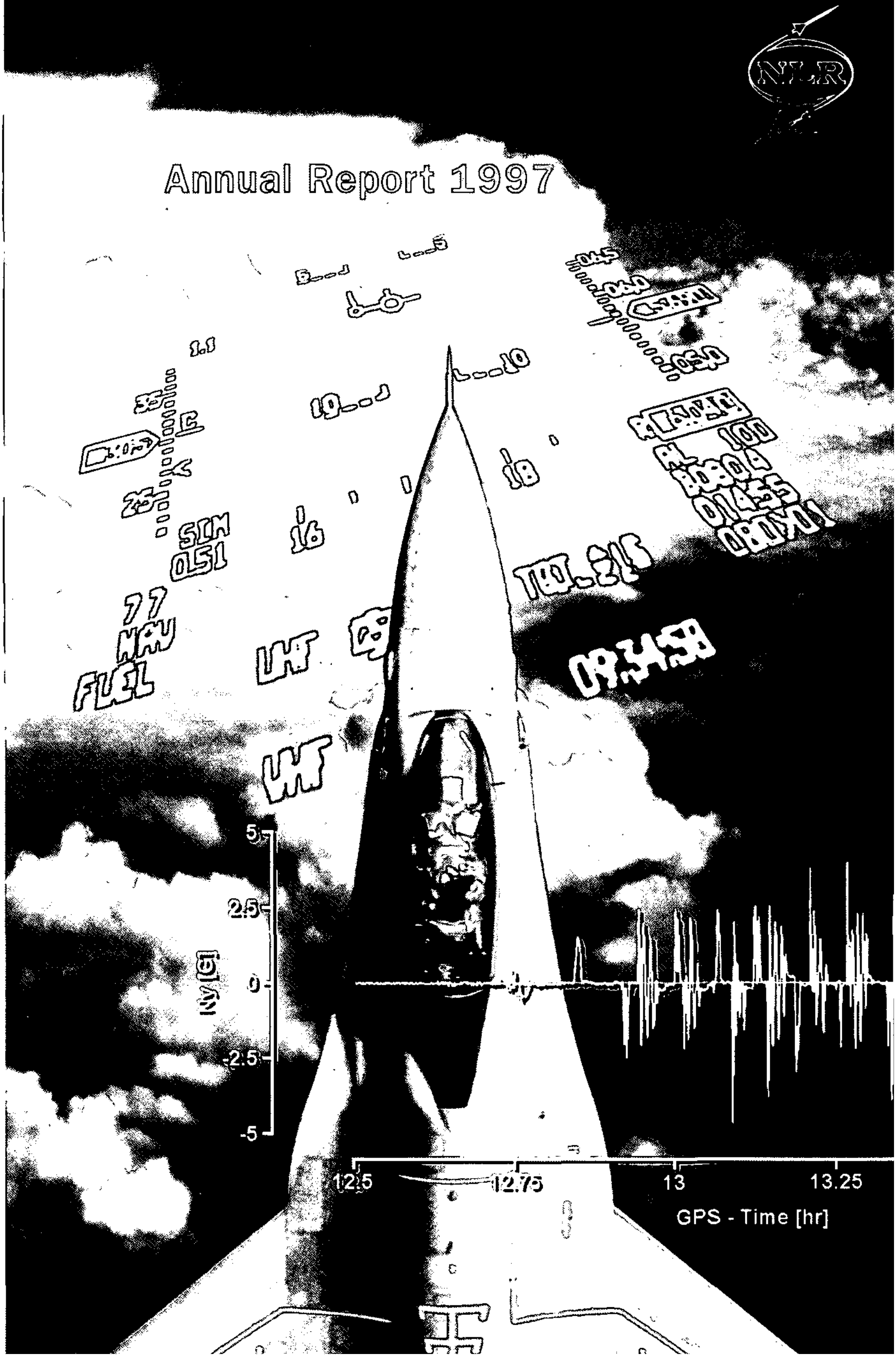
Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 1997



Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

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National Aerospace Laboratory NLR

Annual Report 1997

Board of the Foundation NLR*

	Appointed by:
J. van Houwelingen, *Chairman*	Ministers of Transport, of Defence, of Economic Affairs and of Education, Culture and Science
Ir. H.N. Wolleswinkel	Minister of Transport, for the Netherlands Department of Civil Aviation (RLD)
Cdre.ir. D. van Dord	Minister of Defence
Gen.maj. ir. M.R.H. Wagevoort	Minister of Defence, for the Royal Netherlands Air Force (RNLAF)
Mr.drs. A.A.H. Teunissen *(acting)*	Minister of Economic Affairs
Dr. P.A.J. Tindemans	Minister of Education, Culture and Science
Ir. H.N. Wolleswinkel *(acting)*	Netherlands Agency for Aerospace Programmes (NIVR)
A. van Bochove	Air Traffic Control The Netherlands (LVB)
Prof.dr.ir. A.W. Veenman	Stork N.V.
Ir. C.J.M. Gresnigt	KLM Royal Dutch Airlines
Ir. R. Uijlenhoet	Amsterdam Airport Schiphol
Ir. E.I.L.D.G. Margherita	Netherlands Organization for Applied Scientific Research (TNO)
Prof.dr.ir. J.L. van Ingen	Delft University of Technology, Faculty of Aerospace Engineering
Mrs. prof.dr. A.J.M. Roobeek	Board of the Foundation NLR, upon nomination by the Works Council
Jhr.mr. J.W.E. Storm van 's Gravesande	Board of the Foundation NLR

Chairman of the Scientific Committee NLR/NIVR*

Prof.dr.ir. P.J. Zandbergen

Board of Directors of NLR*

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

* On 31 December 1997

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1 Introduction

In 1997 NLR went through a process of reorientation after the bankruptcy of Fokker Aircraft in 1996. This reorientation process has resulted in a new mode of operation of the laboratory. The size of NLR – the number of employees – remained roughly at the same level and NLR covers the same spectrum of activities as in the past, but more emphasis is now given to research topics that are related to the operational aspects of civil and military aircraft. As a consequence, much more effort is now spent on disciplines such as ATC/ATM-related research and human factors and less for instance on aerodynamics. Special attention is given to the environmental and safety aspects of aeronautics.

Towards the end of 1997 the Netherlands government defined its position with respect to the future of aeronautics in the Netherlands and especially of the industry surviving after the disappearance of Fokker Aircraft. The government decided to support the industry in its attempts to become a participant in Airbus programmes, particularly the A3xx, as a supplier of systems and subsystems. The government also decided to enable the industry to position itself for possible participation in the development of the Joint Strike Fighter (JSF), a possible successor to the F-16s of the Royal Netherlands Air Force.

In its statement on the Netherlands aeronautics industry, the government recognized and underlined the importance of the knowledge infrastructure of the Netherlands and in particular of NLR as the national aerospace research institute giving indispensable technological support to the industry. As a consequence, the government's budget for NLR's own programme of basic research will be kept at about the same level as in 1997. Since the engineering capability of the industry is limited compared to the situation in the past, there will be a strong demand from this industry for technical support by NLR.

The government of the Netherlands also decided that Amsterdam Airport Schiphol (AAS) will be allowed to accept a further growth of air traffic in the coming years in order to maintain its position as one of the mainports in western Europe. At the same time the government decided that, since the airport is situated in a highly populated area, it has to stay within rather strict boundary conditions as far as environmental – noise and pollution – and safety aspects are concerned. To make possible a significant increase in capacity within the present environmental and safety limits, the development and implementation of advanced technical means is needed, and NLR as the national research institute is expected to contribute largely to this process.

It may be clear from the above that NLR has high expectations for work in the coming years. Together with an increasing contribution from NLR to support the aircraft operations of the Royal Netherlands Air Force and Navy and an expected growing share in space technology activities in the Netherlands it will result in a strong demand for NLR's supporting services.

More and more the development of the technology for future aircraft and aircraft operations and for the air transport system is a matter of international co-operation. In 1997 NLR participated in many research projects of the European Union (EU), Eurocontrol and the Western European Armament Group (WEAG).

In 1997 NLR also continued to give strong support to a more intensive co-operation between the European research institutes, within both the Group for Aeronautical Research and Technology in Europe (GARTEUR) and the Association of European Research Establishments in Aeronautics (AEREA). In addition, the co-operation with the German Aerospace Research Centre (DLR) was further expanded by integrating the operation of the aeronautical high-speed wind tunnels of DLR and NLR into the foundation German-Dutch Wind Tunnel (DNW).

J. van Houwelingen,
Chairman

2 General Survey

2.1 Mission and Means

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

With sites in Amsterdam and in the Noordoostpolder, NLR owns wind tunnels, laboratory aircraft, research flight simulators and an Air Traffic Control research simulator. NLR has available an extensive set of equipment for gathering, recording and processing flight test data. NLR also has facilities for research in the areas of structures and materials, space technology, remote sensing and environmental testing. NLR's extensive computer network includes a 32-GFlops NEC SX-4 supercomputer, tools for software development and advanced software for computational fluid dynamics and for calculations of aircraft and spacecraft structures.

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

2.2 Activities in 1997

In 1997 NLR's turnover was 143 million guilders compared to 140 million in 1996. The income from contracts was 99 million guilders, two million lower than in 1996. In 1997 about 40% of the total of NLR's activities were related to the development and 60% to the operation of aircraft and spacecraft; 85% of NLR's activities were related to aeronautics and 15% to space. Civil and military research amounted to 65% and 35% respectively. About 30% of the work under contract was carried out for foreign customers.

The total operating costs of NLR, amounting to 143 million guilders, included personnel costs of 105 million guilders.

Services Provided under National Contracts

Activities under contract to Dutch customers amounted to 69 million guilders. These contracts included work for the Netherlands Agency for Aerospace Programmes (NIVR) under its programmes for aeronautics and space research and technology. A number of research programmes were executed under contract to the Royal Netherlands Air Force, the Royal Netherlands Navy, the Netherlands Department of Civil Aviation (RLD), Air Traffic Control The Netherlands (LVB), Fokker Aviation and Fokker Space. NLR also carried out work to support the Ministry of Defence, the DNW, the European Transonic Wind Tunnel (ETW) and several other government services and private companies.

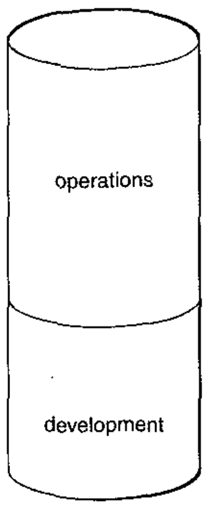
Contracts from Fokker concerned among other things the development of components of the NH90 helicopter. A major part of the work for the RLD was related to studies on airworthiness and regulations, on present and future ATC systems and on safety and environmental aspects of aeronautics. Research on present and future ATC systems was also performed under contract to the LVB, KLM Royal Dutch Airlines and Amsterdam Airport Schiphol.

Services Provided to Foreign Customers

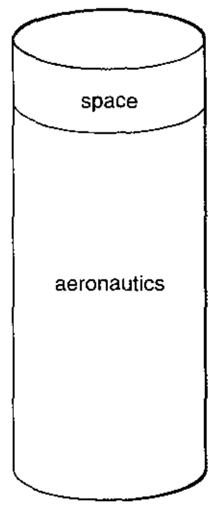
Research carried out under contract to foreign customers amounted to 30 million guilders. Major customers were the European Space Agency, the European Union and Eurocontrol.

Research and Equipment

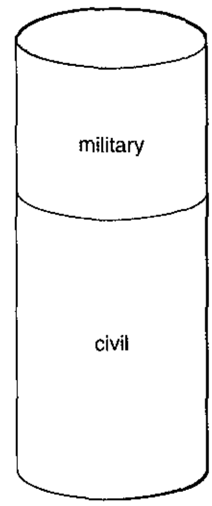
NLR spent 25 million guilders on its basic aerospace research programme supported by the government, aimed at preserving NLR's capability to support its customers in the future. Research aimed at the development and modernization of NLR's research facilities amounted to 17 million guilders. A total of 14 million guilders was used for capital investments, of which the construction of a new office building in Amsterdam, the purchase of facilities for structural testing and investments in new systems for the DNW were the most important ones.



