Acquisition System (TEMPDAS), which will handle measurement signals generated by thermocouples placed on the test object (Satellite) during thermal testing in the Large Space Simulator (LSS) at the Space Research and Technology Centre at 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 have a self-calibration capability. The DCU is space-qualified equipment. NLR has built and delivered two DCUs to ESTEC.

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

Under contact to ESA/Astrium, NLR continued its support to Signaal Special Products in the design and qualification of non-volatile mass memory for use in the ISS. Discussions with Astrium were continued about a next generation MSD incorporating solid state flash-memory for Columbus, based among other things on a study contracted by the NIVR. Furthermore Astrium awarded NLR a contract for the delivery of two flight boards for the Data Management System for the Russian Service Module and two flight boards for the Columbus Space Station.

Instrumentation

Measurement and Analysis Techniques for In-Flight Research

Position Reference System

A new GPS receiver was tested for applicability in highly accurate flight path measurements using differential code and carrier phase techniques. It was found that within a distance of 100 km from the ground station the position accuracy did not deteriorate by more than a few centimetres.

Parameter Identification

The migration of the library of data processing software supporting the Non-Stationary Measurement method (NSM) to the UNIX workstation environment of the Data Processing Station for Flight Test Data was completed. The method can be used for the identification of stability and control derivatives, for flight path measurements during stall tests, for angle-of-side slip and angle-of-attack measurements and for vane calibrations.

Wing Deflection Measurements

A method for measuring wing bending and torsion, based on the correlation between the actual and a reference situation of video images of a geometrical pattern on the wing, will be applied to an F-16 fighter aircraft to demonstrate its feasibility on that aircraft. Provisions for the mounting of the camera were installed and a black-and-white pattern was designed and applied to the wing.

Flight testing Uninhabited Aerial Vehicles

Research was done into the instrumentation requirements for flight testing of Uninhabited Aerial Vehicles (UAVs).

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 completed with the analysis of the data gathered during demonstrations at Le Bourget and in a ProATN/EOLIA flight trial campaign in the Netherlands.

GNSS Projects

Within the EU-projects SHINE and ECUREV, NLR is responsible for the testing of tools and equipment developed within the framework of the projects. In the SHINE project, a low cost integrated GPS/AHARS receiver will be developed. NLR will evaluate the performance of the equipment both in ground-based tests and in airborne trials. For ECUREV, NLR has performed tests in the Netherlands and at the Canary Islands on a demonstration set, developed for the promotion of the extension of EGNOS outside Europe.

Particle Image Velocimetry for Wind Tunnel Application

The EU's Fifth Framework project EUROPIV2 will demonstrate the 3-D stereoscopic capabilities of modern PIV technology. The project started this year. An experiment plan for the test to be conducted in the DNW-LST wind tunnel was set up.

Support to EUROCONTROL

Automatic Dependent Surveillance Data Link Tests

Research aircraft of NLR flew in Automatic Dependent Surveillance Broadcast (ADS-B) trials conducted by EUROCONTROL in Germany, France and in the Netherlands. The trials were aimed at assessing the performance and maturity of three candidate ADS-B technologies. A Mode S Extended Squitter, a VHF Data Link Mode 4 and a Universal Access Transceiver were installed in the aircraft. The Fairchild Metro II research aircraft

took part in three trials. In addition to the testing of the air-to-ground communication as in earlier trials, the air-to-air communication with a second aircraft was tested for all three datalink technologies separately. In the trial at Brétigny, France, NLR's Citation II acted as second aircraft. The third trial, in which a Swedish aircraft also took part, was organised by NLR in the airspace near the Dutch airport of Eelde.

Civil Flight Test Support

Flight Tests with Fokker Aircraft

For Stork Aerospace a flight test instrumentation system for vibration measurements on board a Fokker 50 was composed, installed and operated. For measurements on an F-28, an instrumentation package was readied.

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 was installed on the ship. This system was used to receive and process telemetry data from a Sea King helicopter instrumented by the UK Defence Evaluation and Research Agency (DERA). The design of a data acquisition system to be installed in a Cougar helicopter was started.

F-16 MLU Flight Test Instrumentation

Work under contract to the RNLAF for the extension and maintaining of a flight test measurement system in an F-16B MLU aircraft was continued. In close co-operation with the RNLAF, a high-speed camera system was installed in an adapted AMRAAM tip launcher on the aircraft. The camera system consists of five cameras remotely controlled from the aft cockpit. The system proved its value during separation tests of external fuel tanks. Several changes of the flight test instrumentation system were implemented including the measurement of currents and voltages of the aircraft's electrical power system, improvements of the cockpit instrumentation control and display system and the installation of a video camera located at the aerial refuelling light for monitoring wing deflection.

Hercules C-130 Air Data System Tests

To prove its capability to fly under the rules of the Reduced Vertical Separation Minima (RVSM) the performance of the Air Data System of a Hercules C-130 of the Belgian Air Force was assessed.

King Air SE-KDK of LFV Norrköping and Metro PH-NLZ for Automatic Dependent Surveillance Broadcast (ADS-B) flight test at Groningen Airport Eelde

Digital Infrared Image from first flight of Orpheus Infrared Line Scanner Digital Data System

NLR participated in the project by providing a trailing cone static pressure measurement system and a data acquisition system, and contributed to the development of the flight test programme. The instrumentation system was operated by NLR during the trial flight.

Military System Development

F-16 MLU/ORPHEUS Interface

Based on the ORPHEUS MLU Interface Demonstrator (OMID) developed in 1999 for the use of the ORPEUS reconnaissance system on the F-16 MLU version, an OMI production model was designed. Three units were manufactured and tested on board the F-16 MLU. The OMI fits in the F-16 pylon to avoid the need for modification of the ORPHEUS system itself. OMI converts the commands on the F-16 Generic Recce Interface (GRI) into signals compatible with the current ORPHEUS.

F-16 MLU/MARS Modification

As in the case of ORPHEUS, the Medium Altitude Reconnaissance System (MARS) was to be adapted to the F16 MLU 'Generic Recce Interface'. To this purpose a modification kit was designed and implemented on all four MARS systems of the RNLAF. In conjunction with this development the MARS Test Tool, developed as a maintenance tool for MARS, was also modified.

ORPHEUS Infrared Line Scanner Digital Data System

Obsolescence of some parts of the ORPHEUS reconnaissance system started to threaten the operational life of the infrared line scanner part of that system. By replacing the analog circuitry after the I/R detector and the wet film camera by a digital system with a solid state PCMCIA-based data memory, the system was renovated. On the ground the data was replayed by means of the DIRECTD image processing system. DIRECTD, another NLR-development for the RNLAF, provides increased flexibility and functionality for the photo interpreters of the RNLAF with respect to the earlier wet film system. Flight tests with the digital system started and yielded high quality reconnaissance data.

Parafoil Development

Under contract to Fokker Space NLR participated in a KNTP study for the Dutch Ministry of Defence into the functional requirements, possible system concepts and feasible development

F-16 MLU Flight Test instrumentation: modified AMRAAM tip launcher with camera inside

programmes of autonomously controlled parachutes ('parafoils') for use by the Dutch defence organizations. NLR contributed in the assessment of limiting conditions for the dropping of large loads (up to 500 kg) from the Hercules C-130 transport aircraft and in the study into system architectures, both for bigger and smaller versions with loads up to 180 kg.
As a result of this study, a joint FS/NLR proposal for the development of a small parafoil demonstrator for the *Korps Commando Troepen* of the Royal Netherlands Army was being considered.

Instrumentation for Testing High Voltage Railway Electrical Power Supply System
On the basis of its broad experience in the development, operation and management of large measurement systems for the flight testing of aircraft, NLR was contracted by the directorate Railinfrabeheer of the Netherlands Railways to install and operate 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 cargo trains. The system measures some 300 voltages, currents and safety switch activation parameters at seven locations along a railway track, on a static load and on a train, with a total sample rate of 625k per second. Data is routed from the remote locations to a central site for monitoring purposes by means of fibre optic transmission cables. All systems were installed on location and tested.

Instrumentation for testing high-voltage railway power supply system: static load train

Facilities and Equipment

Instrumentation

Instrumentation for Research Aircraft

Activities for the The Future Avionics System Test Bed (FAST) were aimed at the improvement of the EMC properties of the test equipment installed at the position of the pilot flying the aircraft during the experiment. The development of an experimental Autopilot/Flight Conductor was continued. Measures have been taken to reduce the risk of interference problems between Satcom equipment and GPS receivers. Work was done to improve the laboratory test suite in order to be able to perform tests at the laboratory while the target equipment is installed in the aircraft

Avionics Flight Test Facilities

The Avionics Flight Test Facilities (AFTF) project is aimed at upgrading the flight test instrumentation facilities in four areas. For concise and versatile data acquisition, a standardising concept for using single board computers built to the PC-104 standard was developed. It will first be applied for a helicopter flight loads measurements box. The environmental specifications of industrial PCs were tested against the RTCA DO 160 requirements. A generic test plan was set up for testing solid state recorders for airborne data recording. Two commercially available systems for quick-look data processing were evaluated.
For the conversion of the software of the computer-controlled system for maintenance testing of the flight test instrumentation data acquisition units to a Windows environment, software modules for the control of the test equipment were developed and tested.

Test, Measurement and Calibration Equipment

The head/eye tracking systems were extensively used for man-machine interface(MMI) research in ATM simulations at EUROCONTROL in Brétigny. A new, lighter and less voluminous camera was introduced, providing better comfort for the person under test.

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.

3.8 Engineering and Technical Services

Introduction

The year 2000 was a very productive one for the Engineering andTechnical Services.
Some 50 percent of the work was in support of one of the divisions of NLR, the other 50 percent came from direct contracts with external customers and basic research.
Due to the high volume of work, a large part of the production was subcontracted to external companies, while, almost continuously, up to three additional designers were temporarily engaged.

Models and Test Equipment

Several wind tunnel models or model parts were produced for various customers. Most of the models were to be tested in various DNW wind tunnels, including the DNW-HST, DNW-SST, DNW-LST and DNW-NWB, but some in other wind tunnels. The variety of models was large again, ranging from models of civil aircraft to fighters, rocket launchers and helicopters.

In various cases co-operation was sought with other European model builders, both from research establishments (DLR and ONERA) and industry, in order to meet the extremely short lead times demanded by the customers. This co-operation approach will be extended and repeated more often in the future, since it is a very powerful tool to overcome the capacity problems associated with the extremely short lead times. Presentations were given to the DNW and ETW managements to emphasize the capabilities of the mother institutes to support the related wind tunnels. For ETW the co-operation concentrated on the reduction of lead time for cryogenic models in particular, although many of the benefits of co-operation are valid for wind tunnel model production in general.

Apart from wind tunnel models of aircraft and spacecraft, various models were produced again for non-aerospace products such as trains, ships, bridges, wind turbines, buildings, etc, most of them to be tested in the DNW-LST or the -LLF.

Strain Gauge Balances

Research on strain gauge balances was continued, especially for cryogenic applications, this in connection with the two balances for ETW's twin sting rig built by NLR in 1997. These two balances were expected to be delivered to ETW in early 2001.

Predesign studies on two internal balances for DNW-HST were started, while the design work for an internal balance for a US client was also started.

Various batches of balances were instrumented with strain gauges for the Dutch nautical research institute MARIN, using the knowledge and experience in this field as developed for applications at NLR.

Support

Supporting activities for the various divisions of NLR contributed to roughly 50 per cent of the total work volume of the Technical and Engineering Services.
To name but a few, various moulds for carbon reinforced composite products were made for the Structures Division, engineering mock-ups for the Flight Division, a missile launcher was modified with high-speed camera housings for theAvionics Division, research models were made for the Fluid

Wing with pressure instrumentation and nacelle with turbine powered simulator for high speed semi-span model

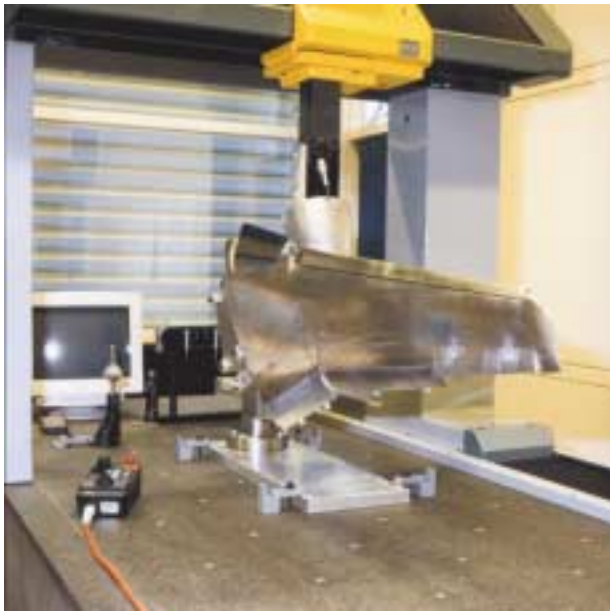
Dynamics Division, and many other supporting jobs were performed.
Also, the operation of the DNW wind tunnels in Amsterdam and Noordoostpolder was supported on request, both by the development of new or modified tunnel equipment and by daily assistance.

Research

In the field of the development of wind tunnel models, particular attention was given to remotely controlled mechanisms for control surfaces, also for operation in cryogenic conditions. The benefits of these 'smart' controls are considerable in expensive wind tunnels.

For the DNW-LLF the existing air bridge (RALD) was improved for future operations on models of the A380 and the A400M.

An important part of the research budget was spent on investigating new techniques for the reduction of lead times of wind tunnel models. Especially production techniques such as 5-axis high-speed milling and stereo-lithography look very promising in this respect, but require special attention before application.
The continued research on balances was especially focussed on cryogenic applications, while research into compensation techniques for balances was continued.