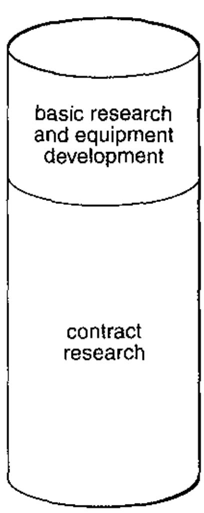
Division of the work into development and operations support



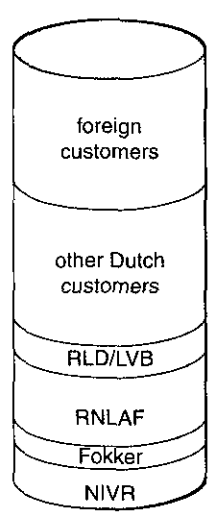
Division of the work into aeronautics and spaceflight support



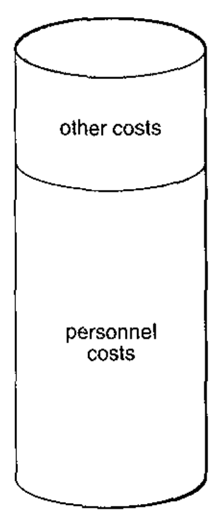
Division of the work into civil and military support



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

National and International Co-operation

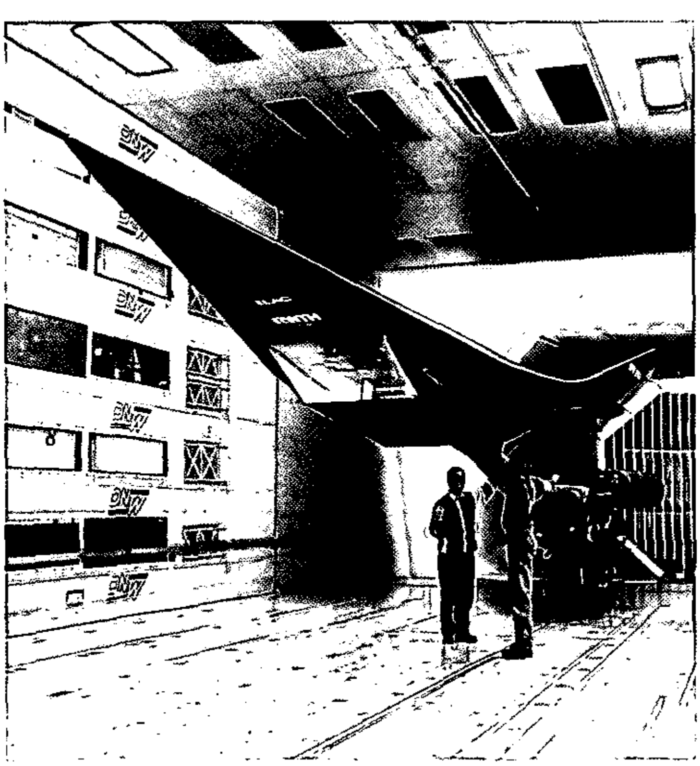
A large part of NLR's basic research is carried out as NLR's own contributions to European research projects both on the civil (EU, Eurocontrol) and military (EUCLID, WEAG) sides. Another significant part is carried out in connection with co-operative programmes under the aegis of GARTEUR, the Group for Aeronautical Research and Technology in Europe, in which Germany, France, the United Kingdom, the Netherlands, Spain and Sweden take part.

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

Although the European Transonic Wind Tunnel (ETW) located near Cologne, Germany, was fully operational and performed several tests for customers, the so-called initial operation period was extended until mid-1999. This enables the participating countries, Germany, France, the United Kingdom and the Netherlands to distribute their financial support to ETW GmbH better over the coming years.

The seven aeronautical research establishments of the countries of the European Union continued their common activities under the agreement for co-operation within the Association of European Research Establishments in Aeronautics (AEREA). The association will execute joint research programmes and establish a joint approach towards the planning, use and management of large facilities.

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



ELAC, a hypersonic generic aircraft model in the 8m*6m test section of the DNW Large Low-speed Facility

Collaborative activities of the research institutes Aero-Gas Dynamics and Vibration Laboratory (LAGG) of Serpong and NLR, together with Nusantara Aircraft Industries (IPTN) and the universities Delft University of Technology and *Institut Teknologi Bandung* were continued under an Aerospace Programme for Education, Research and Technology. The co-operation is co-ordinated by NLR and by the Agency for the Assessment and Application of Technology of Indonesia.

In previous years, NLR was very active in NATO's Advisory Group for Aerospace Research and Development (AGARD). NLR was represented in most of the AGARD Panels and participated in the activities of many Working Groups. NLR continued these activities, now under the aegis of the NATO Research and Technology Organization (RTO), which carries out the activities formerly executed by AGARD.

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

Quality Assurance

The ISO 9001/AQAP-110 quality assurance certificates of the Fluid Dynamics, Informatics and Space Divisions were extended. Progress was made in obtaining certifications for the other divisions. An accreditation for EMC testing was obtained, and the calibration accreditations for forces, pressures and electronic quantities were extended.

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.

The Minister of Defence appointed Cdre. ir. D. van Dord as successor of Drs. E.A. van Hoek in the Board of the Foundation. Drs. P.G. Winters, appointed by the Minister of Economic Affairs, left the Board; pending the appointment of his successor, Mr.drs. A.A.H. Teunissen became acting member of the Board. Stork N.V. appointed Prof.dr.ir. A.W. Veenman, taking the seat formerly occupied by Fokker. KLM Royal Dutch Airlines appointed Ir. C.J.M. Gresnigt, who succeeded Ir. C. den Hartog.

As of 1 June 1997, Drs. L.W. Esselman R.A. was appointed Financial Director of NLR, succeeding Mr. J.A. Verberne R.A., who made use of the early retirement scheme. Since then the laboratory was headed by the directors mentioned on page 3.
Drs. A. de Graaff was *Associate Director.*

On 31 December 1997 the Heads of Divisions and Services were:
Prof.ir. J.W. Slooff, *Fluid Dynamics Division*
Ir. J.T.M. van Doorn, *Flight Division*
Dr.ir. G. Bartelds, *Structures and Materials Division*
Ir. B.J.P. van der Peet, *Space Division*
Ir. W. Loeve, *Informatics Division*
Ir. H.A.T. Timmers, *Electronics and Instrumentation Division*
Ir. J. van Twisk, *Engineering and Technical Services*
Ir. W.F. Wessels, *General Services*
Drs. L.W. Esselman R.A., *Administrative Services*

The senior staff further included Mr. E. Folkers, *Secretary* and Ing. F.J. Sterk, *Head Support Staff.*

The Fluid Dynamics Division was reorganized as of 1 January 1997. Since then the Division consists of the following Departments: Transonic and Supersonic Wind Tunnels, headed by Ir. W.M. van der Poel, Aerodynamic Engineering and Aeroelasticity, headed by Ir. R. Houwink, Theoretical Aerodynamics, headed by Dr. B. Oskam and Aeroacoustics, headed by Dr. H.H. Brouwer.

As of 16 June 1997 Ir. A. Gebhard succeeded Ir. J.M.A. van den Heuvel as Co-ordinator Defence Projects.

The Structures and Materials Division was reorganized as of 1 July 1997. From then it consists of the following Departments: Loads and Fatigue, headed by Ir. H.H. Ottens, Structures Technology, headed by Dr.ir. J.F.M. Wiggenraad, and Laboratory Facilities, headed by Ing. H.J. Hersbach.

As per 1 October 1997, the Engineering and Technical Services were reorganized. Since then they consist of the following Departments: Technical Design, headed by Mr. A. van den Berg, Technical projects, headed by Ir. H.B. Vos, Production Workshop, headed by Ing. W.A.M. Schrijver, Production Control, headed by Ir. J. van Twisk and Service Workshop, headed by Mr. F. Hofman.

As per 1 November, Ir. M.P.A.M. Brouwer was appointed head of the Laboratories and Thermal Control Department of the Space Division, succeeding Ir. H.A. van Ingen Schenau.

The organization of the laboratory on 31 December 1997 is shown on page 12.

At the end of 1997 NLR employed a staff of 896 (compared with 907 at the end of 1996), of whom 399 (393) were university graduates. Of the total, 773 (814) were employed on a permanent basis, and 123 (93) had temporary appointments. About 60 per cent of the staff were posted in Amsterdam, 40 per cent in the Noordoost-polder. A breakdown of the staff is given on page 13.

Organization Diagram

31 December 1997

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

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

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

Associate Director — Drs. A. de Graaff — DO

Support Staff — Ing. F.J. Sterk — DD

- *Public Relations* — Ms. J.F. van Esch — DPR
- *Publications* — Dr. B.J. Meijer — DPI

Co-ordinators:
- *Defence Projects* — Ir. A. Gebhard — CPD
- *Aircraft Development Projects* — Ing. P. Kluit — CPO
- *Spaceflight Projects* — Drs. J.C. Venema — CPR
- *Aircraft Operations Projects* — Ir. J.A.J. van Engelen — CPG
- *Basic Research and Equipment Development* — Ir. J.A.J. van Engelen — CEW
- *Quality Assurance NLR* — H. Blokker — CKZ

Secretary — ers — DJ
- *Legal* — *DJ*
- *Filing* — *DB*
- *Security* — *DB*

Personnel — J. van Druten — DZ

Co-ord. AGARD/Indonesia — ›mbroek — DA

Company Welfare Work — .. Blazer — DM; Diekema — DM

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

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

Flight
Ir. J.T.M. van Doorn — **V**

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

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

- **Loads and Fatigue** — Ir. H.H. Ottens — **SB**
- **Structures Technology** — Dr.ir. J.F.M. Wiggenraad — **SC**
- **Laboratory Facilities** — Ing. H.J.C. Hersbach — **SL**

Space
Ir. B.J.P. van der Peet — **R**

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

Informatics
Ir. W. Loeve — **I**

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

Electronics and Instrumentation
Ir. H.A.T. Timmers — **E**

- **Avionics** — **EA**
- **Electronics** — Ing. H. Slot — **EE**
- **Instrumentation** — Ir. R. Krijn — **EI**

Enginee… Technic…
Ir. J. van … — T

- **Technic…** — A. van d… — TO
- **Technic…** — Ir. H.B. V… — TP
- **Producti…** — Ing. W.A. … — op r
- **Producti…** — Ir. J. van … — TW
- **Service** — F. Hofma… — TV; TW