Wing of low-speed wind tunnel model on 3D co-ordinate measuring machine for geometry inspection

As usual, the continued development of CADCAM systems was monitored, for CATIA the changes from V4 to V5 software, and for Autocad and Mastercam the general development.
Research was done to investigate the optimal use of the new 3D-coordinate measuring machine, the DEA Scirocco, acquired in 1999.
The basic structure for an acquisition database that will enable faster and more reliable cost estimates to be made for wind tunnel models in particular, was defined.

Facilities

A new four-axis high-speed milling machine (OMV-MAV-412) was selected, ordered and received, and a new CNC lathe was selected for procurement in 2001.
Modernization of the paint shop was completed.

Tail section of low-speed wind tunnel model with remotely controlled elevator and rudder

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. P.C.E. Swelheim, regio director of ABN AMRO;
- KTZ drs. G.J. van Beek Calkoen, head of the Department of Scientific Support of the RNLN;
- Prof. Visser of Twente University, accompanied by three members of the staff of Twente University;
- Prof.ir. W. Dalmijn, decaan of the TU Delft Faculty of Design, Construction and Production;
- Lt.Gen. D.L. Berlijn, Commander of the Royal Netherlands Air Force;
- At another occasion, Lt.Gen. D.L. Berlijn, Commander of the Royal Netherlands Air Force, accompanied by Maj. F.H. van Wieren and Cdr. C.W.M. Rasch;
- Prof.Dipl.-Ing. H. Stoewer, TU Delft;
- Ir. J.P.J.M. Remmen, of the Ministry of Transport, member of the Board of NLR;
- Mr. B.A.C. Droste, Lt.Gen b.d., Chairman of the Netherlands Institute for Aerospace Programmes (NIVR);
- The Burgomaster, Mr. J. van Houwelingen, and members of the Committee of General Administrative Matters of the Council of Haarlemmermeer;
- BGen Ir. H.J.G.J. Teussink, Director of Plans and International Materiel Relations of the Ministry of Defence;
- Mr. G. Ybema, State Secretary of Economic Affairs, accompanied by delegations of the Ministry and of the Province of Flevoland.

Foreign Visitors

- Five members of the staff of Lockheed Martin, for discussions on the Joint Strike Fighter;
- Four staff members of the Italian Agency Air Navigation Services (ENAV);
- Dr. K.N. Street, Counsellor Defence Research and Development of the Embassy of Canada in London;
- Dr. H.-M. Spilker of the Bundesministerium für Bildung und Forschung, Germany, member of the Supervisory Board of the European Transonic Windtunnel GmbH;
- Mr. Fuller and Mr. McLaughlin of LM Aero, accompanied by members of the staffs of Stork and TNO-TPD;
- Prof. B. Gal-Or, of Technion Israel Institute of Technology, Haifa;
- A delegation of six officials from the United Arab Emirates;
- Prof.Dr. Hua Jun, Vice President, and a delegation from the Chinese Aeronautical Establishment (CAE);
- Messrs T. Edwards and H. Bilimaria, of NASA Ames;
- Attendants of the ISPRS Congress held at Amsterdam RAI, who were received at NLR Noordoostpolder;
- Representatives of Boeing and of FAA R&D;
- Staff of Eurofighter International;
- Candidates for the NLR Board member to be nominated by the Works Council;
- Technisch Wetenschappelijk Attaché's from The Hague and from Netherlands embassies.

Excursions

- Students Engineering and Operational Technology of Hogeschool Amsterdam;
- Students Applied Physics and Control Technology of Hogeschool Eindhoven;
- Students Technical Cognition Science of the Groningen University;
- Students Electrical Engineering of Noordelijke Hogeschool Leeuwarden;
- Members of Vliegsport Avia Noord;
- Students from Indonesia participating in the Master of Science Programme in Engineering Mathematics of Twente University;
- Students of TU Delft, members of the Mathematics and Information Technology Society 'Christiaan Huygens';
- Students of Fachhochschule Hamburg, Germany, Fachbereich Fahrzeugtechnik;
- Students of the Instituut Defensie Leergangen;
- Members of the Royal Netherlands Society *Onze Luchtmacht*, Regio Soesterberg;
- Members of the F–27 Friendship Association;
- Members of the Aeronautical Study Society 'Sipke Wynia' of Hogeschool Haarlem;
- A group of visual artists;
- Members of the Technical Physics Study Society 'Ångström' of Hogeschool Rijswijk;
- Students of Chemical Technology at Fontys Hogescholen, with graduating subject Fibre Reinforced Plastics;
- Students of Nederlands Luchtvaart College of Hoofddorp;

- Members of *Kwaliteitskring Flevoland*;
- Arbo co–ordinators of the Netherlands Large Technological Institutes;
- Members of VERON, society of radio amateurs;
- Study Society 'Hora Est' of the Engineering Faculty of Eindhoven University;
- Members of the Society Fibre Reinforced Plastics (VVK);
- Members of the Society *Onze Luchtmacht*, Regio Noord;
- Students of Aerospace Engineering of the TU Delft.

Exhibitions

- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) at Asian Aerospace 2000, at Singapore;
- At the Maastricht Exhibition and Congress Centre, MECC, NLR participated with a stand at the ATC 2000 Conference, and showed its capabilities in the area of Air Traffic Management research;
- At the International Training Equipment Conference (ITEC) in the Congress Centre in the Hague, NLR showed its simulation capabilities within the stand of the Netherlands Industrial Simulator Platform (NISP);
- In the field of materials, NLR participated in the *Journées Européennes de Composites* (JEC), Paris;
- NLR participated in the stand of the Vereniging Gasturbine (VGT) at the ASME Turbo exposition at Munich, Germany;
- NLR contributed to the exhibition at the 55th Anniversary Symposium of the Aerospace Study Society 'Leonardo da Vinci', TU Delft;
- At the nineteenth ISPRS Congress in Amsterdam RAI, organized by ITC, NLR showed some of its space–related activities;
- NLR participated in the stand of the Netherlands Aerospace Group (NAG) at the Farnborough Air Show;
- At ILA 2000, Berlin, NLR participated in the stand of the Netherlands Industrial Space Organization (NISO);
- At the KIvI Defence Technology Symposium at Delft, NLR was present with a booth;
- NLR was present at the Open Days of the RNLAF at Volkel Air Base;
- NLR showed its EMC activities at the EMC 2000 Exposition at Brugge, Belgium;
- At the 26th European Rotorcraft Forum, organized by the NVvL in The Hague, NLR showed some of its helicopter-related activities;
- NLR presented space-related activities in a booth at the IAF Congress in Rio de Janeiro, Brazil;
- At the NIID Symposium, organized by the Netherlands Defence Manufacturers Association (NIID) in The Hague, NLR showed some of its activities for the industry.

Events

- Well-attended New Year Receptions for NLR staff in Amsterdam and Noordoostpolder;
- Introductory meetings for new employees in Amsterdam and Noordoostpolder;
- Workshop on constellations of Small Satellites held at NLR Amsterdam;
- Meeting of the Netherlands Aerospace Group (NAG) at NLR Amsterdam;
- Course on Integrated Noise Model INM–6;
- Meeting of the *Nederlandse Vereniging voor Precisie Technologie* (NVPT);
- Symposium 'Technology for the Future National Airport' held at NLR Amsterdam;
- Eurocontrol Technical Interchange Meeting at Amsterdam;
- Meeting of the International Science and Technology Centre, ISTC, on Airborne Monitoring;
- JSF Embedded Training demonstration at NLR Amsterdam;
- Meeting of the *Vereniging Gasturbine* (VGT) at NLR Noordoostpolder;
- Workshop 'Wake Vortex Encounter' at NLR Amsterdam.

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 1999 under NLR's own Programme for Basic Research and Development of Facilities;
  - the Preliminary Work Plan for 2001;
  - NLR's own Programme for Basic Research and Development of Facilities for 2002;

- 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

During the year two vacancies remained open. The vacancy concerning the succession of Prof.ir. C.J. Hoogendoorn, appointed by NLR, remained filled by him ad interim. The vacancy caused by the resignation of Ir. F. Holwerda, appointed by NIVR, remained open. The appointments of the sitting members and the chairman were extended by one term, as is usual once every four years.

At the end of 2000 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 2000, an inventory of the availability of the members of the Subcommittees was made. For a variety of reasons the following members were no longer available for a new term:

- Dr.ir. R. Coene and Maj. (Klu) ir. T. de Laat of the Subcommittee for Aerodynamics;
- Prof.dr. Joh. Arbocz of the Subcommittee for Structures and Materials;
- Prof.dr.ir. Th. van Holten and Ir. H. Benedictus of the subcommittee for Flying Qualities and Flight Operations/Air Transport;
- Drs. P.W.J. ten Hagen of the Subcommittee for Applied Mathematics and Information Technology;
- Prof.ir. H. Wittenberg, Ir. P.Ph. van den Broek and Prof.ir. N.J. Mulder of the Subcommittee for Space Technology.

The appointments of the other members were tacitly extended by a term.

On 8 March Prof.ir. D. Bosman, Chairman of the Subcommittee for Avionics (previously Electronics and Instrumentation) suddenly died. Prof. Bosman was commemorated in meetings of the Scientific Committee and the Subcommittee. Many assisted at the cremation ceremony.

Prof.ir. G.L. Reijns, member of the Subcommittee for Avionics, was found ready to take up the chairmanship of this subcommittee until mid-2003. In the Subcommittee for Flying Qualities and Flight Operations, Prof.ir. E. Obert took the office of chairman. Prof.Dipl.-Ing. H. Stoewer took the office of chairman in the Subcommittee for Space Technology.

The Subcommittee for Aerodynamics was extended by one member, and in the Subcommittee for Structures and Materials one new member was appointed. The lack of a member having as a background the Netherlands Civil Aviation Authority (NLA) was considered a deficiency that it was hoped would soon be made up for.

In the Subcommittee for Information and Communication Technology, previously Applied Mathematics and Information Technology, one new member took office. In the Subcommittee for Space Technology one new member took office, whereas three very busy members could be retained. The Subcommittee for Avionics was reinforced by a new member taking office.

The members of the NIVR staff who previously acted as secretaries of the subcommittees – a task taken over by NLR staff – were introduced as attached NIVR representatives in the subcommittees.

At the end of 2000 the subcommittees were composed as follows:

Subcommittee for Aerodynamics
Prof.dr.ir. J.L. van Ingen, *chairman*
Prof.dr.ir. P.G. Bakker
Ing. J. van Hengst
Prof.dr.ir. H.W.M. Hoeijmakers
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
Prof.dr. A.E.P. Veldman
Mw.ir. M. Zeilemaker (NIVR)

Subcommittee for Space Technology
Prof.Dipl.-Ing. H. Stoewer, *chairman*
Prof.dr.ir. J.A.M. Bleeker
Dr.ir. N.J.J. Bunnik
Civ. Eng. N.E. Jensen
Ir. P.L. van Leeuwen
Prof.dr.ir. L.P. Ligthart
Dr. A.M. Selig
Prof.dr.ir. P.Th.L.M. van Woerkom
Prof.ir. K.F. Wakker
Ir. D. de Hoop (NIVR)

Subcommittee for Structures and Materials
Prof.dr.ir. H. Tijdeman, *chairman*
Ir. N. Fraterman
Prof.dr.ir. Th. de Jong
Ir. J.B. de Jonge
Kol. Ir. J.W.E.N. Kaelen
Ir. A.J.A. Mom
Ir. A.R. Offringa
Prof.dr. A. Rothwell
Ing. E. van Teeseling
Ir. L.H. van Veggel
Ir. J.J. Wijker
Prof.dr.ir. S. van der Zwaag
Ir. F.J.M. Beuskens (NIVR)

Subcommittee for Information and Communication Technology
Prof.dr.ir. P. Wesseling, *chairman*
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 (NIVR)

Subcommittee for Flying Qualities and Flight Operations/Air Transport
Prof.ir. E. Obert, *chairman*
KTZSD b.d. ir. K. Bakker
Ir. W.G. de Boer
Mr. J. Hofstra
Dr.ir. R.J.A.W. Hosman
Ir. H.J. Kamphuis
Lt.Kol. H.J. Koolstra
Ir. H. Tigchelaar
Dr.ir. H.G. Visser
Ir. G.C. Klein Lebbink (NIVR)

Subcommittee for Avionics
Prof.ir. G.L. Reijns, *chairman*
Ir. W. Brouwer
Ing. H. de Groot
Lt.Kol. Ing. H. Horlings
Ir. S. O. van de Kuijt
Prof.dr.ir. L.P. Ligthart
Ir. P.J.G. Loos
Kol. ir. E.B.H. Oling
Ir. L.R. Opbroek
Dr. R.P. Slegtenhorst
Prof.dr.ir. M.H.G. Verhaegen
Ir. A.P. Hoeke (NIVR)

Concluding Remarks of the Committee

As usual the Committee extensively considered the capacity and level of the scientific research carried out by NLR, both under NLR's own Programme for Basic Research and Development of Facilities and under NIVR Basic Research contracts and other customer's contracts. In that the Committee recognized that work for customers may include the extension of scientific knowledge as well. The volume of NLR's own Programme amounts to approximately 30 per cent of NLR's activities. The Committee considers the volume of NLR's own programme to be the minimum, the more so because it includes a large component consisting of participations in European programmes.

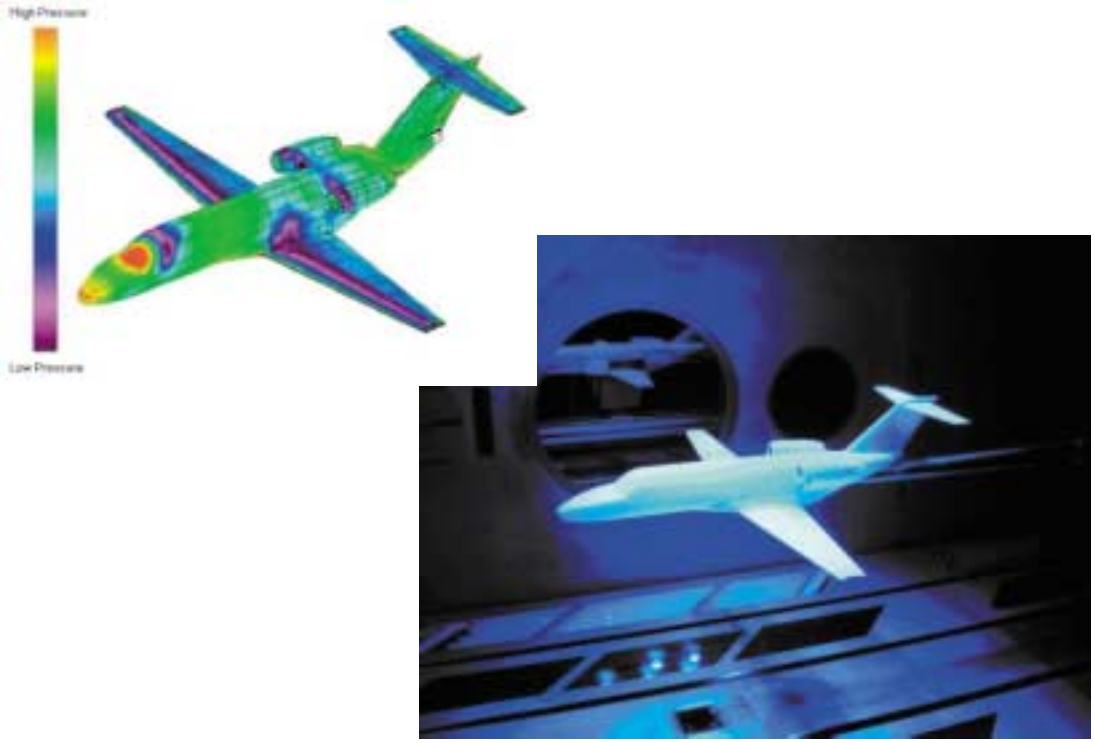
The Committee has also paid attention to the pace of the integration of activities and establishments in the field of aerospace in Europe. For a considerable time the Committee has agreed with integration activities in the field. Various recent initiatives were considered: the co-operation between the German-Dutch WindTunnels (itself a co-operation between DLR and NLR) and the *Office National d'Études et de Recherches Aérospatiales* (ONERA); the initiative of the European Union for a Group of Personalities that is preparing a report containing a long-term vision on aeronautics; and the long-term plans of the European Space Agency (versus the view of the *Centre National d'Études Spatiales*). The trend towards integration is, however, counteracted by a trend towards privatization and commercialization that governments often impose on establishments. By that the establishments will no longer be able to co-operate openly, but will have to defend commercial interests. One example is the largely privatized Defence Evaluation and Research Agency of the UK that in fact has succumbed as a co-operation partner. The establishments themselves keep alive the wish to determine their own future. Harmonization of activities is the minimum required for putting into action the available means for new concepts optimally, at any rate if a certain counterweight to the supremacy of the USA is aimed at.

Co-operation is therefore still a difficult process, but it cannot be evaded, both for societal reasons and for withstanding the competitive pressure of the USA and retaining inspiration in Europe. The openness in Europe provides a good point of departure, but the development of ideas on the track to be followed is required.

Although a great deal of attention is paid to the subjects mentioned below, the Committee feels that they can be accentuated further:

- safety and reliability in aeronautics, and the partial studies required for it;
- possibilities and limitations of the use of COTS (Commercial Off The Shelf) components;
- Health Monitoring and Prognostics Management;
- the prominent position of the Netherlands in the field of aeroacoustics, which should be confirmed – NLR supported by NIVR could set itself up as a Centre of Expertise;
- the activities in the field of gas turbines and components for these, which should be better displayed in Work Plans and NLR's own Programme;
- concerning space technology, the importance of applications for defence and the opportunities entailed by being able to take part in developments, which should be put forward better.

In conclusion the Committee notes it is highly impressed by the qualities of the work carried out, revealed among other things by the reports discussed, as has been reported by several subcommittees.



Boeing PSP (Pressure Sensitive Paint) method applied on a Cessna model in the DNW-HST (below), and typical results (top)

6 International Co-operation

6.1 NATO Research and Technology Organization (RTO)

Introduction

The NATO Council established the NATO Research and Technology Organization (RTO) in 1996. 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.

Mr. N. Holme succeeded Dr. M. Yarymovych as chairman of the R&T Board in March 2000. Mr. K.A. Peebles succeeded Drs. E. van Hoek as the director of the RTA in July 2000.

The AVT panel's proposal to reorganize its mode of operation was implemented as a result of the decisions taken at the RTB meeting.

The Board approved the implementation of the Strategy Document and approved RTO Panel Chairman to provide Task Leadership.

Dr. ir. A. van Meeteren of the Netherlands was selected for being awarded the Von Kármán Medal 2000.

Netherlands Participation in RTO

R&T Board

Drs. E. van Hoek succeeded Cdr. Ir. D van Dord as voting member of the RTB.

The Netherlands members of the R&T Board (RTB) were:

- Drs. E. van Hoek 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, of the Netherlands Ministry of Defence, resigned as national co-ordinator on 1 November. He will be succeeded by Ir N. Pos, also of the Netherlands Ministry of Defence, in Januari 2001.

6.2 German-Dutch Wind Tunnels (DNW)

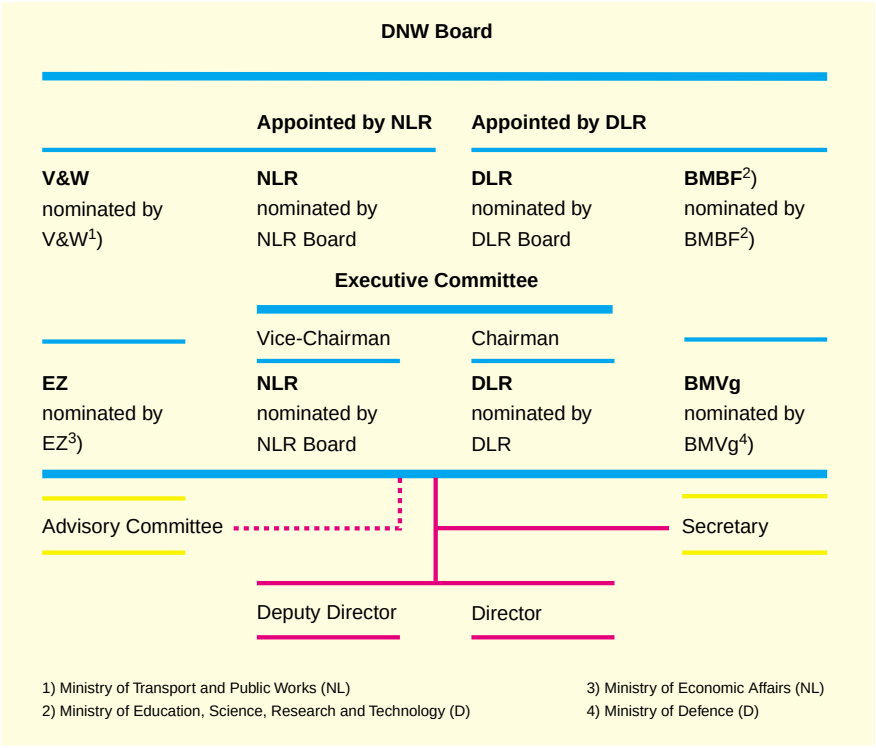
The Foundation German-Dutch Wind Tunnels (DNW) was jointly established in 1976 by NLR and the German Aerospace Centre (DLR) as a non-profit organization under Dutch law. The main objective of the DNW organization is to provide a wide spectrum of wind tunnel test and simulation capabilities to customers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

In addition to the jointly developed Large Low-speed Facility (LLF), the largest low-speed wind tunnel in Europe, DNW operates all major aeronautical wind tunnels of NLR and DLR. The wind tunnels operated by DNW are grouped in three business units 'Noordoostpolder' (NOP), 'Amsterdam' (ASD) and 'Göttingen und Köln' (GUK). In addition to the LLF, two 3–m low–speed wind tunnels, LST and NWB (the latter located in Braunschweig) as well as the Engine Calibration Facility (ECF) belong to Business Unit NOP. The main facilities in Amsterdam are the transonic wind tunnel HST and the supersonic wind tunnel SST. The transonic wind tunnel TWG and the cryogenic low-speed wind tunnel KKK are the major facilities of Business Unit GUK.

The Board of DNW

The Board of the Foundation DNW consists of members appointed by NLR, DLR and the German and Dutch governments. At the end of 2000 the Board consisted of:

Prof. Dipl.-Ing. V. von Tein, *Chairman*
DLR
Dr.ir. B.M. Spee, *Vice-Chairman*
NLR
B.A.C. Droste
Netherlands Agency for Aerospace Programmes (NIVR)
Drs. L.W. Esselman, R.A.
NLR
DirBWB K. Heyer
Ministry of Defence of Germany (BMVg)
Prof.Dr.-Ing. H. Körner
DLR
Ir. J.P.J.M. Remmen
Ministry of Transport of the Netherlands (V&W)
MinR. Dr. H.-M. Spilker
Ministry for Education, Science, Research and Technology of Germany (BMBF)
Secretary: Dipl.Kff. A. Stader MBA
DNW



Schematic of the organization of the Foundation DNW

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 2000 the Advisory Committee consisted of:

Dr.-Ing. J. Szodruch (Chairman)
EADS Airbus
Dipl.-Ing. R. Birrenbach
Fairchild Dornier
Mr. A. Cassier
Eurocopter France
Mr. A. Garcia
EADS Airbus
Dipl.-Ing. B. Haftmann
EADS Airbus
Prof.Dr.-Ing. P. Hamel
DLR
Prof.Dr.ir. J.L. van Ingen
Delft University of Technology
Dr.-Ing. E. Krämer
EADS Deutschland
Mr. H. Schrecker
EADS Airbus
Prof.ir. J.W. Slooff
NLR
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

Business Unit NOP

The DNW-LLF, the main wind tunnel facility of Business Unit NOP, had another very successful year, mainly due to the relatively high number of test days for helicopter testing. Expressed in the number of total shifts sold, this market segment counted for about a quarter of the tunnel occupation. The aircraft segment (including propulsion simulation) was relatively smaller than the year before, but still represented more than half of the tunnel occupation. Testing of cars and trucks in the LLF stayed on the same level as in previous years. The two smaller low-speed wind tunnels, LST and NWB, were both well occupied. The aeronautical segment in the LST was at a level higher than average.

The major share of LLF aircraft testing came from the German and French Airbus partners. Most of the testing was done for the development of the A380, although a two-week tunnel entry was devoted to the smallest member of the Airbus family, the A318. The investigations on the A380 were done with a new large low-speed model for testing in the LLF. Testing included both unpowered and powered A380 configurations without and with ground effect. During one wind tunnel entry, DNW's microphone wall array, installed flush with the test section floor, was very successfully used in parallel to standard measurements. Investigations of the vortex sheet behind a semi-span model equipped with turbofan propulsion simulators were done with a traversing 5-hole probe rake. Large transport aircraft (A340/A380) configurations were also tested in the NWB. In these cases the subject of interest was the determination of dynamic derivatives using NWB's Oscillatory Motion Support.

The two smaller low-speed wind tunnels were both used for tests on the same full model of the Fairchild Dornier Do-728. The LST tests consisted primarily of power-on measurements with blown nacelles to determine the characteristics of thrust reversers in ground effect. In addition to the full model, an isolated blown nacelle was also used for this purpose. The tests in the NWB comprised the development of the high-lift system as well as the control devices, and the simulation of ice effects.

Fairchild Dornier model on ground board in the DNW-LST

As a continuation of a 1998 LLF test entry, the second phase of a helicopter research programme was carried out for ATIC, a Japanese helicopter research company. In addition to the standard measurement techniques used in 1998, several new methods were applied. DNW's out-of-flow acoustic array was successfully applied for identifying noise sources. The Particle Image Velocimetry (PIV) technique was used to determine downwash velocities above, below and even in the rotor plane.
In the framework of the European research programme HELIFLOW, a test entry took place in the LLF with a model of a Bo-105, owned and operated by the DLR Institute for Flight Research. Especially for this test a 3/4 -open test section configuration was created. A main topic was the determination of trim conditions for helicopter handling during sideward flight in ground effect. The PIV technique was used to measure flow phenomena of the ground vortex. NLR used these measurements for the validation of CFD calculations predicting ground vortex development.
In a helicopter test performed in the LST for the NH90 consortium, the unsteady aerodynamic characteristics of the rotor hub/fuselage combination were determined.

Business Unit ASD

The high levels of occupancy in 1998 and 1999 were followed by another busy year. Although an important part of the year, a total of ten weeks, was used for maintenance and updating of tunnel systems, an extensive series of tests was conducted in the wind tunnel facilities inAmsterdam, especially the HST.

In terms of market segments the main part of the testing efforts were made for civil aircraft, and a significant number of tests were dedicated to military aircraft. Space-related activities decreased to a very low level. Also the level of research-related tests was extremely low.

Civil aeronautics testing comprised various full-span and half-span model tests for several airframe manufacturers, including engine simulation by through-flow nacelles and turbofan propulsion simulators. Sting interference investigations were performed using a fin sting set-up in the HST. Component testing was done on a tail model.

Three methods of Pressure Sensitive Paint (PSP) were applied in the HST. First, the DNW scanning decay method was applied on a wing of the Embraer ERJ-170 aircraft. Second, the Boeing PSP intensity method was used on a Cessna configuration. Finally, the DLR intensity method was used for the AerMacchi M-346 advanced trainer aircraft. Pressure Sensitive Paint allows the pressure distribution on the entire surface of an aircraft model to be acquired. This is a great step forward in the field of non-intrusive measurement techniques in aerodynamics.