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

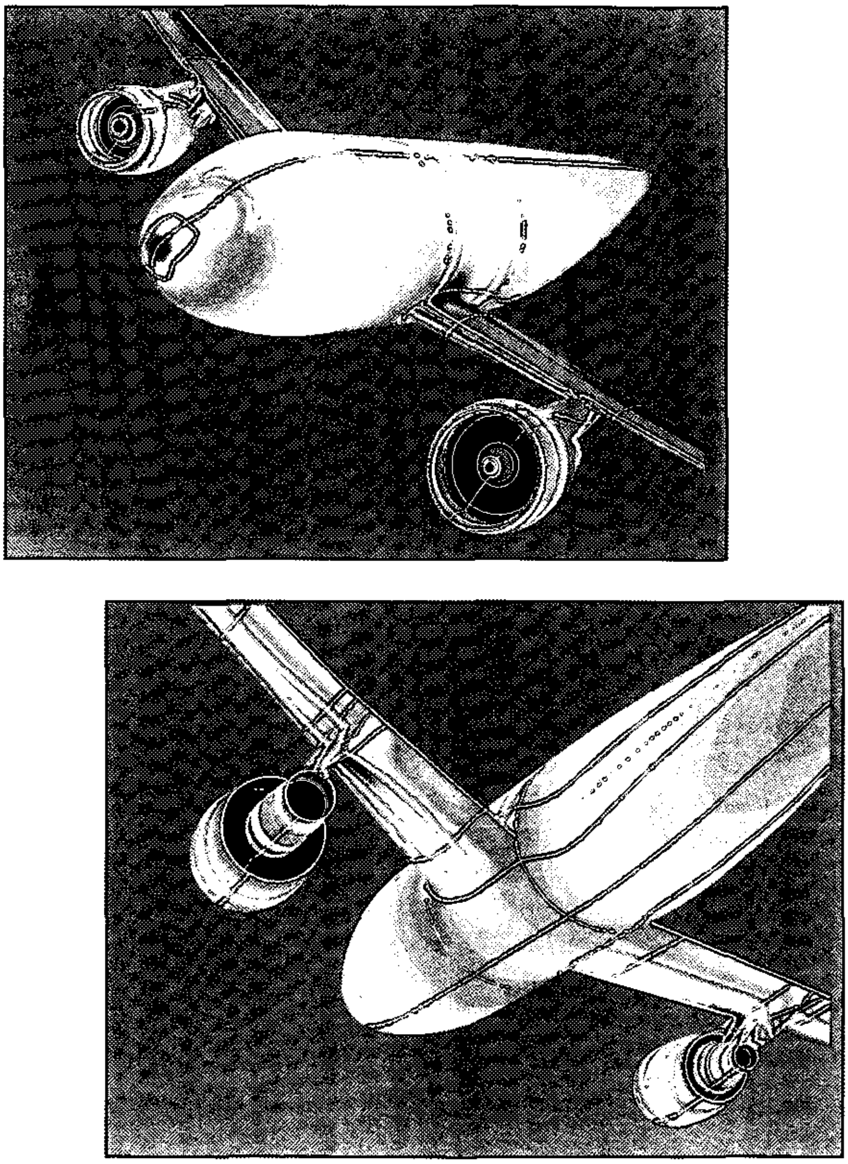
- **Buildings** — Ing. H. van der Roest — **GG**
- **Electrical Engineering** — A.M.G. Reijntjens — **GE**
- **Domestic Services and Guarding** — G. Lipsius — **GZ**
- **Library and Information Services** — Ir. W.F. Wessels — **GB**
- **Document Processing** — Ing. D.J. Rozema — **GT**

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

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

Table 1 - The NLR staff (Cat. I: university graduates, Cat. II: advanced technical college graduates, Cat. III: others) at the end of 1997 (between brackets the numbers at the end of 1996)

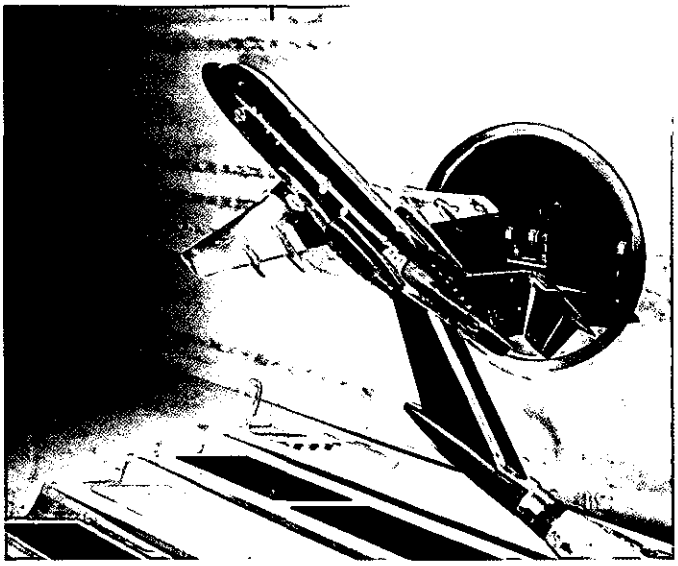
		Cat. I		**Cat. II**		**Cat. III**		**Total**	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
- Support Staff		16	(15)	7	(6)	11	(10)	34	(31)
		19	(18)	7	(6)	11	(10)	37	(34)
Fluid Dynamics Division	A	5	(2)	2	(2)	2	(2)	9	(6)
- Transonic and Supersonic Wind Tunnels	AF	4	(9)	17	(21)	8	(20)	29	(50)
- Experimental Aerodynamics	AX	–	(13)	–	(7)	–	(–)	–	(20)
- Aeroacoustics	AK	7	(7)	3	(2)	1	(–)	11	(9)
- Theoretical Aerodynamics	AT	15	(18)	–	(–)	–	(–)	15	(18)
- Aerodynamic Engineering and Aeroelasticity	AE	11	(6)	3	(3)	–	(–)	14	(9)
- German-Dutch Wind Tunnel	AD	4	(4)	17	(16)	19	(20)	40	(40)
		46	(59)	42	(51)	30	(42)	118	(152)
Flight Division	V	3	(4)	1	(1)	1	(1)	5	(6)
- Flight Testing and Safety	VV	15	(10)	6	(6)	1	(1)	22	(17)
- Flight Simulation	VS	12	(12)	15	(16)	1	(1)	28	(29)
- Operations Research	VO	23	(21)	5	(6)	2	(1)	30	(28)
- Man Machine Integration	VE	25	(19)	1	(1)	2	(2)	28	(22)
- Helicopters	VH	14	(14)	1	(1)	1	(1)	16	(16)
- Air Traffic Management	VL	37	(38)	5	(5)	–	(–)	42	(43)
- Flight Mechanics	VM	10	(10)	–	(–)	1	(1)	11	(11)
- Transport and Environmental Studies	VT	6	(9)	5	(5)	–	(–)	11	(14)
		145	(137)	39	(41)	9	(8)	193	(186)
Structures and Materials Division	S	2	(1)	1	(1)	–	(–)	3	(2)
- Loads and Fatigue	SB	14	(8)	7	(3)	1	(2)	22	(13)
- Structures Technology	SC	9	(13)	4	(3)	1	(1)	14	(17)
- Materials	SM	–	(7)	–	(4)	–	(–)	–	(11)
- Laboratory Facilities	SL	–	(–)	22	(13)	18	(15)	40	(28)
		25	(29)	34	(24)	20	(18)	79	(71)
Space Division	R	2	(1)	–	(–)	2	(1)	4	(2)
- Remote Sensing	RR	7	(7)	5	(3)	–	(–)	12	(10)
- Systems	RS	15	(15)	–	(–)	–	(–)	15	(15)
- Labatories and Thermal Control	RL	9	(8)	8	(7)	–	(1)	17	(16)
		33	(31)	13	(10)	2	(2)	48	(43)
Informatics Division	I	1	(1)	1	(1)	4	(4)	6	(6)
- Mathematical Models and Methods	IW	17	(14)	–	(–)	–	(–)	17	(14)
- Software Applications	IA	19	(16)	7	(10)	1	(2)	27	(28)
- Data and Knowledge Systems	ID	22	(17)	11	(11)	(–)	(–)	33	(28)
- Computing Services	IC	16	(14)	13	(12)	8	(9)	37	(35)
- Embedded Systems	IS	12	(13)	9	(8)	(–)	(–)	21	(21)
		87	(75)	41	(42)	13	(15)	141	(132)
Electronics and Instrumentation Division	E	2	(1)	–	(1)	1	(1)	3	(3)
- Avionics	EA	16	(14)	7	(7)	–	(–)	23	(21)
- Electronics	EE	6	(5)	20	(18)	4	(4)	30	(27)
- Instrumentation	EI	8	(11)	17	(20)	6	(7)	31	(38)
		32	(31)	44	(46)	11	(12)	87	(89)
Engineering and Technical Services	T	4	(1)	–	(–)	1	(1)	5	(2)
- Technical Projects	TP	2	(5)	4	(4)	1	(1)	7	(10)
- Technical Design	TO	1	(1)	8	(11)	1	(1)	10	(13)
- Production Workshop (Workshops)	TW	–	(1)	6	(16)	11	(19)	17	(36)
- Production Control	TV	–		5		1		6	
- Service Workshop	TS	–		3		4		7	
		7	(8)	26	(31)	19	(22)	52	(61)
General Services	G	1	(1)	2	(2)	–	(–)	3	(3)
- Buildings	GG	–	(–)	2	(2)	1	(1)	3	(3)
- Electrical Engineering	GE	–	(–)	4	(4)	7	(5)	11	(9)
- Domestic Services and Guarding	GZ	–	(–)	2	(2)	36	(36)	38	(38)
- Library and Information Services	GB	2	(2)	3	(3)	5	(3)	10	(8)
- Document Processing	GT	–	(–)	3	(4)	29	(29)	32	(33)
		3	(3)	16	(17)	78	(74)	97	(94)
Administrative Services	O								
- Administration	OA	1	(1)	20	(17)	13	(15)	34	(33)
- Stores and Dispatch	OM	–	(–)	1	(1)	4	(4)	5	(5)
- Purchasing	OI	1	(1)	4	(6)	–	(–)	5	(7)
		2	(2)	25	(24)	17	(19)	44	(45)
Grand total		399	(393)	287	(292)	210	(222)	896	(907)



Propulsion-airframe interaction: Navier-Stokes solution for Counter Rotating Unducted Fan (port) and conventional turbofan (starboard)

3 Research Activities

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



Test in the upgraded HST for the F-28 Re-Engineing project of Fokker Aviation

3.1 Fluid Dynamics

Summary

The activities in fluid dynamics and related areas were affected by three major developments. First, the reorientation with respect to NLR's market and activities, necessitated by the termination of transport aircraft development by the Fokker Aircraft Company, continued. Second, Phase II of the modernization of the transonic wind tunnel HST was successfully completed, resulting in an increased productivity, an expanded envelope of operation and reduced operation cost. Third, the operations of the HST, the supersonic wind tunnels SST and CSST and the model engine calibration facility ECF were transferred to the Foundation German-Dutch Wind Tunnel (*Duits-Nederlandse Windtunnel* – DNW) along with the operation of a number of wind tunnels of the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) on 1 July. As a consequence of these developments the Fluid Dynamics Division went through a major process of restructuring and reduction of personnel.

On the other hand, NLR was quite successful in acquiring research work in the area of fluid dynamics, to be executed in the period 1998–2000, as part of the Fourth Framework Programme of the European Union. In particular this was the case in the areas of aeroacoustics and Computational Fluid Dynamics (CFD). Also the prospects for the occupation of NLR's wind tunnels improved considerably in the second half of 1997, as did the prospects for the activities in the defence and space sectors.

In spite of the substantial reduction of the total volume of activities in fluid dynamics in 1997, NLR continued to execute research and development activities in the areas of experimental aerodynamics (in co-operation with DNW), applied aerodynamics, Computational Fluid Dynamics, aeroelasticity and aeroacoustics, albeit with a shift in emphasis from topics supporting civil aircraft design towards topics related to aircraft operations.

NLR also continued the participation in several projects of the BRITE/EURAM (Basic Research in Industrial Technologies for Europe/European Research on Advanced Materials) programme as well as the participation in most of the Action Groups of GARTEUR (Group for Aeronautical Research and Technology in Europe), joint activities of AEREA (Association of European Research Establishments in Aeronautics) and bilateral NLR-DLR research activities.

More specifically, research was executed in the following areas:

- applied aerodynamic aspects of high-lift devices, supersonic transport aircraft, experimental (wind tunnel) simulation at high Reynolds numbers, propulsion/airframe interaction, combat aircraft, helicopter rotors, aircraft and helicopter operations in adverse wind climate conditions, and space vehicles;

- aeroelastic simulations for transport aircraft and combat aircraft and Limit-Cycle Oscillation phenomena;
- the aeroacoustic aspects of propellers, turbofan noise, wind turbines and high-speed trains and the computational modelling of atmospheric noise propagation;
- the aerodynamics of high-speed trains in tunnels, ventilation of tunnels for motorized traffic and the vibration and aeroelastic characteristics of (suspension) bridges;
- Computational Fluid Dynamics methods for the numerical simulation of steady and unsteady flows based on the Euler and Reynolds-averaged Navier-Stokes equations;
- the development of new instrumentation and measurement systems such as pressure-sensitive paint, particle-image velocimetry for wind tunnel testing and microphone array systems for the location of acoustic sources.

Applied/Configuration Aerodynamics

Aerodynamics of Wings of Transport Aircraft

Research activities in the aerea of the aerodynamics of wings of transport aircraft were reduced significantly as a consequence of the Fokker demise.