With conventional pressure measurement techniques, the surface pressure is measured at discrete locations through pressure taps or pressure sensors installed flush into the model. These methods provide better absolute accuracy, but cannot cover the complete pressure distribution of a three-dimensional aircraft model in a wind tunnel. Other methods for the visualization of the flow on the surface of the model, such as oil or phenol coatings, do give information about the wall streamlines, but do not allow the pressure distribution to be determined quantitatively.

The PSP method provides not only qualitative pressure images for detecting fine vortex structures or separation effects, but also quantitative absolute pressure values at all visible positions of the model, almost without affecting the surface of the model. All pressure values over the complete model as well as model parts were integrated to obtain the flow-induced forces and (hinge) moments at a given flow condition.

Business Unit GUK

The Business Unit GUK operates five wind tunnels. The main facilities are the transonic wind tunnel TWG in Göttingen and the cryogenic low-speed wind tunnel KKK in Cologne. The three smaller facilities, all located in Göttingen, comprise the hypersonic Ludwieg tube RWG, the cryogenic Ludwieg tube KRG and the high-pressure low-speed wind tunnel HDG. These facilities are mainly used for aerodynamic research performed by DLR institutes, although KKK has industrial clients for the major part.

The availability of the TWG was severely restricted by a three-month repair and maintenance period required after the occurrence of a short-circuit in the main drive motor. The remaining time was very busy. The trend of the past few years towards dynamic testing with moving and flexible models as well as complex measurement techniques continued. 2D-airfoil testing included forced and free pitch and oscillation as it occurs at helicopter blades. Transient roll manoeuvres of fighter aircraft were tested with a generic model provided with remotely controlled aileron deflection. Civil aviation activities were concentrated on flexible wing structures and flow control devices.

The KKK is a high-Reynolds-number facility for high-lift optimization of 2D aerofoils and half-span models. Several aerofoil and half-span model tests were performed for the Airbus A380 development. In addition to industrial development work, an increased number of research experiments were done. For instance, DLR used a swept constant-chord half-span model provided by EADS to examine trailing edge devices of different geometries at take-off and landing configurations.

The smaller facilities were used for various research projects. For example: tests were performed concerning active and passive flow control on generic bodies in the HDG. Active and passive control of the flow by means of suction, blowing or cavities, but then on aerofoils, has been applied in the KRG. In the same facility also research on flexible adaptive structures (bumps flaps, trailing edge devices) was performed. Current research on missile control in the RWG concerned cross-flow jets and grid fins.

6.3 European Transonic Windtunnel (ETW)

On behalf of the Netherlands, NLR is a seven per cent 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.

In 2000 a number of industrial tests were performed, yielding good results and satisfied customers. Moreover, the ETW was involved in several projects of the European Union. Although Airbus shifted the decision on its A380 project into 2001, it confirmed the suitability of the ETW for A380 wind tunnel tests.

Both the commisioning of the twin sting model support system and the introduction of an anti-vibration system further improved the testing capabilities of the ETW.

Supervisory Board

At the end of 2000, the membership of the Supervisory Board was as follows:

France

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

Germany

Dr. H.-M. Spilker	BMBF
Prof.Dipl.-Ing. V. von Tein	DLR
Prof.Dr. H. Körner	DLR

United Kingdom

Dr. R. Kingcombe	DTI
Dr. D.J. Mowbray, *Chairman*	DERA

The Netherlands

Ir. J.P.J.M. Remmen	V&W
Dr.ir. B.M. Spee	NLR

The Managing Director, Dr. W. Burgsmüller (G), was assisted by:

– Dr. G. Hefer (G), Manager Projects
– J.-P. Hancy (F), Manager 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 2000 Italy joined GARTEUR as the seventh nation.

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 2000 the GARTEUR Council was composed as follows.

France

IGA G. Bretécher	DGA/DSA/SPAé *)
Ms. Dr. D. Nouailhas	ONERA **)
ICA M. Moraillon	DGAC/DPAC
ICA A. Brémard	DGA

Germany

Dr.-Ing. J. Bandel	BMWi *)
Mr. W. Riha	DLR **)
LB Dir. K. Heyer	BMVg
Dr.-Ing. K. Haag	DLR

United Kingdom

G.T. Coleman	DERA *)
Dr. O.K. Sodha	DERA **)
Mr. D.M. Way	DTI
Mr. A.F. Everett	MOD

Spain

Mr. A. Moratilla Ramos	OCT *)
Mr. P. Garcia Samitier	INTA **)
Mr. R. Herrero Arbizu	MdCyT
Mr. J.M. Carballal Prado	MdD

Sweden

BGen.G. Langemar	FMV *)
B. Uggla	FFA **)
A. Gustafsson	FOI
B. Johansson	VINNOVA

The Netherlands

E. van Hoek	MvD *)
Ir. F.J. Abbink	NLR **)
Dr.ir. B.M. Spee	NLR
Mr.drs. A.A.H. Teunissen	MEZ

Italy

Prof. S. Vetrella	CIRA *)
A. Amendola	CIRA **)
M. Mazolla	MURST-SSPAR
Col. O. Spedicato	MDif

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

In 2000, France provided the chairman for the GARTEUR Council and the chairman for the Executive Committee as well as the Secretary. The persons involved were:

IGA G. Bretécher *Council chairman*
Dr. D. Nouailhas *Executive Committee chairman*
E. Maire *Secretary*

The GARTEUR Council met in Farnborough (UK) and in Capua (I).

The Executive Committee had nine meetings and organized two workshops with the Groups of Responsables to discuss the 'GARTEUR View on Future Aeronautics Research and Technology'.

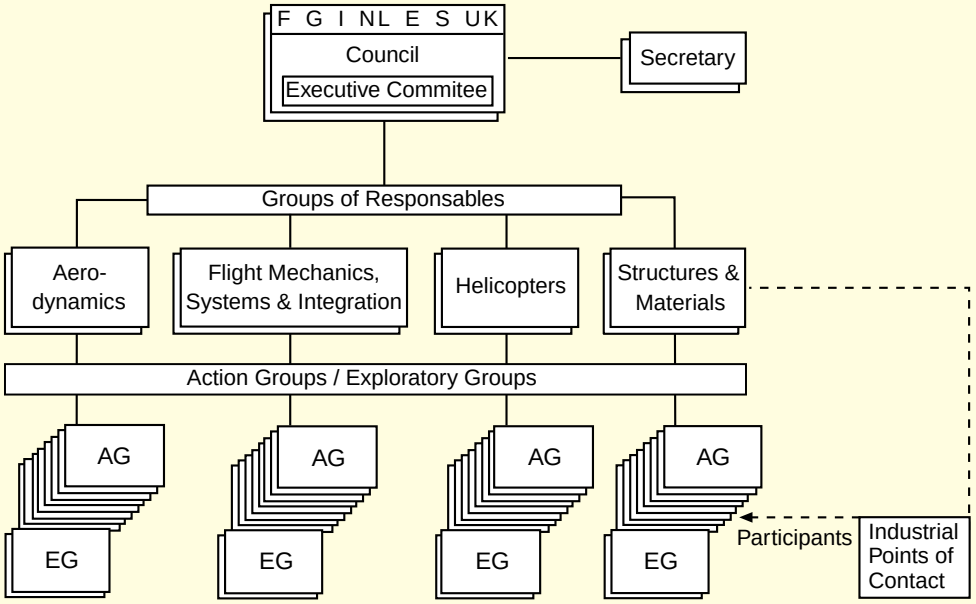
NLR Participation

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	0	0
Structures and Materials	8	8
Total	23	19

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



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

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 has been 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.

A joint Executive Board (JEB) and a DLR/NLR Board Working Group, consisting of representatives of DLR and NLR, guide and control this task.

Joint Executive Board at the End of 2000:

Prof.Dr. W. Kröll	DLR
Prof.Dipl.-Ing. V. von Tein	DLR
J. van Houwelingen	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 as all aeronautical wind tunnels of NLR and DLR were embedded into the DNW organization as from the year 2000.
It is envisaged that DNW will create an Aerodynamic Testing Alliance (ATA) together with ONERA. The objectives are joint marketing and joint development of measuring techniques and test rigs.

It has been agreed to establish a joint DLR/NLR organization in the area of ATM and Airport traffic movement, AT-One GmbH, in 2001. The aim of AT-One will be to jointly market the DLR and NLR services and products in relevant market segments and to increase the harmonisation of DLR's and NLR's research programmes and facilities.
DLR and NLR have also been working towards practical arrangements for collaboration between their workshops that design and manufacture wind tunnel models.

DLR-NLR Programme Committee

The DLR-NLR Programme Committee continued to stimulate and monitor bilateral precompetitive DLR-NLR research.

The following projects were executed:
- Low-speed Propulsion-Airframe Integration
- CFD for Complete Aircraft
- Development of B2000 Software

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 foster 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 creating a Union between regional centres. In this Union, strong organizational ties should result in integrated management of joint activities, pooling of facilities and the creation of interdepencies and Centres of Excellence. A formal association under Dutch law was created in 1999, 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 2000 the Board was composed of:

IGA J.P. Rabault, *Chairman*	ONERA - F
Prof.Dr. W. Kröll	DLR - D
Dr. G. Reid	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).

From 1999 co-operation in EREA research projects are as much as possible delegated to GARTEUR, EU, WEAO and other fora. However, three EREA projects were executed in 2000:

- EWIN: the establishment of an EREA intranet connection and an EREA website.
- SERINE: the creating of a secure datalink between the EREA partners.
- ADAPTIVE WING: a research project to study the feasibility of an adaptive structure to reduce aerodynamic drag. The activities will result in projects to be executed in the EU Framework Programme.

In addition, contacts with Airbus resulted in the Joint Concept Review Team (JCRT), a group of specialists from Airbus and EREA to investigate future configurations of large passenger transport aircraft. Two exploratory Projects were initiated, one of which, proposed by NLR, aims at investigating the merits of twin fuselage configurations.

Several EREA working groups have been active in investigations of the potential for future pooling and integration of resources. The group on turbulence modelling will create a joint European Team, the first example of a virtual institute in EREA. The working group on laboratory aircraft has finished an extensive inventory of resources and has proposed to facilitate mutual use and pooling of flight test resources.

Bilateral contacts between EREA partners have been strengthened. One example is the feasibility study to integrate fixed-wing aircraft research and technology development activities of ONERA and DLR. Such bilateral co-operation may be open to other EREA partners at a later stage.

At the end of the year 2000, major institutional changes were implemented in Sweden and initiated in the UK. FFA, the Swedish EREA partner, has been merged with FOA, the Swedish defence institute. DERA, the UK partner in EREA, will be split into a public part (DSTL, the Defence Science and Technology Laboratory) that will remain under the Ministry of Defence and a private part (QinetiQ), in which private shareholders can participate. It is still unclear what the consequences of DERA's partial privatisation on the DERA membership of EREA will be.

Personnel Exchange

Personnel exchange stimulates the creation of interdependence amongst the Associates and creates the right European spirit amongst the establishments. The Board handled 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 promoting information exchange amongst the establishments on EU-related issues. The ARG, chaired by Drs. De Graaff (of NLR), is incorporated in EREA. Exchanging information and preparing project proposals for calls for proposals were still the main objectives of the ARG. The ARG strengthened links to research organizations and universities outside the seven EU nations involved in EREA and to Israel. The contacts with VZLU of the Czech Republic were intensified.

In relation to the European Research Area (ERA) initiative of the European Commission, the EREA Board met with Commissioner for Research, Mr. P. Busquin. It was concluded that the research co-ordination mechanisms proposed under ERA perfectly match the intentions of EREA. Representatives of EREA participated in several workshops of the Commission to prepare the Sixth Framework Programme. Furthermore, the ARG together with the European industry prepared the structure of the future EU Technology Programme in support of air transport and the aeronautical industries' competitive position. The resulting document (ARTE21), to be presented to the Commission during the Aerodays 2001 in Hamburg, was to be followed by a more detailed description of potential research to be undertaken at a European level in the next Framework Programme.

6.6 Co-operation with Indonesia

Introduction

The co-operation with Indonesia centred around the evaluation of the APERT co-operation, which was completed in 2000, and brainstorming about possibilities for future co-operation. There were also other contacts, varying from temporarily hiring of Indonesian specialists by NLR, support of NLR for Indonesian students at Delft University of Technology and Twente University via VNO/NCW fellowships, and commercial contacts.

APERT 95

The interim Aerospace Programme for Education, Research and Technology (APERT) was started in 1992 as follow up of preceeding co-operation programs started in 1981. Participating parties comprise Indonesian and Netherlands aerospace research institutes, universities and industries.

Organization

The APERT Governing Group did not change in 2000, albeit that some members took up different functions:

Indonesia

Prof.dr.ir. Djoko Suharto (ITB)
Prof.dr.ir. Harsono Djojodihardjo (ITB)
Prof.dr.ir. Sularso, MSME (Min. E&C)
Dr.ir. Suleiman Kamil (ITB)
Dr. Said Jeni (BPPT)
Dr.Ing. Ilham Habibie (PT Dirgantara (Iae), former IPTN)

Project Co-ordinator

Ir. R. Mangkoesoebroto (Intrasarana)

The Netherlands

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

Project Co-ordinator

Ir. R. Ross (NLR)

Status

Most of the work was completed. One PhD student was in the final stage at TU Delft. His draft thesis was handed over, although completion was not yet finished at the end of 2000.
The transfer of the NLR transonic Pilot Wind tunnel to Indonesia is on hold until it is clear if the operation of such a facility fits in the Indonesian policy. It was dismantled and stored.