In a collaborative project with the Indonesian aircraft industry IPTN (*Industri Pesawat Terbang Nusantara*), the Indonesian research institute LAGG (Aero-Gas Dynamics and Vibration Laboratory) and the US Boeing Company, the effect of wing sweep on the performance of wing leading-edge slats is studied. In the Indonesian Low Speed Wind Tunnel a second tunnel entry has been made of the high lift model with variable sweep. The scope of the measurements has been extended to include a case with a higher incidence.

NLR participates in the BRITE/EURAM Eurosup project on the multipoint design and optimization of a wing for a supersonic transport configuration. The manufacturing of three different wings (one for supersonic cruise, one for transonic cruise and one for take-off conditions) has been started, and wind tunnel tests in the DNW-HST and DNW-SST wind tunnels were planned.

The AEREA partners DERA (Defence Evaluation and Research Agency), DLR (*Deutsches Zentrum für Luft- und Raumfahrt*), ONERA (*Office National d'Etudes et de Recherche Aérospatiales*), CIRA (*Centro Italiano Richerche Aerospaziali*), INTA (*Instituto Nacional de Tecnica Aeroespacial*) and NLR have initiated wind tunnel tests in the ETW (European Transonic Wind tunnel) to study the effect of Reynolds number variations on aircraft performance and its simulation in conventional wind tunnels by the so-called aft-fixation technique. Measurements have been performed on the ETW reference model with the F-4 wing geometry. Supporting flow calculations have been made with the NLR MATRICS-V code, indicating good agreement with the wind tunnel tests.

NLR continued its activities in the BRITE/EURAM MDO project for multi-disciplinary design, analysis and optimization of aerospace vehicles. Optimization of a functional representing Direct Operating Costs (DOC) for a long-range high-capacity civil transport aircraft with a numerical simulation system consisting of MATRICS-V (wing aerodynamics) and B2000 (structures) resulted in a configuration with 25 per cent reduction in total aircraft drag for a 2.5 per cent increase in total aircraft weight.

Within the scope of the Aerospace Programme for Education, Research and Technology (APERT) for co-operation between the Netherlands and Indonesia, NLR started the execution of the APERT 95 Joint Research project Transonic Transport Wing Design for Improved Buffet Onset Lift. This project is executed under contract to the Royal Netherlands Academy of Sciences (KNAW). The work was started with an investigation of how an Euler code for the optimization of the transonic performance of isolated wings by wing-shape variations can be embedded in an industrial aerodynamic design environment for wing/body shapes, including the interference effects of flap/slat systems and propulsion systems.

Propulsion Airframe Interaction

NLR continued its participation in the BRITE/EURAM ENIFAIR (Engine Integration for Future Aircraft) programme. The objective of this programme is to develop the key technologies needed for the aerodynamic integration of the next generation of turbofan engines, including the close coupling of engine and wing. The ENFLOW CFD system was applied to a number of configurations, and the results demonstrated the positive impact of grid adaptation on (structured) grid quality when a fixed period of time is available for grid generation. Initial comparisons between CFD results obtained with a k-omega turbulence model and experimental data at a free stream Mach number of 0.75 were encouraging.

NLR also participates in the BRITE/EURAM programme APIAN (Advanced Propulsion Integration Aerodynamics and Noise) on the aerodynamic integration of propeller-driven aircraft. The programme encompasses low speed wind tunnel tests (in the DNW-LLF) and high speed tests (in the S-1 of ONERA) for the complete configuration with installed propeller and isolated propeller tests in the DNW-HST, including the assessment of Reynolds number effects on the performance of the propeller. The preparation of the DNW-HST test, involving hardware development, was continued.

The wing configuration studied in the BRITE/EURAM programme ENIFAIR is also the subject of a collaborative programme between DLR and NLR utilizing the so-called ALVAST wind tunnel model. This model was measured as a semi-span model configuration in the DNW-LST in 1996, and new tests are foreseen in the DNW-NWB. At NLR the Counter Rotating Ultra-high-bypass Fan (CRUF) simulator has been calibrated to complement the DNW-NWB measurements. The analysis of the results is an ongoing collaborative effort.

Aerodynamics of Combat Aircraft

CFD technology development for military applications was continued as part of the Western European Armament Group (WEAG) TA-15 programme Computational Methods in Aerodynamics. The three types of activities described below have been carried out.

Validation of Steady State Navier-Stokes Computations

New computations of generic inlet geometries show that CFD results obtained with the k-omega turbulence model are in better agreement with experimental data, compared to the 1996 results obtained with the Baldwin & Lomax turbulence model. Similar computations of the flow over a generic afterbody with supersonic flow from the engine exit have also led to a better correlation between CFD data and experimental results.

Time-accurate Inviscid Flow Computations

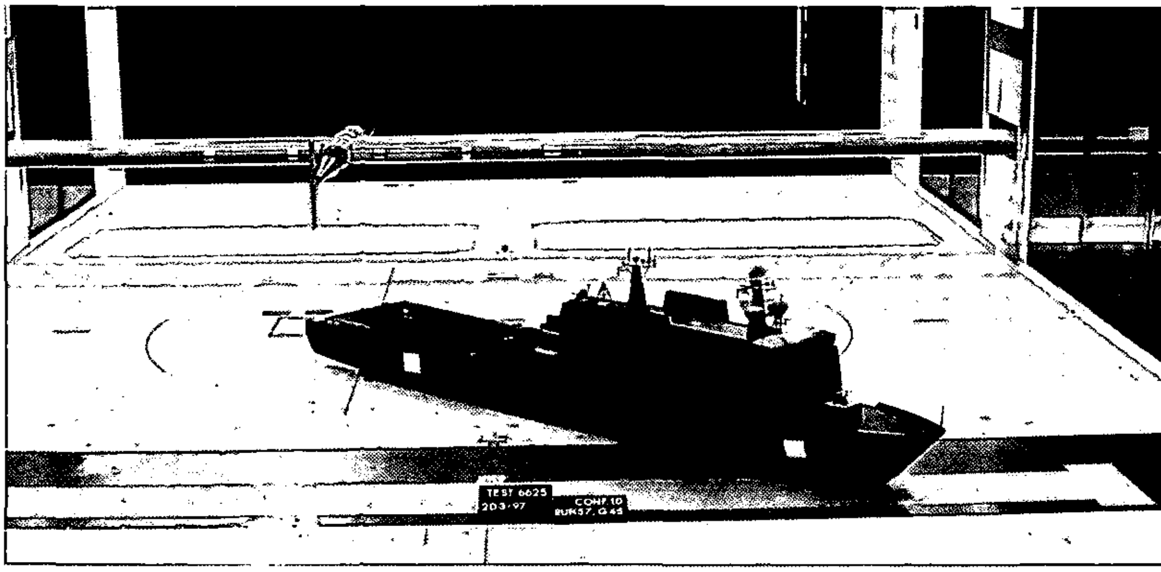
The computations of flows about sharp-edged delta-wings with leading-edge separation were continued. The computational results and the favourable comparison with the low-speed wind tunnel data suggest that the Euler equations can be used to predict a number of aerodynamic quantities such as dynamic stability derivatives of military aircraft at high incidence with acceptable accuracy. This conclusion is in line with the favourable agreement between CFD data from NLR and from DASA-LM, which is emerging from WEAG TA-15 Common Exercise IV.

HST Experiment for Delta Wing with Side-slip

Surface pressure measurements have been executed covering a range of incidence and side-slip angles at Mach numbers of 0.4 and 0.85. Results show that non-zero side-slip angles give rise to asymmetric vortex burst. Furthermore this asymmetric vortex burst is found to depend strongly on whether a non-zero side-slip angle is reached from zero side-slip angle or from a higher side-slip angle, resulting in a substantial hysteresis effect in the rolling moment.

Helicopter Aerodynamics

The contribution of NLR to the BRITE/EURAM project EROS (Development of a Common European Euler Code for Helicopter Rotors) of the Fourth Framework Programme was continued. In this project a common European computer code for helicopter rotor aerodynamics is being developed, based on the Euler equations. NLR contributed to the formulation of the method and to the algorithms for the flow solver and for the grid generator. For the grid generator, which is based on the CHIMERA



Model for helicopter-ship qualification in the DNW-LST

approach and for which NLR is the co-ordinator, results of efforts of all partners were collected.

The BRITE/EURAM project HELISHAPE (Rotorcraft Aerodynamics and Aeroacoustics) has been completed with a final validation report by all partners. In this project, preceding the EROS project, a common European computer code for helicopter rotor aerodynamics based on the unsteady full potential theory was developed. This computer code has become available to all participating partners.

Support was given in the analysis and modelling of the effect of aeroelastic deformation of a helicopter rotor on its aerodynamic characteristics. This effect was subsequently implemented in the helicopter rotor code HERO.

Operations and Safety Related Aerodynamic Research

Assistance was provided in the execution of wind tunnel tests in the DNW-LST on the wind climate on and around ships. The test results are used to investigate the interaction between helicopters and wind on ships under operational conditions.

NLR also contributed to a study made by the Royal Netherlands Meteorological Institute (KNMI) on the accuracy of the reference wind measurements on Amsterdam Airport Schiphol in view of terrain roughness and buildings. A more basic study on this respect was initiated by NLR to find out if measurements on a scale of 1:1000 can still be considered as representative for wind climate studies, notably to simulate the effects of the wake of adjacent buildings on the wind field above a runway.

As part of the BRITE/EURAM project CONTAMRUNWAY, NLR contributed to the modelling of the effect of water spray on the lift and drag characteristics of aircraft during take-off on very wet runways.

Earlier work on the development and characteristics of wake vortices of aircraft configurations found a continuation in the new BRITE/EURAM project WAVENC (Wake Vortex Evolution in Far-wake Region and Wake Vortex Encounter), in which the mid and far field development of vortex wakes will be studied including their interaction with a following aircraft.

Hypersonic and Space Vehicle Aerothermodynamics

NLR contributed, in collaboration with Dassault Aviation and with Fokker Space, to the European participation in the NASA X-38 Crew Rescue Vehicle demonstration programme. The primary objective of the European participation is to establish a clear path through which key technologies needed for potential future European programmes, such as a lifting-body Crew Transfer Vehicle, can be acquired through co-operation. These collaborative efforts to improve the X-38 volumetric and structural performance and to satisfy ESA's Crew Transfer Vehicle requirements have resulted in changes to the X-38 vehicle. These changes are predominantly on the lee-side of the X-38 to mitigate adverse, transonic flight characteristics of the earlier, 1996 aerodynamic shape of the common CRV/CTV (Crew Rescue Vehicle/Crew Transfer Vehicle) configuration. The work demonstrated that CFD codes and the parallelization on the NLR NEC SX-4 supercomputer have evolved to a point where solutions of the full Navier-Stokes equations can be used in the space vehicle design process timely and accurately.

In collaboration with TNO-PML (*Prins Maurits Laboratorium*), the performance of a ramjet intake model for a hypersonic vehicle has been studied experimentally with emphasis on intake efficiency.

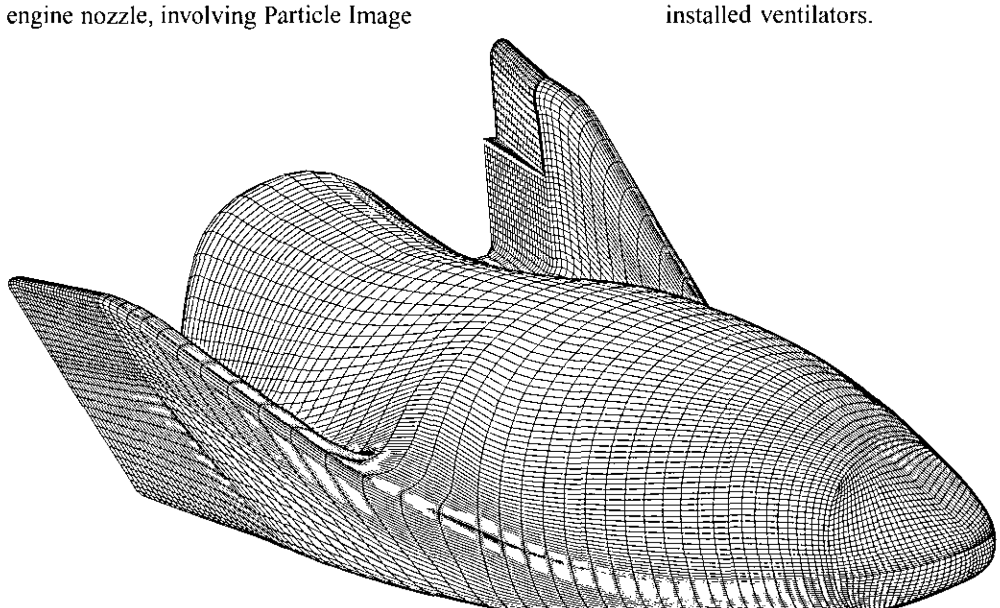
In collaboration with ESA/ESTEC (European Space Research and Technology Centre) a detailed investigation on the unsteady base flow of the ARIANE 5 launcher and Vulcain rocket engine nozzle, involving Particle Image Velocimetry (PIV) measurements was executed in the pilot transonic wind tunnel PHST.

The reorientation of activities in the national programme AEOLUS (Advanced Earth to Orbit Launcher Upgrade Studies) towards hot structures such as vehicle control surfaces was continued. NLR participated in a team concerned with the planning of the potential design, development and manufacturing of the rudders for the X-38 V-201 spacecraft to be launched by the US Space Shuttle. This team involved Fokker Space, Stork Product Engineering, TNO-PML, the Delft University of Technology and NLR.

Non-Aerospace Aerodynamics

Utilizing NLR experience on shock tunnels, a small test facility for studying wave phenomena introduced by high speed trains in tunnels was developed. In this Train Tunnel Test Facility (T3F), train speeds up to 500 km/h were simulated. A comparison was made of experimental results with theoretical estimates of wave phenomena for some simple tunnel geometries, showing excellent agreement.

A study was made on aspects of forced ventilation of motor traffic tunnels. Analysis of on-site measurements has provided additional knowledge on the effectiveness and efficiency of installed ventilators.



Surface grid of X-38 spacecraft, used to support the design, development and manufacturing of the rudders

Vibration tests and analysis of the suspension cables of the Erasmus bridge in Rotterdam were continued. The tests on this new bridge were necessary in view of the occurrence of high amplitude cable vibrations during moderate wind speeds in combination with rain at the end of 1996. Measurements made after the mounting of vibration dampers confirmed their effectivity in solving the vibration problem.

Aeroelasticity

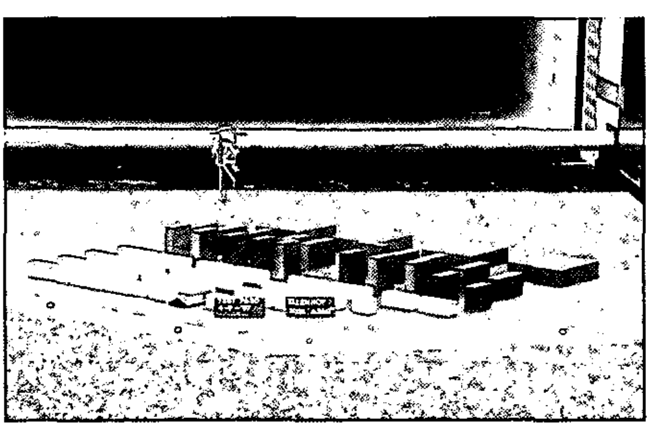
The computer code for aeroelastic simulation of transport-type aircraft, AESIM, has been further developed. In this method the flow is modelled on the basis of an unsteady full-potential flow representation, and dynamic aircraft deformation is modelled using vibration modes imported from the MSC/NASTRAN programme. The manual for the volume grid generation was completed and an extensive manual of the complete AESIM method was brought into its final form. Test cases, including a Fokker 100 T-tail, a fighter wind tunnel model and a full scale fighter wing, were run. A number of improvements were implemented to satisfy portability requirements, potential customer requirements with respect to ease-of-use and requirements for the implementation of more advanced CFD methods based on the Euler and Navier-Stokes equations.

The research programme on Limit Cycle Oscillations (LCO) of fighter-type aircraft configurations was completed, including data reduction of the flow visualization test in the High Speed Tunnel (HST). In this test, carried out in 1996, the unsteady flow about an oscillating simple-strake semi-span model was visualized using a 'vapour screen' technique and Particle Image Velocimetry (PIV). Attention was focused on shock-wave and vortex development and on motion, in order to relate the spatial flow field information with data on pressures, overall forces and moments from previous experiments. Besides data in the printed report all visualization data were transferred to a CD-ROM, suitable for further computer aided analysis. The data will be used for further development and validation of LCO prediction methods.

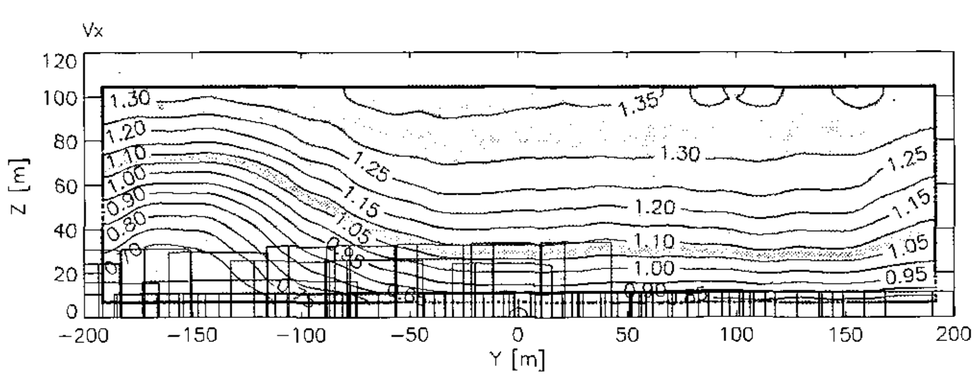
The participation in the GARTEUR Action Group (SM) AG-19, 'Ground Vibration Testing Techniques', was completed with the publication of the final report on the vibration measurements on a standard structural model.

Aeroacoustics

Research on propeller noise was carried out in the BRITE/EURAM project APIAN (Advanced Propulsion Integration Aerodynamics and Noise)



Model of buildings in the DNW-LST



Measured wind velocity distribution

in which the sound field of installed propellers is investigated. The NLR contribution to this project consists mainly of an extension of the computer program DIFRÉF that computes the scattering of propeller noise by the fuselage and its boundary layer. The existing version of DIFREF was developed within the BRITE/ EURAM project SNAAP (Study of Noise and Aerodynamics of Advanced Propellers), one of the predecessors of APIAN. A pilot program was written for the diffraction of a two-dimensional sound field by a non-circular cylinder.

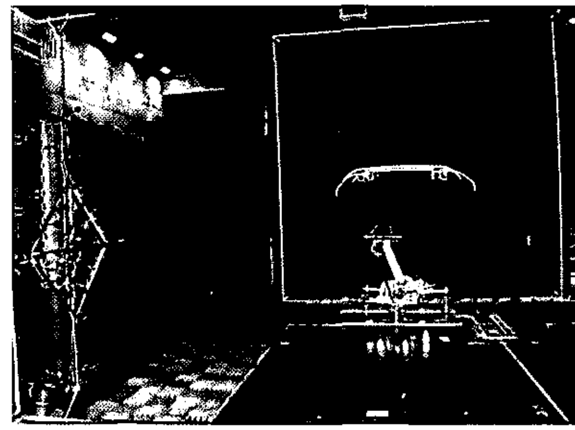
The lifting surface method for the computation of propeller noise was extended to include the leading edge suction force. Under some circumstances this force rotates over 90 degrees to the suction side of the blade. Incorporation of this effect in the acoustic computation has yielded improved agreement with the experimental data from SNAAP.

The NLR fan noise model, originally designed and used for wind tunnel research on the generation of fan noise, was used as a sound source for research on acoustic liners for engine inlets. An extensive description of this experiment, carried out in the NLR Small Anechoic Wind Tunnel (KAT), is given in the *Capita Selecta*.

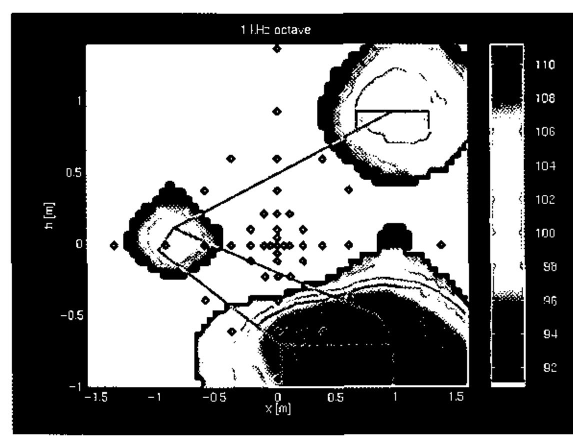
A computation method for the modelling of fan interaction noise, also based on the lifting surface theory, was used to study the effect of swept stator vanes. It was found that at conditions relevant for a modern, very high bypass design, noise reductions in the order of 8 dB are obtainable with 20 degrees of vane sweep.

Investigations under contract to NIVR (the Netherlands Agency for Aerospace Programmes), on the influence of wind and temperature gradients on the propagation of sound from an aircraft to the ground, were continued. A pilot computer program based on ray acoustics, written in 1996, was improved and extended to include, amongst other things, propagation over acoustically soft terrain and atmospheric damping.

Non-aerospace aeroacoustic research was carried out on the noise of wind turbines and high-speed trains. The research on wind turbine noise was



Aeroacoustic measurements on a full-scale current collector of a high-speed train in the DNW-LLF



Noise source locations determined using a microphone array system

carried out in the European JOULE projects STENO (investigation of Serrated Trailing-Edge NOise, focused on the blade tip region) and DRAW (development of Design tools for Reduced Aerodynamic Noise of Wind turbines) as well as in the national wind turbine programme TWIN (*Toepassing Windenergie in Nederland*). NLR participated in the TWIN AORA (*Aanvullend Onderzoek Reductie Achterrandgeluid*) project, aimed at more detailed knowledge of the noise-reducing mechanism of serrations.
Acoustic measurements on a full-scale current collector of a high-speed train in the DNW showed the source-locating capabilities of a microphone array system designed and operated by NLR.

Computational Fluid Dynamics

Reynolds-Averaged Navier-Stokes Methods

A large part of the research and development activities in Computational Fluid Dynamics continued to be devoted to the further development of the ENFLOW system of computer codes for accurate Reynolds-averaged Navier-Stokes computations of complex flows. The work is carried out in close co-operation between the Fluid Dynamics and Informatics Divisions of NLR. The ENFLOW system is used in many different projects, which are executed by NLR under contracts awarded by the Netherlands Agency for Aerospace Programmes (NIVR), the Ministry of Defence, the Royal Netherlands Academy of Sciences (KNAW) and the European Union.

The numerical modelling to solve the flow equations comprises: smooth, semi-structured multi-block grids; central differencing finite-volume discretization; explicit time integration, combined with residual averaging and multi-block/multigrid convergence acceleration. The system can work with several algebraic turbulence models, two-equation turbulence models of k-omega type.

Development activities for the ENFLOW system resulted in the following achievements:

- The behaviour of the k-omega turbulence model near solid walls was improved, by introducing a k-γ variant of this model (γ=1/ω);
- Improvement of the jet-engine-inlet boundary conditions for inlet flows and k-ω/γ turbulence models was completed;
- The thin-layer version Reynolds-averaged Navier-Stokes equations was replaced by the version with the full Reynolds-averaged Navier-Stokes equations;
- The grid adaptation code ENADAP was made operational. This code may be used to accurately tune multiblock grids to boundary-layer flow gradients;
- The graphical-interactive block-decomposition code ENDOMO was improved;
- The iterative solution algorithms for elliptic grid generation in block volumes were made considerably more robust;
- The graphical interface of the interactive grid generation code ENGRID was modernized to the same level as the graphical interface of the block-decomposition code ENDOMO. This modernization enhances productivity in multiblock grid generation and code maintenance;
- To improve the numerical accuracy of Navier-Stokes computations in boundary layers, matrix artificial dissipation was introduced as standard.