Evaluation and Continuation

The APERT programme was evaluated, along with other projects, by an International Evaluation Commission, which stated that 'the Dutch aerospace cluster is in a unique position to contribute to the continuity [of the Indonesia aerospace knowledge infrastructure', implicitly advising to continue the co-operation in some form.
There were informal contacts between a Dutch member of the Governing Group, the Dutch Project Co-ordinator and the Netherlands Ministry of Education, Culture and Science (OC&W) on the form of a possible continued co-operation. The Indonesian side provided information about the aerospace policy of the new government.

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Capita Selecta

1 Development, Installation and Operation for Qualification of a Flight Test Instrumentation System in an F-16B Mid Life Update Aircraft

Under contract to the Royal Netherlands Air Force (RNLAF), NLR has developed a new flight test instrumentation system for the Lockheed Martin F-16 in Mid Life Update (MLU) configuration. This modular system, based on an instrumentation data bus, was designed to enable the test aircraft to remain available for operational tasks. It has recently been used in the airworthiness qualifications of a forward looking infrared navigation pod and a targeting pod.

Flight Test Instrumentation System

Introduction

The F-16 aircraft of the RNLAF are planned to be operational until 2020. A major modification programme, the Mid-Life Update (MLU) programme, started in 1998, is expected to be completed in 2001. In December 1997 the RNLAF awarded NLR a contract to develop and install a new modern instrumentation package in one of its F-16B MLU aircraft. This package must replace a flight test instrumentation system NLR developed and installed in 1984 and 1987 in F-16A and F-16B aircraft of the RNLAF. These systems have been used for both operational test flights and flight tests with technical objectives. The operational test flights mainly consisted of mission training flights where the recording of data may improve tactics or the quality of a system. The flight tests with technical objectives were mainly part of special programmes, for example for the certification of new stores or for technical evaluations of new or modified aircraft systems.

Requirements

Functional Requirements

The functional requirements for the new system are comparable with the specifications of the older system with the following major extensions:

- Input capacity for four dual-redundant Mil-Std-1553 multiplexer databuses, while selections of data to be recorded and displayed are made at system set-up;
- Recording of all data communication via these buses in a format that enables data to be exchanged with the Lockheed flight test facilities at Edwards Air Force Base, USA;
- A maximum data throughput rate of at least 5 Mbit/s;
- A real-time data display to present selectable sets of plots in-flight.

The F-16B MLU J-066 'Orange Jumper' test aircraft

Recorded Parameters

The recorded parameters can be divided into a basic set of parameters, which will be recorded during every test flight, and additional parameters related to flight test programmes. The basic set of parameters includes aircraft configuration, position, attitude, control and angular rates and accelerations. The sample rates of these parameters vary from 16 to 256 samples per second.
Examples of flight test programme related parameters are:

- Accelerations at the wing tips, tail section and pilot's seat in limit cycle oscillation and flutter trials;
- Store release commands and camera running signals in store separation trials;
- Strain gauge and acceleration data at parts of the airframe in structural load measurements;
- Angle-of-attack and angle-of-sideslip in flight handling characteristics and in-flight performance tests.

Most of these parameters require sample rates of at least 256 per second. The signals to be measured stem from specially installed transducers, e.g. accelerometers and an angle-of-attack and sideslip nose boom.

Operational Requirements

The most demanding requirement was to preserve the original operational capabilities of the aircraft with the basic instrumentation equipment installed. Also, additional cooling, requiring adaptation of the aircraft environmental control system, had to be avoided. Adaptations to the cockpit layout had to be kept to a minimum.

Angle-of-attack and angle-of-sideslip nose boom

To increase the efficiency of flight testing an in-flight presentation of parameters had to be added. At the aft crew station, the full instrumentation display and control functions had to be available. At the forward crew station, the instrumentation control provisions are limited to the functions essential for a single-pilot flight, because of space restrictions.

Other Requirements

A great deal of emphasis was laid upon configuration control and documentation. All changes to the aircraft were documented in separate drawing sets and incorporated in technical manuals. All flight test instrumentation was installed in accordance with normal aircraft installation practices and specifications of the aircraft manufacturer.

The first flight tests with the F-16 MLU were foreseen in June 1999. Because of the short time available for design, manufacturing and installation of the system, long term developments had to be avoided and commercially available equipment had to be applied as much as possible.

Project Realization

Parties Involved

System requirements were defined by the RNLAF and NLR's Operational Research Department. NLR's Instrumentation Department designed the system. The RNLAF actively participated in the project, especially in the design and installation of aircraft modifications, additional brackets and wiring. Most of the equipment was purchased from external suppliers. In-house developments were necessary for the cockpit control system and the software for the cockpit display.

Planning

In December 1997 a well-defined pre-design had been prepared, which made it possible to design, manufacture and test the system in less than one year. The modification of the aircraft started in September 1998 at Woensdrecht Air Force Base, and was followed by the installation of the system in the beginning of 1999. After ground tests a first flight with the new instrumentation was made in June 1999. Because no serious problems were encountered no further flights were necessary. The aircraft was ferried a few days later to Leeuwarden

Air Force Base, where it was put into use for both its operational tasks and test flights. In the second half of 1999 the system was finalised and the documentation was completed. In May 2000 the old system was decommissioned.

System Design

System Lay-out

The requirement for easy reconfiguration and expansion of the system seemed to be in contradiction with the requirement to keep the additional equipment and cabling to a minimum. However, by choosing a modular distributed system concept, based on an instrumentation data bus, both requirements could be met. This concept allows equipment to be installation in small locally available spaces rather than requiring one large space for a centrally installed system. In the latter case, standard aircraft parts would have to be removed, in conflict with the requirement to keep the aircraft fully available for its operational tasks.

Data Acquisition System

The data acquisition system has the following components:

- Programmable Master Unit (PMU), a unit that controls the system and acquires the data from the remote data acquisition units and mux-buses. The unit is capable of performing calculations, including conversion to engineering units. The output data are formatted into three independently configurable data streams, which are distributed to respectively a Cockpit Display and Control System, a Recording System and optionally a Telemetry System. The maximum data throughput rate is 24 Mbit/s.
- Programmable Conditioner/Encoder Units (PCU), used as remote data acquisition units at places were enough space is available to mount these relatively large units.
- Micro Miniature Signal Conditioners (MMSC), significantly smaller (and more expensive) than the PCU and used where space is a limiting factor.

The above units communicate via a command/respond data bus, extended with extra wires for camera control and for power supply to the remote data acquisition units. The wires are bundled in a specially manufactured cable, which is routed from the PMU through the aircraft in five branches. Connections to this bus are provided at specified locations. The system is programmed by means of special set-up software, which runs on a standard (laptop) PC, connected via a serial port to the PMU.

Check-out of the J-066 test aircraft

Recording System

The basic configuration of the recording system consists of a Merlin ME-981 data to video encoder and a TEAC V-80 Hi-8 airborne video cassette recorder. The recorder is located in the cockpit, easily accessible for the flight test engineer. Currently the system is capable of recording the data from the PMU at up to 2.2 Mbit/s, together with the cockpit voice signal. To meet the requirement of exchanging data with Edwards AFB, the system can be expanded by replacing the recorder by a triple-deck version and adding two encoders with dual mux-bus interfaces.

Real-time Display and System Control

The data from the PMU can be visualised on an Instrumentation Display Panel at the aft crew station of the cockpit. This display is installed in a modified Aft Seat HUD Monitor console, mounted on top of the glareshield. This console also houses the Cockpit Electronics Unit, which processes the data to be displayed, and the Instrumentation Selection Panel, which is the user interface to the system. Four predefined screen layouts with plots of the traces of up to four parameters can be selected. The test pilot in the forward seat can select the image of the IDP on his right-hand Multi-Function Display. Common control func-

tions such as instrumentation power switching, starting the recorder and event markers are available on panels at both the forward and aft crew station.

Camera System

A camera system is used to record the separation trajectory of an external store. The flight test engineer can select up to five high-speed cameras independently. When a *camera run* signal is activated, the cameras run with a pre-set speed of 16 to 200 frames per second. The *store release* signals and a time reference are recorded on the edge of the film. For synchronisation with the other data, the store release signals are also recorded by the data acquisition system.

The cameras can be connected via a special camera interface to any of the connectors of the instrumentation data bus. Usual locations to mount the cameras are a modified tip launcher, a modified centreline pylon and a chaff/flare dispenser at the tail of the aircraft.

Flight Safety

Mechanical and electrical analyses have been performed to prove that the modified aircraft is safe to fly. Strength calculations for the new or modified parts have been made. Electrical safety analyses considered the interfaces with the aircraft systems. Environmental tests on separate parts proved the integrity of the instrumentation. To avoid problems with regard to Electro-Magnetic Interference the aircraft was subjected to a Safety of Flight Test.

The results from the safety analyses were reviewed in a Safety Review by the RNLAF. Based on this review the Director of Materiel of the RNLAF released the aircraft for both operational use and flight test programmes.

Airworthiness Qualification of Navigation and Targeting Pods

Introduction

In 1997 the Royal Netherlands Air Force (RNLAF) ordered a number of BAE Systems 'Falcon Owl' forward-looking infrared navigation pods (in short: nav pod) and a number of Lockheed Martin 'Enhanced Targeting Pods' (in short: tgt pod) for the F-16MLU aircraft. NLR was tasked to assist the RNLAF in the airworthiness qualification of the pods for the F-16MLU.

Qualification Process

In an earlier joint effort of the RNLAF, the Royal Netherlands Navy and NLR, the qualification of military aircraft was described in a 'Regulation for the Qualification and Continued Airworthiness of Military Aircraft in the Netherlands'. The Regulation includes both airworthiness and operational aspects.

Aft seat HUD monitor console with instrumentation display

The airworthiness qualification of the nav pod and tgt pod was the first F-16 qualification project that was subject to the new Regulation.

First, the compatibility of the pods to the aircraft environment is proved. Next, it is shown that the combination of aircraft with pod or pods remains safe within the operational environment.

The following sections cover the airworthiness qualification of the pods.

Equipment and Installation

The nav pod is about 2.5 m long and is mounted to the left-hand inlet station of the F-16. The pod contains a forward looking infra red line scanner and a laser spot locator. The pod is used for low-level, low light (night, smoke) navigation, and for identification of targets, designated by an airborne or a ground based laser system.

The nav pod is based on earlier designs, but quite heavily adapted to the RNLAF requirements. Therefore the pod is considered as a new design from an airworthiness standpoint. Moreover, its predecessors have not been approved for use on any F-16 aircraft version.

The tgt pod is also 2.5 m long and is mounted with a pylon to the right hand inlet station. The pod contains a laser target designator, a small-field-of-view infrared sensor and a daylight TV sensor. It is used to designate targets; the sensors enable the crew to identify the target.

The tgt pod is almost identical to the LANTIRN targeting pod: only the daylight TV sensor has been added. The original LANTIRN targeting pod is qualified for use with F-16C/D versions.

Qualification

Navigation Pod

As mentioned above, the nav pod was treated as a new design. Along the lines of the qualification process, the manufacturer of the pod supplied the required qualification data to NLR. Verification of the data has been carried out by NLR, which resulted in a release for flight test of a mass model of the pod in September 1999 and release of the operational pod in August 2000.

F-16 MLU test aircraft of the RNLAF equipped with navigation pod and targeting pod

Targeting Pod

The LANTIRN targeting pod is qualified for carriage on F-16C/D versions under operational conditions matching or surpassing those defined for the RNLAF F-16MLU. Since the difference between the RNLAF version of the tgt pod and the original LANTIRN pod is minimal, airworthiness qualification was based largely on similarity. The tgt pod has been released for operational use by the end of 2000.

F-16 MLU with the Pods

Engine inlet mounted pods are qualified for the F-16C/D for a large number of configurations. The F-16C/D is in many aspects similar to the F-16 MLU and was therefore taken as a reference. Still, differences exist that affect the compatibility of the F-16 MLU aircraft with the nav pod and the tgt pod. First, the aircraft structure of the F-16 MLU differs from the F-16C/D versions, which may restrict the operational use of the F-16A/B compared to the F-16C/D. In particular the allowable aerodynamic and inertia loads imposed on the aircraft by the pods may be restricted, the service life of aircraft components may be reduced, and flutter characteristics may be affected negatively. Second, the F-16 MLU is equipped with an analogue flight control system, and the F-16C/D with a digital system, which may result in different flying qualities. Third, the nav pod has not been qualified earlier for use on any F-16 version.

An airworthiness qualification programme was therefore carried out to prove the compatibility of the pods with the aircraft. During this programme about 25 flights with the F-16 MLU test aircraft have been executed between July 1999 and

December 2000. The standard instrumentation system in the test aircraft was supplemented to meet the requirements of the programme.

Flying Qualities Analysis and Flight Tests

The flying qualities, in particular the sensitivity of the aircraft to enter departure from controlled flight, were analysed using an in-house developed F-16 flight control simulation tool. The analysis showed the impact of the pods on the departure sensitivity to be small within the defined operational envelope of the aircraft.

Seven test flights with the test aircraft in 'worst case' external store configurations (as identified in the analysis) without and with pods were dedicated to verify the flying quality characteristics. In these flights the test aircraft was equipped with a nose-mounted angle-of-attack / angle-of-sideslip boom. The flight test results confirmed the analysis and were in general judged 'satisfactory'.

Configurations with substantially asymmetric loads showed unacceptable flying qualities when rolling manoeuvres were initiated at negative g (inverted flight). Operation under this condition is, however, prohibited in the aircraft's flight manual.

Flutter and LCO Analyses and Flight Tests

Aircraft such as the F-16 may show flutter and Limit Cycle Oscillations (LCO), non-linear flutter with non-diverging amplitude. The flutter analysis capability available at NLR has been used to predict possible occurrence of flutter / LCO depending on nav pod and tgt pod configurations.

Six flights in worst case LCO configurations were dedicated to the verification of the analysis. The flight tests confirmed the analysis results. In particular the negligible impact of the pods on the LCO behaviour of the aircraft was confirmed.