The ENSOLV flow solver in the ENFLOW system was parallelized on block-loop level. Reasonable parallelization performance was found for most of the important test cases.

In the framework of a DLR-NLR co-operation, turbulent Navier-Stokes results (surface pressures and surface friction) based on the prismatic/tetrahedral grid approach applied to the ONERA M6 wing-alone case (Mach = 0.8395, α = 2.06 degrees and a Reynolds number of 11.72 million) were compared with Navier-Stokes results obtained with the multi-block grid approach (ENFLOW), and with experimental data. The results demonstrate a good accuracy potential of the prismatic/tetrahedral grid approach. The need for grid adaptation is strongly felt in this hybrid approach, however, especially near leading edges with high surface curvature.

The development of the unstructured grid Navier-Stokes solver FANS for multi-element aerofoils was focused on the computation of maximum lift of a three-component high-lift wing section of the Airbus A310 aircraft. Comparison between CFD data and wind tunnel results shows good agreement, provided proper attention is paid to the modelling of the laminar-turbulent transition in the Navier-Stokes equations.

To further validate and improve Reynolds-averaged Navier-Stokes CFD methods, NLR continued its participation in several GARTEUR Aerodynamics (AD) Action Groups:

- (AD) AG-17 'Transonic Euler' for flow computations around complex configurations: NLR delivered to ONERA the draft of the chapter 'Comparison of computational results for the wing-body test cases' of the final report (to be issued by ONERA);

- (AD) AG-20 'Mesh Adaptation', which aims at comparing the effectiveness of different mesh adaptation schemes;
- (AD) AG23 'Three-Dimensional Turbulent Shear Layer Experiment, Phase II', which aims at validating and improving turbulence models for three-dimensional flows;
- (AD) AG-24 'Navier-Stokes Calculations of the Supersonic Flow about Slender Configurations';
- (AD) AG-25 'High Lift Phase IV', which aims at improving maximum lift prediction of multi-element aerofoils;
- (AD) AG-26 'Transonic Wing/Body Navier-Stokes Computations';
- (AD) AG-28 'Transonic Wing/Body Code Validation Experiment'.

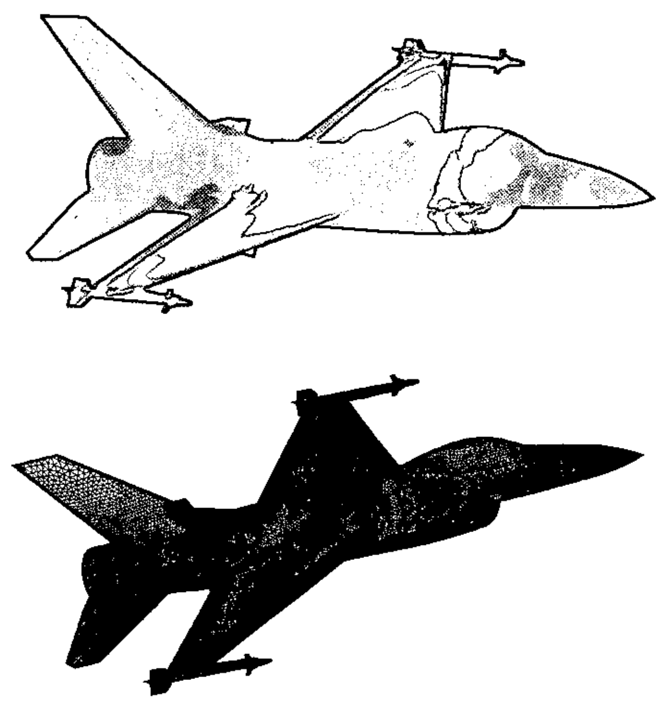
Euler Methods

In the BRITE/EURAM project FASTFLO, an automatic CFD system for three-dimensional flow simulations is being developed to achieve an order of magnitude reduction in CFD problem-turnaround-time for complex geometries. FASTFLO is carried out by NLR and partners DLR, Ingenieur Büro Kretzschmar and DASA-LM of Germany; and FFA and SAAB of Sweden. The functionality of the CFD system is defined by its algorithmic components:

- aerodynamic geometry definition;
- surface triangulation;
- 3D hybrid grid generation (prisms/tetrahedra);
- pre-processing, and flow calculation;
- grid adaptation;
- aerodynamic post-processing;
- visualization.

The problem-turnaround-time including grid generation for a generic fighter configuration was less than half a working day, from initiating the problem to presenting the pressures and the integrated forces, using the Euler equations. This example demonstrated that the potential for superior problem-turnaround-times for complex geometries is within reach and also demonstrates that the computing time of the automatic CFD system is not excessively long on NEC SX-4 supercomputers.

The development of a time-accurate Euler solver based on a continuous Galerkin finite-element method, HEXADAP, was continued. This algorithm is based on an efficient solution method. Full multigrid acceleration was achieved, which enables new applications in unsteady computational aerodynamics to be made without running into problems in terms of the computational time needed to execute the unsteady flow simulations.



Computed pressure distribution and surface triangulation for a generic fighter configuration

Radar Cross Section (RCS) Prediction Techniques

NLR continued the second phase of an RCS Prediction Techniques Project for the Netherlands Ministry of Defence. Progress was made in the mathematical formulation of a hybrid prediction technique based on a combination of high-frequency approximation, and the electric field integral equation. Progress was also made in the parallelization of the electric field integral equation method itself, to enable RCS computations to be made at higher frequencies.

Facilities and Equipment

Wind Tunnels

Phase II of the modernization programme of the transonic wind tunnel HST was successfully completed. The main changes to the facility can be summarized as follows:

The 40-year-old oil-fired power plant was dismantled and replaced by a connection to the public electricity grid. At the same time the 14.7-MW electric drive motors were replaced by a 19-MW drive motor. This has resulted in a considerable improvement of tunnel productivity – as a consequence of faster speed control – and a significant reduction of the costs of energy consumption.

The fan of the HST was provided with new fan and stator blades, designed for improved efficiency. Together with a provision of independent control of power and speed, and an increase of the available power by 25 per cent, this has resulted in an increase of the maximum Reynolds number at high subsonic Mach numbers of more than 50 per cent.

The productivity was further improved by optimizing the control of pressure, temperature and Mach number.

Finally, the settling chamber of the HST was provided with a flow rectifier and new turbulence screens to improve the flow quality in the test section, and with a flow seeding system in anticipation of the application of new flow field measurement techniques requiring flow seeding, such as LDA (Laser Doppler Anemometry), PIV (Particle Induced Velocimetry) and GDV (Global Doppler Velocimetry).

Because of the shut-down of the power plant, the steam turbine drives of two air compressors were replaced by electric drive motors. These compressors are used to fill the 40-bar air storage vessel that supplies pressurised air to run the supersonic blow-down tunnels, SST and CSST, and to pressurise the HST circuit.

After a period of calibrations and reference testing on aircraft and spacecraft models, the first customer for the HST was welcomed in August. The upgrade of the HST has resulted in a considerable increase of productivity, an expanded operational envelope and a significant decrease of operations costs.

Per 1 July 1997 the operation of the transonic wind tunnel HST, the supersonic wind tunnels SST and CSST and the Model Engine Calibration Facility (ECF) was transferred to the Foundation German-Dutch Wind Tunnel (DNW) for a trial period of 2.5 years. At the same time DLR transferred the operation of most of its wind tunnel facilities to DNW as well. This is expected to lead to increased efficiency of wind tunnel operations through better sharing of resources and merging of customer bases.

After more than 40 years of operation, the pilot transonic wind tunnel PHST was definitively closed for efficiency reasons. In the 1960s and 1970s the facility played an important role in transonic aerofoil development for the Fokker F-28 and in supercritical aerofoil research.

Wind Tunnel Wall Interference Studies

An experiment has been performed in the DNW-LST to measure the wall pressure signature of a helicopter tail rotor. The purpose of the experiment is to use the obtained pressure signatures in a theoretical programme to assess the wall-induced disturbances in the rotor plane in order to evaluate the possibilities to make wall interference corrections to this type of experiments.

NLR participates in GARTEUR (AD) AG-18, 'Adaptive Wall Wind Tunnels', which aims to investigate and if possible to quantify the relative merits of flexible wall test sections over conventional test sections. To this end a comparison of test data from several institutes on the same model is made. In this comparison the HST test data are used as a wall-interference-free reference. Further comparisons of theoretical models and improvement of – predictive – correction strategies are envisaged to improve the productivity of this type of tunnels.

Instrumentation and Measurement Systems

With the replacement of the 14.7-MW drive system by a new 19-MW drive motor, the dynamic pressure range of the HST was increased by more than 50 per cent. In order to be able to use this extended range for force measurements a high-load internal six-component balance was manufactured. For the same reason a new Flow Reference System, for the measurement of the tunnel reference pressures, was put into use and integrated in the data-acquisition system of the HST. The data-acquisition system was improved with the installation of new signal conditioning units.

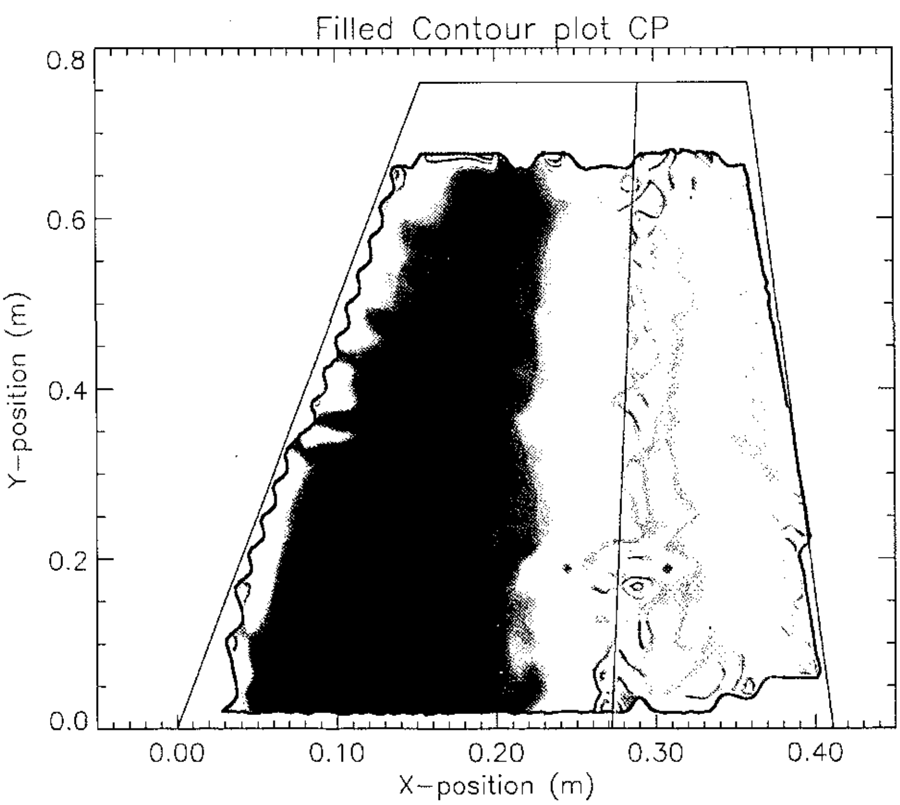
In view of future experiments in the scope of the BRITE/EURAM project EUROSUP, a slender high-load balance was designed for force measurements on a Supersonic Transport Model in the SST and HST wind tunnels.

A rig for high-speed propeller testing in the HST was designed. This rig is to be used for the BRITE/EURAM project APIAN (Advanced Propulsion Integration and Noise).

The existing optical surface pressure measurement system, based on the measurement of the pressure-dependent fluorescence intensity of Pressure Sensitive Paint (PSP), was modified for the measurement of fluorescence lifetime instead of intensity, with the aim to improve the measurement accuracy. This work was a contribution to the GARTEUR Action Group (AD) AG-21, 'Pressure Sensitive Paint', with the objective of demonstrating the possibilities to apply accurate and productive PSP techniques.

The Particle Image Velocimetry (PIV) system, which measures the two components of the velocity vector in the plane of a laser sheet, was successfully applied during base-flow experiments. In the scope of the BRITE/EURAM project EUROPIV, a number of PIV measurements were processed and results of seeding experiments carried out at NLR were reported. This project constitutes a co-operative European action to study the application of Particle Image Velocimetry to problems of industrial interest.