Store Separation Analyses and Flight Tests

Inlet mounted pods are likely to cause interference with stores in their proximity: the 370 gallon pylon tanks at the inboard wing positions, and the 300 gallon tank at the centreline position. Assessment of the separation behaviour of these stores shows that the separation of wing-mounted tanks can be critical, whereas the separation of the centreline tank is not. The separation behaviour of wing-mounted tanks was therefore investigated.

Separation limits for tanks on the right hand inboard wing position (with a LANTIRN targeting pod on the right hand inlet station) have been well established for the F-16C/D versions. Hence for the F-16 MLU the separations limits have been cleared on the basis of similarity.

The BAE Systems nav pod is new to the F-16. Analyses of available tank separation reports for several configurations with and without LANTIRN navigation and targeting pods revealed that these pods hardly effected station 4 or 6 tank separation behaviour. Therefore it was decided to restrict the flight test programme to *checking* the separation of the left-hand tank at limits identical to the LANTIRN pod limits. The check would be carried out as a direct comparison between the separation behaviour of the tank in an already qualified configuration without nav pod, to the same configuration with nav pod. The stores configurations and release test conditions were selected on basis of the analysis. The test aircraft was additionally equipped with two store separation cameras in the left-hand wing tip missile launcher.

The release tests of left hand wing tanks with and without pods and otherwise identical conditions showed hits of the tank rear end against the left ventral fin of the aircraft, destroying the fin. Since tank trajectories, and as a result the hits, were identical, the objective of the programme: show that inlet mounted pods do not affect the separation behaviour of wing mounted tanks, was met. However, the separations are obviously unsatisfactory. This problem, which may be a worldwide F-16 issue, is under further investigation at NLR.

Structural Strength and Fatigue

Aircraft Strength

Discussions with Lockheed Martin Aeronautics Company, the manufacturer of the aircraft, revealed possible overloading of the aircraft centre section structure and the tail control surfaces due to inlet mounted stores. Since no sufficient structural models were available at NLR for these areas, Lockheed Martin was subcontracted to analyse the structural loading of the aircraft in the external stores configurations and under the operational conditions as defined at the start of the programme. This analysis showed no overload cases.

Ventral Fins

F-16's ventral fins may separate from the aircraft as a result of oscillatory loads on the fins due to bodies mounted upstream such as inlet-mounted pods.

Although structurally and aerodynamically improved fins have been mounted in the Mid Life Update programme, it was decided to assess the influence of nav pods and tgt pods on the fins. Between September and October 1999 six flights with the test aircraft in external store configurations with and without pods have been dedicated to the ventral fin issue. In these flights the ventral fins and the fuselage panels to which the ventral fins are attached were instrumented with vibration transducers and strain gauges.
Comparison of a configuration with the nav pod to a configuration without the nav pod (but otherwise similar) showed no significant difference in excitation levels. Comparison of a configuration with the tgt pod to a configuration without the tgt pod (but otherwise similar) showed an increase in the excitation at all right hand ventral fin and fuselage panel transducers by about a factor of two to five in effective value, but only during slow accelerations. As a consequence the chance of fatigue damage to the ventral fins will increase.

Conclusions

A flight test instrumentation system for an F-16B MLU aircraft of the RNLAF has been designed, developed and installed in the aircraft in a relatively short time. Key functionality includes on-board data processing and display, data recording and telemetry provisions. The system enables the aircraft to maintain its full operational capabilities. The system provides the RNLAF with a flight test capability for its F-16 MLU aircraft that is not available elsewhere.

The system has proven its capabilities in a certification programme for a navigation and a targeting pod. In this programme the instrumented test aircraft has played an essential role in the programme, along with simulation and analysis tools available at NLR.

2 RIASS — An Alerting System for Safe Runway Crossing Operations on Amsterdam Airport Schiphol

NLR supports Air Traffic Control the Netherlands (LVNL) in various projects with the introduction of new air traffic control operations and systems.

Several of these projects, including RIASS (Runway Incursion Alerting System Schiphol), are related to the introduction of the future fifth runway. This runway will be located far from the terminal buildings, and the shortest taxiways to it will cross another runway: Runway 01L/19R. The primary goal of RIASS is to warn air traffic controllers against conflicts between aircraft using Runway 01L/19R for arrival or departure and traffic crossing the runway.

NLR actively participates in the following aspects of RIASS:

- Design of RIASS;
- Development of a prototype of RIASS, called MORIASS, for evaluation purposes; and
- Investigation of the safety and efficiency effects of changing to the proposed crossing operation supported by RIASS.

Runway crossings are not new to Schiphol airport. At various spots, crossings are daily practice, although they occur far less frequently than foreseen on Runway 01L/19R.

From the safety point of view, not only frequent crossings ask for special attention, but also the complexity of the taxiways, which make it more probable that pilots get confused and lose their way, and accidentally enter Runway 01L/19R via a crossing or an exit.

In order to deal with the more complex traffic situation around Runway 01L/19R, a new operational concept—the runway controller concept—is introduced. Within this concept, the runway controller is responsible for all traffic on the runway. Moreover, clearances will be given directly to all traffic involved, whereas in the present situation, clearances to for instance towing traffic are co-ordinated via the airport. Benefits from the runway controller concept will be increased situational awareness of the traffic situation and more direct control of traffic.

Design of RIASS

RIASS will serve as a safety net for operations around Runway 01L/19R. It is primarily developed to protect against runway incursions, including conflicts between taxiing aircraft that are crossing the runway and departing or arriving traffic. RIASS will give an alert to the runway controller whenever the danger of a runway incursion occurs.

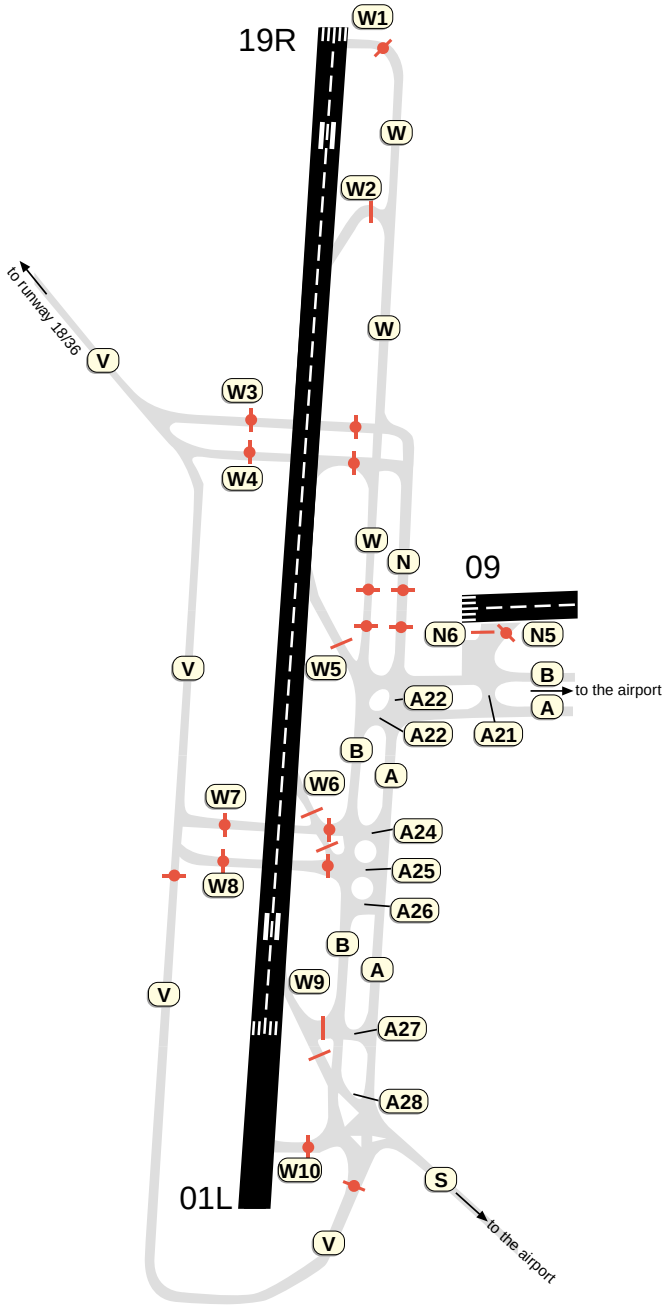


Fig. 1 – Possible layout of runway 01L/19R, Amsterdam Airport Schiphol

Besides runway incursions, RIASS will also protect against unauthorised intrusions of the runway by aircraft or vehicles. This is achieved by monitoring the passage of stop bars, which are placed around exits and crossings of the runway (see the red bars in Figure 1), and by using output of the Vehicle Detection System (VDS). Violation of a red stop bar will generate an alert.

RIASS uses the following runway incursion alerting. First, all aircraft relevant to Runway 01L/19R are detected. Then, for each aircraft, the state (departing, arriving or taxiing) is deduced from the parameters position, speed, heading and altitude supplied by two ground and two approach radars, in combination with the VDS. Next, for each departing and arriving aircraft a so-called safeguarding area is created, which consists of an area around the runway, in front of the aircraft. This area is visualised as a series of pink boxes in Figure 2. Note that the boxes are not to scale: on both sides they extend to 90 metres (or 150 metres in low visibility mode) from the runway centre line. If there is another aircraft present in the safeguarding area, there is a runway incursion, and the system gives an alert.

In a later stage, RIASS will be extended to protect against runway incursions and stop bar violations on the entire airport.

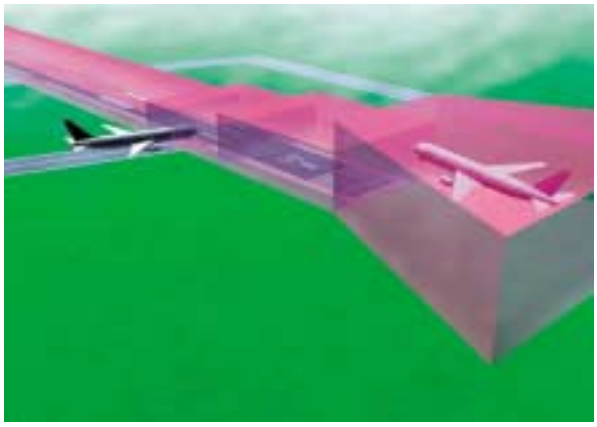


Fig. 2 – A taxiing aircraft enters the safeguarding area of an arriving aircraft: a runway incursion

Evaluations Using the Prototype MORIASS

NLR has developed a prototype of RIASS, called MORIASS (Mock-up Of a Runway Incursion Alert System for Schiphol), to facilitate the realisation of the operational system.

MORIASS is primarily designed as an evaluation tool. Evaluations involving air traffic controllers are intended to:

- Identify how a runway incursion alerting system best supports the runway controllers;
- Develop and fine-tune the underlying alerting algorithms;
- Gather feedback concerning the design of the human machine interface.

In a later stage, MORIASS may also be used for training and education of runway controllers.

Fig. 3 – Air Traffic Controller in MORIASS evaluation session

MORIASS is integrated in NLR's Tower Research Simulator (TRS). This is a full-scale airport control tower, currently simulating a zero-visibility environment. The set-up of the MORIASS simulations contains a runway controller working position with two displays, as shown in Figure 3. The display in the middle of this figure is touch-sensitive and functions as stop bar panel. The other display mainly shows the ground radar picture around Runway 01L/19R, and a small strip simulating data from the approach radar (see Figure 4 for more detail).

The evaluation sessions, in which an LVNL tower air traffic controller, a pseudo-pilot, an experiment leader and an observer participated, typically proceeded as follows. The pseudo-pilot, who controlled the simulated traffic, intentionally created a situation that would result for instance in a runway incursion or stop bar violation. The controller then assessed whether alerting was justified and was given at the right moment. Based on this feedback, either the settings of the algorithm were changed and the situation was repeated, or the situations were slightly adjusted and the algorithm settings were tested again.

After dealing sufficiently with incorrect and missed alerts, the tuning involved balancing between timeliness of alerts and prevention of so-called nuisance alerts. These are correct alerts according to the alerting algorithm, but raised in a situation considered by the controller as safe daily practice.

Qualitative Safety Assessment of Crossing Operation

Before changing an operation, LVNL extensively evaluates the effects on safety, efficiency and environment. To support this evaluation, NLR has performed a qualitative safety assessment for the proposed crossing operation on Runway 01L/19R to identify the safety and efficiency effects.

NLR has developed a qualitative safety assessment methodology with a broad operational scope. This methodology is flexible in incorporating expertise from both air traffic controllers and pilots. While some uncertainties are inherent to the qualitative approach, the methodology enables important safety critical aspects to be identified at an early stage in the development of the operation, thereby serving as a tool to minimize the total cost of its introduction.

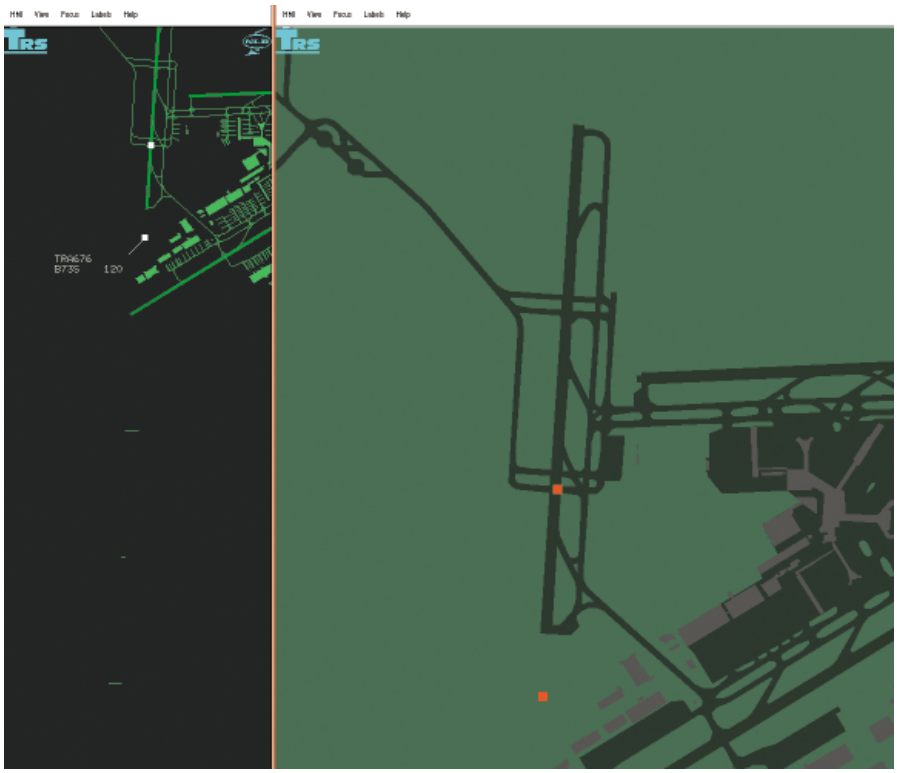


Fig. 4 – MORIASS' combined radar display for the runway controller showing a very late runway incursion

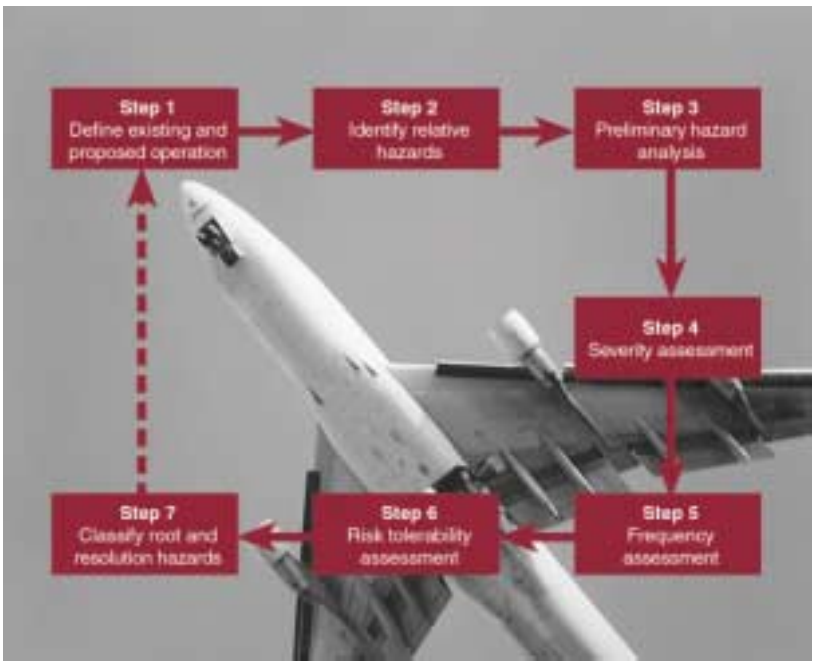


Fig. 5 – Overview of NLR's qualitative safety assessment methodology

NLR's qualitative safety assessment is based on the advisory material of the Joint Aviation Requirements (JAR). NLR has extended the JAR's method—which applies especially to technical airborne equipment—in several directions to make it suitable for assessing the safety from an operational point of view. Besides technical systems such as RIASS, the assessment involves operational procedures, roles and responsibilities of air traffic controllers and pilots, et cetera. Particular attention has been paid to cognitive aspects of the human operators: situational awareness problems may have a large influence on safety.

A stepwise overview of NLR's qualitative safety assessment process is given in Figure 5. The steps of the assessment are described below in more detail:

Step 1: Definition of existing and proposed operation
Especially differences between existing and proposed operation are important, since the attention is often focused on the effects on safety, efficiency and environment resulting from a change of operation.

In the present context, the proposed crossing operation on Runway 01L/19R is largely connected to the efficiency and environmental benefits expected from the introduction of the fifth runway. The objective of the runway controller concept, supported by RIASS, is to maintain or even improve the high level of safety, as well.

Step 2: Relative hazard identification
Concentration on these so-called relative hazards agrees with the focus on safety effects resulting from a change of operation. The hazards are identified in structured brainstorm sessions with air traffic controllers, pilots, and system and safety experts. Subsequently, hazard databases are used to verify the effectiveness of the brainstorms and to identify additional hazards where necessary.

For the RIASS assessment, an instance of a relative hazard is: 'Pilot misunderstands some clearance and starts to take off'. Of course, this can also occur in the existing operation, but the consequences of such an event can be much more severe in the proposed crossing operation.

Step 3: Preliminary hazard analysis
After the list of relative hazards is as complete as reasonably practicable, the hazards are clustered into so-called conflict scenarios. Conflict scenarios are general hazardous situations such as 'Aircraft erroneously in take-off, while another aircraft is crossing the runway'. This conflict scenario contains for instance the previously mentioned

'Pilot misunderstands some clearance and starts to take off', but also 'Runway controller mixes up two aircraft and erroneously gives take-off clearance'.

A graphical impression of the clustering of hazards into a conflict scenario is given in Figure 6.

While the above hazards can initiate a conflict, other hazards complicate the resolution of a hazardous situation, as for instance: 'Pilot not in contact with the right controller' or 'RIASS alert is late'. Such hazards are called resolution hazards.

Step 4: Severity Assessment
The severities of the conflict scenarios are assessed by pilots, air traffic controllers and safety experts. JAR's severity categories 'Minor', 'Major', 'Hazardous' and 'Catastrophic' are used for this classification.

The outcome is that most conflict scenarios can result in situations of wide-ranging severities – depending for instance on aircraft positions and speeds, timeliness of conflict detection, availability of communication means between runway controller and pilots, et cetera.

A general resolution model has been developed to categorise event sequences according to severity. This model also takes into account the various resolution hazards.

Step 5: Frequency Assessment
The aim of the frequency assessment is to estimate for each conflict scenario how often it results in each of the severities identified in Step 4. These frequencies are expressed in JAR's qualitative terms 'Probable', 'Remote', 'Extremely remote' and 'Extremely improbable'.

Primary input to the frequency assessment is again obtained via expert interviews. It usually turns out to be not feasible to estimate the frequencies at once: the conflict scenarios and the various ways to resolve them are too complex. Therefore, a more detailed approach is taken, where probabilities of root hazards, chances of detection and resolution, as well as various reaction times are estimated. Using the 'algebraic rules' of the conflict scenario and resolution model, this expert input is processed to yield estimates of the frequencies.

Step 6: Risk Tolerability Assessment
To assess the risk associated with each conflict scenario, the identified severities are combined with the corresponding estimated frequencies in a

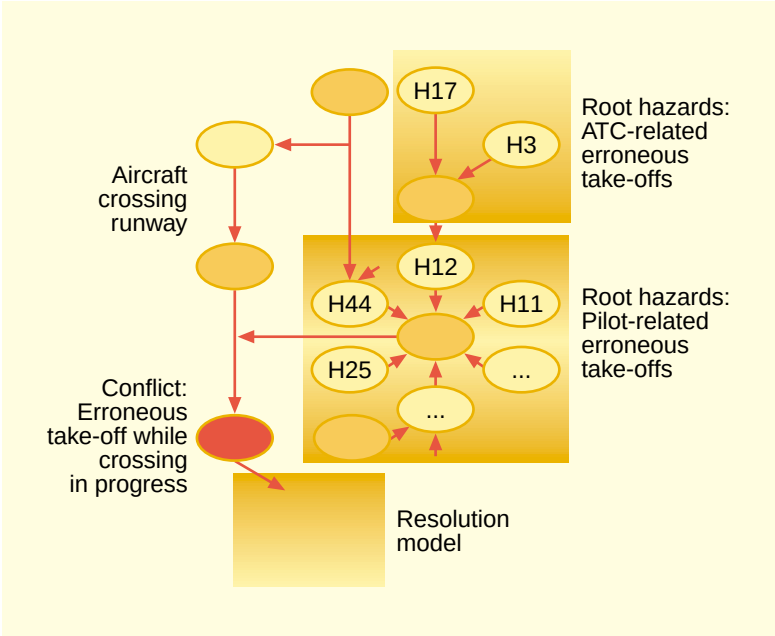


Fig. 6 – Graphic impression of conflict scenario; yellow ovals indicate hazards and orange ones states such as 'aircraft crossing the runway' and 'aircraft in take-off'; the red oval represents the conflict 'erroneous take-off while crossing in progress'.

risk matrix. According to JAR the following combinations of severity and frequency are allowed:

- Minor severity may be 'Probable';
- Major severity must be no more frequent than 'Remote';
- Hazardous severity must be no more frequent than 'Extremely remote';
- Catastrophic severity must be 'Extremely improbable'.

The above combinations are classified as 'Tolerable'. The risk of conflict scenarios containing higher combinations of severity and frequency is classified 'Unacceptable'; if a conflict scenario has only lower combinations, the risk is called 'Negligible'.

A risk tolerability matrix for a hypothetical conflict scenario is shown in Figure 7; the coloured squares represent the identified risk combinations.

Step 7: Classification of root and resolution hazards

Finally, all hazards are classified using the above risk tolerability terms. To this end, it is analysed what 'share' the various hazards have in the total risk of a conflict scenario. This method applies for root as well as resolution hazards.

For high-risk conflict scenarios, this method points towards the hazards contributing most to the risk, and in this way offers indicators of safety bottlenecks in the operation.

The results of the qualitative safety assessment are used by the RIASS design team to further improve the RIASS operation, and by the LVNL management to make decisions towards efficient operational implementation.

Frequency \ Severity	Catastrophic	Hazardous	Major	Minor
Probable	Unacceptable	Unacceptable	Unacceptable	**Tolerable**
Remote	Unacceptable	Unacceptable	**Tolerable**	**Negligible**
Extremely remote	Unacceptable	Tolerable	**Negligible**	Negligible
Extremely improbable	Tolerable	**Negligible**	Negligible	Negligible

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Fig. 7 – Risk tolerability diagram for hypothetical conflict scenario

Concluding Remarks

The introduction of the fifth runway results in major changes to existing parts of Schiphol airport. One of these changes is that a significant number of aircraft cross another runway.

NLR supports the LVNL in three vital ways to develop a crossing operation satisfying high standards of safety and efficiency:

1. Assistance in the design of the alert system RIASS for safeguarding against runway incursions;
2. Development of a prototype alert system MORIASS, which enables early evaluations to be made by operational air traffic controllers;
3. Performing a qualitative safety assessment of the proposed crossing operation. This assessment also identifies the most safety-critical operational aspects, which serves as feedback to the operational concept developers.

These contributions of NLR are aimed at supporting the LVNL in the introduction of a safe and efficient crossing operation in a well-founded and effective way.

3 Research for Crashworthiness of Aircraft Structures

In the past decade, NLR has carried out research and development activities in several areas to improve the crashworthiness of future helicopters and fixed-wing aircraft. The crashworthiness of composite helicopter structures has been studied, and components for the NH90 helicopter have been developed. In a national collaboration, a crashworthy troop seat has been developed. In several international collaborations, NLR has been involved in the development of crashworthy composite and metal aircraft structures. The potential for further improvement is expected to incite continuing collaborative research and development.

Crashworthiness can be defined as the capability of an aircraft to protect the occupants from serious injury and death in case of accidents that are potentially survivable. In the case of fixed-wing aircraft, such accidents are characterized by impacts with the surface at modest speeds and fairly horizontal flight paths. They mainly pertain to problematic take-off and landing situations, or of aircraft, running out of fuel or losing engine power, that are attempting a controlled emergency landing or ditching. Such accidents form a significant percentage of all fixed-wing aircraft accidents. Helicopters often fly at low speeds and low altitudes, and helicopter accidents are therefore more often potentially survivable.

Aircraft structures have inherent crashworthiness, because they are able to absorb energy by permanent deformation. In this respect, bigger aircraft structures can absorb more energy than smaller ones. In an accident, the survivability of the occupants is governed by several conditions, of which the most important are the fact that their speed must be decreased gradually to zero, that they must not be severely impacted by their surroundings, and that they can escape before a fire breaks out. Since the seventies, the aeronautic community, with the objective to reach improvements in all these conditions has pursued dedicated design for crashworthiness. The authorities have defined specific design requirements, and new structural concepts and numerical simulation capabilities have been developed by the industry. Even airports are now required to install 'frangible' approach light structures, which break, distort or yield upon impact, while absorbing minimal energy, so as to present a minimum hazard to aircraft.