The development of a microphone array system to be used at the DNW-LLF for the determination of the location of acoustic sources was initiated. Advanced algorithms for the use of arrays with non-redundant microphone distances, designed in 1996, were used as a basis for the development of data-processing software. Also a number of microphones were tested in order to make the best choice for the construction of the array system.



Demonstration of the Pressure Sensitive Paint technique

3.2 Flight

Summary

The total volume of activities consisting of contract research, basic research and development of facilities related to flight operations reached the same high level as in 1996. Work was done in many national and international, mainly multidisciplinary projects under contract to, among others, the Royal Netherlands Air Force (RNLAF), the Netherlands Department of Civil Aviation (RLD), Air Traffic Control The Netherlands (LVB), the Royal Netherlands Navy (RNLN), the Netherlands Agency for Aerospace Programmes (NIVR), the European Union (EU) and Eurocontrol.

In the area of *flying qualities and flight control systems*, Action Group (FM) AG-08 of GARTEUR, the Group for Aeronautical Research and Technology in Europe, completed its research project on the efficiency and transparency of the flight control design cycle. This Action Group was chaired by NLR.

An investigation was initiated into the feasibility of the Advanced Continuous Descent Approach, a new environmentally-friendly approach procedure.
A study on Technical Operational Measures Schiphol (TOMS) was started. The objective of this study is to investigate the effects of such measures on the reduction of noise without degradation of the level of safety and without reduction of airport capacity.

The GARTEUR Action Group (FM) AG-07 on windshear, which studied the numerical simulation of forward-looking windshear detection systems, completed its work.

With respect to *air traffic management* (ATM), NLR continued its participation in many Eurocontrol programmes and in the European Commission's Fourth Framework Programme ECARDA (European Coherent Approach for the Research and Technology Development of ATM), as well as supporting the Netherlands aeronautical cluster. Activity areas were: ATM concepts; ATC (Air Traffic Control); Communication, Navigation and Surveillance; Aeronautical Telecommunication Network; Avionics; Human Machine Interface; airport traffic management; and facilities and basic research.

In the field of *human factors*, work was carried out with respect to the development of displays in 'glass cockpits' (for the Free Flight scenario, among other things); the development of enhanced and synthetic vision systems; investigations of working positions and working methods for air traffic controllers; and the formulation of cockpit certification requirements.
Activities on human factors in aircraft maintenance were continued in a study for the RLD and in a project of the European Union.
The RNLAF was supported in a study to get insight in specific mission requirements and pilot tasks. The RNLN was supported by analysing industry proposals for NFH90 crew stations.

In the area of *military support* NLR assisted the RNLAF in several projects: in international EUCLID (European Co-operation for the Long term In Defence) projects on concepts of simulation-based training systems and simulation techniques; in a national technology project on the feasibility of an integrated smart self-protection system; during flight tests with the F-16, with transport aircraft and with helicopters; on the analysis of the properties and performance of weapon systems; on the tactical and operational use of fighter aircraft and on the safety analysis of airshow flight demonstration programmes.

In the area of *helicopters*, NLR participated in the activities of three GARTEUR Action Groups ((HC) AG-07, (HC) AG-09 and (HC) AG-10) and in the EU's Fourth Framework projects HELIFLOW and EROS.
In co-operation with Fokker Aerostructures and SP Aerospace and Vehicle Systems, NLR continued its participation in the Design and Development phase of the NH90 programme.
NLR supported the RNLAF in the area of the CH47-D Chinook Avionics Control & Management System improvement, and the RNLN in the execution of tests in the DNW-LST wind tunnel on a model of the new Amphibious Transport Ship.

Controller positions of the NLR ATC Research Simulator (NARSIM)

Within the scope of *policy analysis*, studies were performed on the use of metrics of aircraft noise exposure and on the development of future air transport structures.

In the field of *transport and environmental studies* NLR participated in several international studies on aviation emissions.
Noise exposure and third party risk were calculated and analysed for actual and future situations of several airfields in the Netherlands.
The development of third party risk calculation methods and models for regional and military airfields was continued.

Aircraft operations with NLR's Metro II research aircraft especially concerned flights for the flight inspection of the radio navigation aids in the Netherlands.
Activities have started to prepare the Cessna Citation II for large European projects dedicated to the realization of aircraft/ATM integration.

With regard to *facilities and equipment*, the NLR ATC Research Simulator (NARSIM) was further refined and upgraded, especially to support an operational experiment in a 4D ATM environment of the Programme for Harmonized Air traffic management Research in Eurocontrol (PHARE).

With the Total Airspace & Airport Modeller, a workstation tool for the simulation of airspace and airport operations, work was conducted to support policy decisions for future airport infrastructure.
The Traffic Organization and Perturbation Analyzer facility was used to assist in safety assessment studies.

To enable a multitude of simulation experiments to be performed in several configurations, modifications were made to the NLR Research Flight Simulator (RFS) and the National Simulation Facility (NSF). In addition to the Display Control Panels, two Generic Control Displays were installed in the RFS cockpit. The NSF was equipped with colour multi-function displays and an Electronic Warfare Management System.

Flying Qualities and Flight Control Systems

Flying Qualities

Interim results of an investigation into the development of design guidelines for low speed lateral/directional handling qualities of civil transport aircraft equipped with advanced fly-by-wire flight control systems were reported. The study was performed under contract to the Netherlands Agency of Aerospace Programmes (NIVR) in a co-operation with GARTEUR partners in Action Group (FM) AG-06, 'Low Speed Lateral/directional Handling Qualities Design Guidelines, Phases 2 to 4'.

Effects of Control Augmentation

Under contract to the Netherlands Department of Civil Aviation (RLD), an investigation was carried out to gain a better understanding of the effects of control augmentation systems on aircraft handling during approach and landing in adverse weather conditions. Results of an evaluation experiment carried out on an MD-11 training simulator in Long Beach, USA, were analysed.

Robust Flight Control

The GARTEUR Action Group (FM) AG-08 'Robust Flight Control in a Computational Aircraft Control Engineering Environment', chaired by NLR, has completed a research programme into the efficiency and transparency of the flight control design cycle (see also Capita Selecta). Twelve advanced control design techniques have been demonstrated on the basis of a civil and a military flight control problem. A Literature Survey Data Base providing references and summaries of articles, reports and books on robust flight control has been developed. A prototype Computational Aircraft Control Engineering Environment that offers facilities for design process definition and execution including tool integration and a central data repository, has been developed. A GARTEUR Specialists' Workshop was held for 120 members of the European Flight Mechanics community and a monograph on the results of the Design Challenge has been published by Springer Verlag.

Advanced Continuous Descent Approaches

New environmentally-friendly procedures are becoming feasible with the introduction of new approach, navigation and flight management systems. One promising procedure is the Advanced Continuous Descent Approach (ACDA), which allows the aircraft after passing the Initial Approach Fix to start a continuous, low-power descent to the runway threshold along a curved approach path with both lateral and vertical guidance. During the greater part of the approach, the aircraft is kept in a clean configuration, while the engines are operating near flight idle. Based on promising results of a preliminary study, an investigation into the feasibility of this approach concept, funded by NIVR, was initiated. Provisions for the airborne and ground (ATC) side were defined and implemented in simulation software. An experiment test plan for an ACDA simulation study, comprising both the RFS and NARSIM, was written.

Technical Operational Measures Schiphol

Research on a series of technical operational measures at Schiphol (TOMS) was carried out by NLR and subcontractors. These measures are aimed at reducing community noise caused by arriving and departing aircraft without degradation of the safety level and without significant reduction of airport capacity during peak hours. During Phase 1 of this project, rough estimates were made of the possible noise reductions for a number of proposed measures. At the same time, calculations were made to convert these noise reductions into capacity benefits. A study was initiated to determine a method for qualitative safety assessment of proposed new flight procedures. This study is intended to provide the safety evaluation tools for the safety validation of a specific new measure. Based on the results of the TOMS Phase 1 study, funded by Amsterdam Airport Schiphol (AAS) and KLM Royal Dutch Airlines, a project plan was written for the second phase.

Windshear

The GARTEUR Action Group (FM) AG-05, 'Flight in Windshear Conditions, Phase 1', whose aim was the numerical simulation of forward-looking windshear detection systems, published its final report. In collaboration with the follow-on GARTEUR Action Group (FM) AG-07, 'Flight in Windshear Conditions, Phase 2', and under contract to the RLD and the NIVR, Phase Ib of the project WINDSTREAM (Windshear Technology Research Advances Masterplan) was finalized. Results of the work showed that the use of a laser/lidar-based forward-looking windshear detector, which provided the information for the generation of coloured windshear icons on an Electronic Flight Instrument System (EFIS) Navigation Display in the cockpit, improved flight safety and enhanced the situational awareness of the flight crew. The data analysis and reporting of last year's windshear experiment (Phase II of the WINDSTREAM project), focusing on the use of a Doppler weather radar including a windshear detection mode, was continued.

Mathematical Models of Aircraft and Helicopters

For many years NLR has been developing helicopter mathematical models used in off-line simulations to support helicopter operators in the area of flying qualities. As the demand for high-level support constantly increases, a project to set up a (low cost) pilot-in-the-loop helicopter simulation demonstrator has been started.
A modified fixed-base mock-up, including a monitor for the out-the-window view, three instrument displays and controls, was used as a simulation environment. Several flight conditions and manoeuvres have been successfully flown by two pilots, demonstrating the ability to perform highly realistic helicopter simulations. The new pilot-in-the-loop helicopter simulation capability enables NLR to improve the level of support available to helicopter operators. In accordance with the specification from GARTEUR Action Group (HC) AG-09, 'Mathematical Modelling for the Prediction of Helicopter Flying Qualities, Phase 3' in which NLR participates, the generic helicopter model was further improved.
In co-operation with the Technical University of Braunschweig, NLR completed the validation of the Fairchild Metro II model using the Research Flight Simulator.

Flight Management System Training and Demonstration

A training tool based on a Personal Computer (PC) has been developed for the Rockwell Collins GNSS Navigation and Landing Unit (GNLU) Multifunction Command and Display Unit (MCDU) for the Airbus A300 B4. Based on the current development environment of the Research Flight Management System, this tool is initially used for the familiarization of Airbus A300 pilots with the Rockwell Collins GNLU MCDU. The development has been finished with the delivery of the final version and the certification of this tool as a training aid.

Air Traffic Management

National solutions in the field of Air Traffic Management must fit within European supranational guidelines and structures. NLR's participation in international programmes of Eurocontrol and of the European Commission's Fourth Framework and in other programmes enable it to provide effective support to the Netherlands aeronautical cluster, in particular Amsterdam Airport Schiphol, KLM, LVB and RLD.

NLR is one of the leading organizations in PHARE-X, a consortium consisting of NLR, National Air Traffic Services Ltd (NATS), Sofréavia, and the Defence Evaluation and Research Agency (DERA) that has successfully been bidding for Fourth Framework tasks. NLR has been active in several areas, as detailed below.

Support to the LVB

In co-operation with the LVB, NLR delivered a new version of a runway usage advisory system, giving guidance to air traffic controllers in the optimum use of available runways, taking into account meteorological factors and environmental aspects.

Further support was provided for the conflict detection functions for the new ATC system of the Netherlands, the Amsterdam Advanced ATC system (AAA). An analysis was made of the aircraft modelling in the AAA simulator. Support was also provided at technical expert level to the Mode-S surveillance programme of the LVB.

A prototype Human Machine Interface (HMI) was produced to better control Continuous Descent Approaches (CDA), and prevent unnecessarily large separations between aircraft, by Advanced CDA or ACDA.

For the Steering group on the Optimization of the Capacity of Schiphol (SOCS), consisting of experts from LVB, RLD, KLM and AAS, the possibilities and the techniques to be implemented for a Schiphol Advanced Surface Movements Guidance and Control System (A-SMGCS) were explored.

In co-operation with the RLD, the LVB's Flight Track and Monitoring System (FANOMOS) has been maintained and upgraded.