Military Helicopters

Design for crashworthiness was pioneered for military helicopters, where the potential for improvements was highest, since accidents often occur at low speeds although the structure surrounding the occupants, that is available for energy absorption, is minimal. Therefore, the major threat to helicopter occupants in a crash is abrupt vertical deceleration, which may lead to fatal spine injuries. As a result, design requirements were defined, such as the notorious MIL-STD 1290, and structural concepts to integrate energy-absorption mechanisms have been developed. These mechanisms primarily consist of specially designed energy-absorbing landing gears, crushing sub-floor structures and stroking seats (Fig.1). The concepts have the objective to provide survivability for

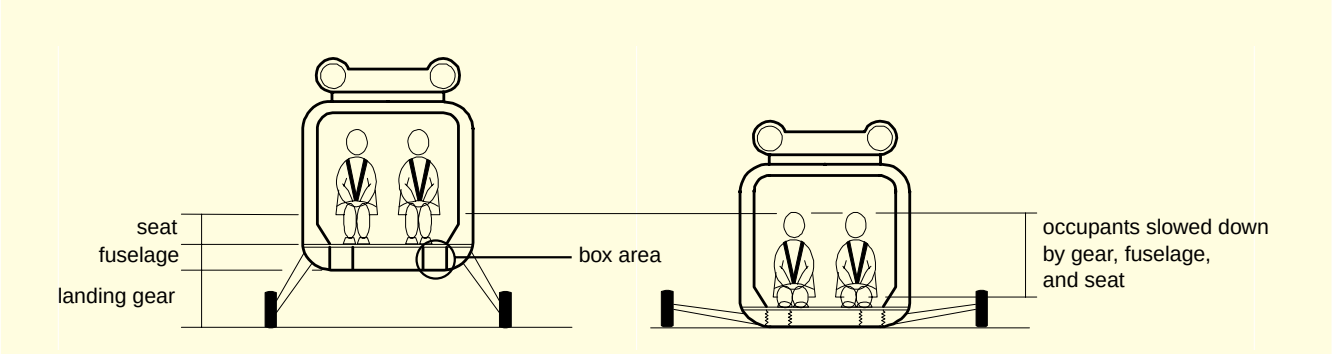

Fig. 1 – Mechanisms for energy absorption (courtesy Jim Cronkite/Bell)

Fig. 2 – NH90 helicopter model

accidents with a vertical velocity of up to 11 m/s. The use of composite materials for fuselage structures was also pioneered for military helicopters, such as the NH90 helicopter. The lack of plastic deformation of composites and their complicated failure modes have presented a big challenge to the designers, to provide the structure with sufficient crashworthiness. Another aspect that is currently under investigation, both in the US and in Europe, is the water impact scenario. Many helicopters operate over water, which means that it is not unlikely that accidents involve an impact with the water surface. Compared to designing crashworthy concepts for impacts on land, this requires new innovative structural solutions, and more complicated simulation techniques.

Large Aeroplanes

For large commercial aeroplanes, the vertical velocity in a survivable accident situation is a smaller problem than for helicopters, because the sub-floor structure is significantly more substantial. Made from aluminium, a material with a large capacity for plastic deformation and energy absorption, this structure has enough inherent crashworthiness. The major threat to such aircraft results from the large forward velocity that must be decreased, and the significant potential for post-crash fires. Since the eighties, the attention has focused on the definition of more stringent requirements for seats and their attachments to the floor, and studies aimed at the prevention or delay of the outbreak of fires were performed. In this respect it should be noted, that GLARE, a fibre-metal laminate expected to be used as a fuselage skin material on the Airbus A380, has a significantly longer burn-through time than aluminium, hence will provide the passengers with more time to escape.

Shell Structures

Typically, aircraft structures are shell structures made of lightweight materials. The structural concept of a shell structure is such that its operational loads are carried 'in-plane', for which it is most efficient. However, accidents impose loads transversely to the shell surface, which easily leads to penetration. Hence, energy absorption is achieved mainly by deformation of the sub-structure, such as frames, ribs, bulkheads and spars. This is also the case for other accidental impacts that have to be considered in the design of aircraft: bird strikes and impacts by runway debris, tire fragments and engine components. Although these are not considered to be scenarios pertaining to the concept of crashworthiness of an aircraft, they do affect flight safety.

Design of NH90

During the past decade, NLR has been contributing to the development of technology to design crashworthy aircraft structures. Because the aerospace industry in the Netherlands took part in the development of a helicopter, the NH90 (Fig.2), and because the Royal Netherlands Air Force was going to operate helicopters on a much larger scale than before, a combined study was undertaken by Fokker and NLR under contract to the Ministry of

Fig. 3 – Sine-wave beam concept for energy absorption

Fig. 4 – Crash tube for NH90 nose landing gear and fabrication tooling

Defence, during the years 1990-1992. The objective of this study was to become acquainted with typical crashworthiness aspects of helicopters, in particular with structures made of composite materials. The failure behaviour of composite materials was studied, and a design, fabrication and test cycle was carried out for one of the most promising structural components for energy-absorbing helicopter sub-floor structures, the sine-wave beam (Fig.3). This project was followed by a project to develop a 'crash tube' for the nose landing gear of the NH90, which must absorb additional energy in crash situations. This project was carried out for SP aerospace & vehicle systems, the company that is responsible for the development of the landing gears of the NH90 (Fig.4).

Fig. 5 – Troop seat with energy absorption capability

European Projects

Within Framework Programme III of the EU, NLR and Fokker participated in a project entitled 'Crashworthiness for Commercial Aircraft', focused on aluminium fuselage structures. NLR's contribution consisted of the definition of three 'potentially survivable' crash scenarios, based on accident statistics, to become a frame of reference for numerical analyses. In this project, NLR also used the 'KRASH' finite element code to study the effect of local floor design, as generated by Fokker, on the acceleration pulse imposed on the passengers. KRASH is a relatively simple code, which was developed in the US for the FAA and the US Army to evaluate and improve the crashworthiness of general aviation aircraft and military helicopters. The introduction of large troop-carrying helicopters in the RNLAF, such as the Chinook and Cougar, raised the issue of the potential survivability of personnel seated on troop seats. Based on design specifications from the Italian helicopter manufacturer Agusta and in co-operation with students of Hoogeschool Haarlem, a crashworthy troop seat was developed. It was tested at the drop tower of Twente University, (Fig. 5). Also, a structural concept was developed for the bottom skin panels of a helicopter fuselage that would be able to withstand the pressure of an impact on water (Fig.6). Regular composite skin panels would fracture immediately, resulting in a reduced capability of the substructure to absorb impact energy, and in immediate water ingress. This concept is currently being evaluated in EU project CAST, a project with Westland and Agusta, dedicated specifically to water impact of helicopters.

Within Framework 4 of the EU, NLR participated in a project entitled CRASURV, on the crash survivability of composite aircraft structures. NLR's contribution consisted of the design and fabrication of composite 'boxes' made of sine-wave beams (Fig.7), which represented generic helicopter sub-floor structures. In collaboration with Alenia, a composite fuselage sub-floor structure was developed, based on the ATR commuter (Fig.8). These structures were fabricated and tested in a vertical scenario, at DLR and CEAT, respectively. The test results were used to validate new numerical simulation capabilities, developed in the same project. In parallel, new material models for crushing composites, impacted at high speed, were developed in EU project HICAS, for which NLR used the B2000 finite element code. At present, NLR participates in EU project CRAHVI, on crashworthiness for high velocity impacts. In this project, NLR focuses on the modelling of bird strikes on a horizontal stabiliser, and new design concepts for leading edges.

For many years, NLR has advised the Netherlands Department of Civil Aviation (RLD) with respect to the development of design requirements, guidelines and test methods for frangible approach light masts. Currently, a capability for computer simulation, using KRASH, of the impact of the wing of a light aircraft against a frangible approach light structure is being developed (Fig.9), in co-operation with Twente University.

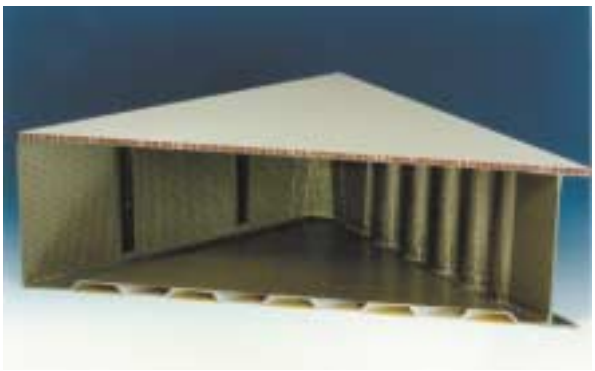

Fig. 6 – Generic helicopter sub-floor structure with tensor skin

Fig. 7 – Generic helicopter sub-floor structure

Fig. 8 – Composite energy-absorbing sub-floor structure for a commuter aircraft

Fig. 9 – Impact test of a light aircraft wing section against a frangible approach light mast (courtesy Exel Oy)

Numerical Analysis

The subject of crashworthiness will be a challenging issue for a number of years to come, because the potential for improvements is still significant. Major improvements can be made only if crash events can be simulated accurately by numerical analysis. Predicting the sequence of events and the deformation process during a crash is difficult, and its success depends on the development of solution techniques and of models that represent material behaviour beyond initial failure, especially for composite materials.

European Collaboration

Most of the work in crashworthiness is carried out within the framework of European projects, in which the Structures Technology Department of NLR co-operates closely with the Structural Integrity Department of DLR Stuttgart, the Structure and Damage Mechanics Department of ONERA, and the large scale crash test facility at CEAT. This close collaboration with European colleagues on safety issues began in 1992 and has been continued in five projects funded by the European Union. It might be speculated that these joint activities may one day lead to the establishment of a European 'Centre for aircraft structural safety', in order to better serve the European aircraft industry and support the safety authorities.

Appendices

Appendices

1 Publications

In 2000, NLR published a total of 709 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

NLR–TP–97656 U

Objective quantitative tracker performance analysis
Presented at the Colloquium on Surveillance Sensor Tracking, Delft, The Netherlands, June 1997
Hogendoorn, R.A.; Neven, W.H.L.; Westland, J.

NLR–TP–97657 U

ARTAS: Multisensor in an ATC environment
Presented at the Sensor and Propagation Panel Symposium, Lisbon, September 1997
Hogendoorn, R.A.; Neven, W.H.L.

NLR–TP–98448

A pilot model for helicopter manoeuvres
Presented at the 24th European Rotorcraft Forum, Marseille, France, 15–17 September 1998
Vorst, J. van der

NLR–TP–98599

Integrated management of design processes and data: The CACE environment prototype
Presented at the 7th Symposium on Computer Aided Control System Design (CACSD '97), Gent, Belgium, 28–30 April 1997
Spee, J.B.R.M.; and Bijwaard, D.J.A.

NLR–TP–98600

Collaborative engineering environments – Two examples of process improvement
Published in the Proceedings of the 8th Annual International Council on Systems Engineering 1998 'People, Teams and Systems', Vancouver (BC), Canada, 26–30 July 1998
Spee, J.B.R.M.; Laan, D.J.; and Bijwaard, D.J.A.

NLR–TP–99241

Development and verification of the FCDM safety critical avionics module
Presented at the Data Systems in Aerospace Conference (DASIA '99), Lisbon, Portugal, 17–21 May 1999
Udo, R; and Sluis, E. van de

NLR–TP–99341

A concept for a predictive maintenance facility for a space robot
Presented at the Data Systems in Aerospace Conference (DASIA'99), Lisbon, Portugal, 17–21 May 1999
Bos, J.F.T.; Heemskerk, C.; and Verhaegen, M.

NLR–TP–99420

Analysis and validation of GNSS performance
Presented at the 3rd Symposium on Global Navigation Satellite Systems, GNSS '99, Genoa, Italy, 4–8 October 1999
Vermeij, J.H.; Berg, A.N. van den; Farnworth, R.; and Breeuwer, E.

NLR–TP–99424

On behavioural inequalities
Published in The Mathematics of Systems and Control: From Intelligent Control to Behavioral Systems (1999), University of Groningen, ISBN 90–367–1112–6
Dam, A.A. ten; and Nieuwenhuis, J.W.

NLR–TP–99438

The advanced crew terminal, an integrated, common, low-cost and configurable toolset for operations activities
Presented at the International Astronautical Congress, Amsterdam, The Netherlands, 4–8 October 1999
Oijen, E.C.; Wolff, H.M.; and Dujardin, P.G.J.P.

NLR–TP–99454

Assessment of wake vortex safety to evaluate separation distances

Presented at the CEAS/AAAF Conference on 'Research for Safety in Civil Aviation', Paris, 21-22 October 1999

Speijker, L.J.P.; Blom, H.A.P.; and Kos, J.

NLR–TP–99478

Upgradable photonic slot routing networks to cope with increasing capacity demands

Presented at SPIE's International Voice, Video and Data Communication Symposium, Boston, USA, 19–22 September 1999

Wedzinga, G.; Chlamtac, I.; Fumagalli, A.; and Carruthers, J.B.

NLR–TP–99485

F-16 engine access cover and ventral fin structural analysis model for evaluation of life enhancing modifications

Presented at ASIP, San Antonio, USA, 30 November 1999

Tongeren, J.H. van; Lof, C.J.; Meijer, J.J.; and Geurts, E.G.M.

NLR–TP–99486

Residual stresses in as-sprayed and heat treated thermal barrier coatings – Measurements and FEM calculations

Presented at the 5th European Conference on Residual Stresses, Noordwijkerhout, The Netherlands, 28–30 September 1999; Published in 'Materials Science Forum'

Koolloos, M.F.J.

NLR–TP–99505

Tail shake vibration – Objective comparison of aerodynamic configurations in a subjective environment

Presented at the 55th American Helicopter Society Annual Forum, Montreal, Canada, 25–27 May 1999

Waard, P.G. de; and Trouvé, M.

NLR–TP–99532

Development of a crashworthy composite fuselage structure for a commuter aircraft

Presented at the CEAS Forum on "Crash Questions", Naples, Italy, 14–15 February 2000

Wiggenraad, J.F.M.; Michielsen, A.L.P.J.; Santoro, D.; Lepage, F.; Kindervater, C.; and Beltran, F.

NLR–TP–99552

Geavanceerde numerieke methoden voor stochastische analyses (in Dutch)

Published in 'De Constructeur', Ten Hagen & Stam

Grooteman, F.P.

NLR–TP–99564

Design and fabrication of tall composite masts for large yachts

Presented at SAMPE Europe 2000, Paris, France, 18–20 April 2000

Vries, H.P.J. de

NLR–TP–99570

Preparing for liquid motion experiments in space: Sloshsat mini-spacecraft dynamics and control

Presented at the 42nd Space Science and Technology Conference, Tokyo, Japan, 28–30 October 1998

Vreeburg, J.P.B.; and Woerkom, P.Th.L.M. van

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2 Abbreviations

AECMA	Association Européenne des Constructeurs de Matériel Aérospatial (The European Association of Aerospace Industries)
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)

ISPRS	International Society for Photogrammetry and Remote Sensing
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
TU Delft	Delft University of Technology
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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