In co-operation with LVB and Eurocontrol, the complete specification for a Medium Term Conflict Detection Method for the European Air Traffic Control Harmonization and Integration Programme (EATCHIP) was finalised.

On behalf of the LVB, NLR took part in activities of international ICAO Panels such as the SSR Improvement and Collision Avoidance Systems (SICAS) Panel, the Aeronautical Telecommunication Network Panel (ATNP), the Automatic Dependent Surveillance Panel (ADSP), the Review of the General Concept of Separation (RGCS) Panel and the All Weather Operations Group (AWOG), and in activities of Eurocontrol in the European Air Traffic Management System Concept Task Force (ECTF). A study was made to analyse the potential impact of Automatic Dependent Surveillance (ADS) on helicopter operations over the North Sea.

Support to the RLD

For the RLD, the Netherlands Department of Civil Aviation, consultancy services were provided in the field of data communication and ICAO Aeronautical Telecommunication Network Panel activities. Support was provided to accompany the introduction of GNSS (Global Navigation Satellite System) in the Netherlands' airspace. RLD was also assisted in the ICAO GNSS panel work.

Further work was carried out on an ATM safety assessment methodology and necessary tools.

Support to Eurocontrol

Major contributions were made to the Programme for Harmonized ATM Research in Eurocontrol (PHARE), especially in the following projects:

- Experimental Flight Management System;
- Common Modular Simulation Environment;
- PHARE Aeronautical Telecommunication Network;
- Airborne Human Machine Interface (AHMI);
- Ground Human Machine Interface (GHMI);
- Phare Advanced Tools;
- Validation;
- PHARE Demonstration 3.

NLR leads the AHMI and GHMI projects. The laboratory is one of the main sites of the PHARE Demonstration 3 (PD/3), a large scale, multi-site, multi-sector demonstration of an advanced Air Traffic Management concept developed by PHARE partners and intended to be operational after 2015.

NLR provided a full staff member to the PHARE office at Eurocontrol, Brussels.

Several consultancy services were provided to Eurocontrol in the field of reduced vertical separation.

NLR also contributed to FACTOR/CT (Development of Functional Concepts from the EATMS Operational Requirements/Complementary Task), making an assessment of the requirements for a future European ATM system.
NLR is leading the project TOSCA (Testing Operational Scenarios for Concepts in ATM), aimed at finding the impact of the introduction of a number of options in the European ATM system (EATMS) concept on the performance of the complete system.

In an extension to the project EOLIA (European Pre-operational Data Link Applications) conducted by the European Commission's DG-13 (Telecommunications), Eurocontrol requested the development of additional ATC datalink services, designed to relieve the airspace congestion over Europe, 'Downstream clearance' and 'Digital ATIS (Air Traffic Information Systems)'.

Support to the European Union

The European Commission conducts the Fourth Framework Programme European Coherent Approach for Research and Technological Development in Air Traffic Control (ECARDA). This programme is supported by DG-7 (Transport), DG-12 (Science, Research and Development) and DG-13 (Telecommunications), and concentrates on the development of a future European Air Traffic Management system. The programme also aims at stimulating research on ATM in Europe and at improving the European industrial position in ATM. NLR participates in consortiums in many of these projects. The participation of NLR aims to aid the realization of an advanced ATM infrastructure in the Netherlands in order to support the mainport function of Schiphol. The projects can be classified in various domains as follows.

Air Traffic Management (ATM) Concepts

Studies were carried out into advanced Air Traffic Management operational and functional concepts and procedures, including airspace management aspects, operational scenarios, and safety and validation aspects. In several projects, proof-of-concept demonstrators will be developed. These are pre-operational systems that play important roles in the evaluation and validation of the operational feasibility of the new concepts.

Air Traffic Control

Studies were carried out aimed at providing support to air traffic controllers in order to increase the capacity of the air traffic control system and/or to decrease controller workload. The studies concerned new controller workstations with advanced HMIs, advanced ATM functionality (e.g. conflict detection tools, planning tools, problem solvers, arrival and departure managers) which exploit the new CNS (Communication, Navigation and Surveillance) technology (e.g. air-ground data communication, satellite-based navigation and enhanced surveillance).

Airports

Research carried out concerned all aspects related to aircraft movements on the airport surface such as improved surveillance and automated guidance and control for precise departure times, increased use of runway and taxi tracks, landing and approach aids that are less susceptible to multipath effects, optimal taxi routes and gate allocation, and automated assistance for the tower controller.

Avionics and Communication, Navigation and Surveillance

Research on advanced flight management systems concerned: aircraft-based optimal flight routes, Automatic Dependent Surveillance, air-ground data communication, advanced primary flight and navigation displays, Command and Display Units (CDUs), monitoring, alert and warning systems, and integration of avionics with the ATC ground system.

Facilities and Basic Research

The research subjects can be distinguished in: ATC simulators, ATM software tools, tower research simulators, research flight simulators, fast time ATM simulators, safety prediction and analysis tools, capacity prediction and automated ATC environment.

Human Factors

Glass Cockpit Design for Airliners

Prototype CDUs and navigation displays of the new on-screen interactive generation were developed in order to assess the effectiveness of man-machine interaction in real-life flight conditions. Direct manipulation techniques on navigation displays together with tracker ball pointing devices proved satisfactory and flexible for use in a 4D ATM scenario with negotiations with ATC. The prototyped airborne HMI assists the flight crew in strategic route planning and trajectory negotiation using a datalink.

A synthetic 'Tunnel in the sky' format was investigated in the Research Flight Simulator for effectiveness in both nominal and non-nominal conditions. Several formats were investigated for applicability in future ATM scenarios with high traffic densities. The study included aircraft performance, human performance and workload measurements. Aircraft performance was consistently high for all experimental formats, with the format indicating a graphical 'airspace box' providing highest performance. The improved accuracy with respect to the ground tracks can support accurate management of noise footprints of the aircraft, relevant for environmental issues around airports. Moreover, the fact that these improvements were obtained with only very limited training indicates that perspective primary flight displays are a promising alternative. The work was supported by the NIVR and carried out in a collaboration with the University of Leiden.

Work on enhanced and synthetic vision systems (EVS and SVS) under the EU project AWARD (All-Weather Arrival and Departure) was continued. These novel systems are likely to increase the pilot's situational awareness, thereby reducing one of the most common causes of aircraft accidents: Controlled Flight Into Terrain (CFIT). In this area, in-depth studies of many aspects were performed, with an emphasis on human factors and certification. The work included the scrutinization of operational requirements, certification issues and crew procedures, the analysis of crew information requirements, the human-centred design of display content, and the formulation of recommendations for display devices. In addition, part-task pilot-in-the-loop human factors evaluations were prepared.

Free Flight imposes new requirements for displays in glass cockpits. A combination of fast-time simulation, safety hazard analysis and crew-in-the-loop operational context simulations were performed. The fast-time simulation provided data for the selection of a candidate algorithm from such separation strategies as 'rules of the road', intent displays and automatic machine-assisted separation. A clear advantage emerged for a combined solution, resulting in a modified 'voltage potential' algorithm. Safety analysis in specific conditions showed that such a concept could indeed improve safety levels compared to traditional separation procedures. Subsequent simulator experiments revealed effective separation at three times the average European traffic density of today. Effectiveness was expressed by pilot acceptability, subjective safety perception, subjective workload, point of gaze measures and aircraft performance. Physiological pilot workload data are under analysis.

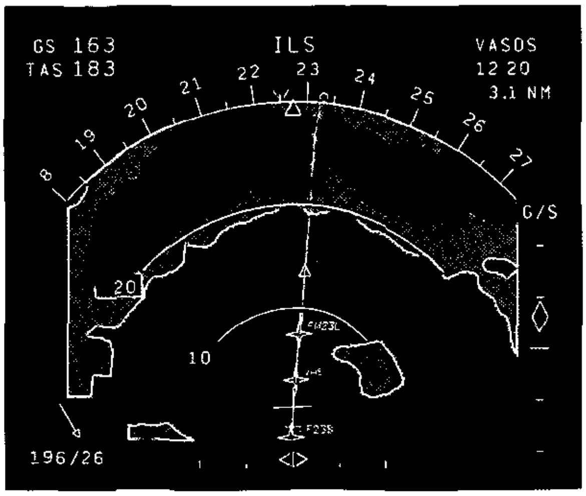
The role of the Flight Management System in future ATM systems is being investigated in two studies supported by the EU. One project, AFMS (Advanced Flight Management System), supports the development of products for the aviation industry that would improve air-ground co-ordination. Specifications for alternative CDU designs, within retrofit limitations, were made and delivered for detailed evaluation.

The European Transport Safety Council (ETSC) is an independent safety promoting organization with a multi-modal orientation. NLR provided the chairman of the ETSC Air Safety Working Party, covering human factors issues, as well as an expert on airport safety and concepts for a systematic approach to safety issues. A conference on survivability in aircraft accidents was organized. It was the third in a series on such issues as cockpit automation, flight duty time limitations, aircraft accident survivability and airport safety.

On invitation by the US FAA (Federal Aviation Administration) and the European JAA (Joint Aviation Authorities), NLR provided a scientist to contribute to re-visiting the flight deck certification process. The result of the discussions made clear that procedures (working methods, checklists, company procedures) need to be an integral part of the overall flight deck certification process.

Controlled Flight Into Terrain

Under contract to the RLD, a flight simulator experiment was executed to investigate the operational implications of advanced ground collision avoidance systems and terrain displays on crew decision making and situational aware-



Terrain data shown on the navigation display in a simulator test ness in the cockpit. Ten crews participated in the evaluations, using the RFS, that involved a number of different alerting and display concepts.

ATC/ATM Controller HMI

In collaboration with Eurocontrol and LVB, work on the design and specification of controller working positions for the next generation ATC/ATM was continued. The en-route interfacing with the terminal area, the subject of the PHARE PD/2 experiments, will be extended with a Multisector planner. The work concentrated on the design of the required HMIs for a gate-to-gate experiment. Based on task-logics diagrams, working procedures were identified, combined and tested for possible task sharing issues between controller teams. In order to assure effective use of the HMI, a computer aided instruction and familiarization package was specified and implemented in a prototype. Working procedures and training are part of an integrated design process developed at NLR. Eurocontrol awarded NLR the responsibility for designing computer aided training within PHARE.

Exploratory work on Free Flight ATM solutions was performed in collaboration with the US NASA and FAA and with support from the RLD. The impact of free flight on the role and required capabilities of air traffic controllers was evaluated in an experiment. A free flight controller working position that allowed aircraft control under three conditions: fully ground-controlled traffic, free flight with aircraft intent displayed and free flight without intent information was developed. Results showed that controllers were open to the concept and were able to indicate achievable benefits. The display of intent information proved essential. In a follow-on study, a display format that allowed the controller to select an aircraft and access the intent information in a format compatible with the display formats in the aircraft was developed. This design assured compatibility between the air and ground perspectives on traffic. Military controllers were observed to be more comfortable with free flight than civil controllers.

In collaboration with NASA and the Catholic University of Washington, alternative working methods for air traffic controllers were investigated using the 'adaptable' and 'adaptive' HMI concepts. State-of-the-art assistance tools were implemented in an experimental controller working position based on the NASA CTAS (Center/TRACON Automation System) concepts and tools. Measures for visual workload were analysed. The results indicate higher measured workload levels with controllers when working with dynamic than with static automation configurations. The use of assistance tools is consistently found to be decreased during high task load conditions.

Ground movement efficiency is more and more required to increase airport capacity, and the human factors issues with respect to equipment design were studied in the context of the EU programme DEFAMM (Development and Demonstration of Facilities for Airport Movement Guidance, Control and Management). Human machine interfaces for ground operations were specified and developed to be included in future field trials on airports.

Military Crew Station Design

The RNLAF was supported by a mission analysis study aimed at the identification of factors that contribute to pilot workload and consequently pose a potential risk for pilot performance and mission effectiveness. Relevant problem areas were derived from existing reports of RNLAF exercises. The results are used to gain insight in workload factors in specific mission segments and specific so-called high level pilot tasks, such as navigation, communication and switchology.

In collaboration with DERA, the RLNAF and TNO, a research programme into advanced display and pilot support tools was defined. This programme was named POWER (Pilot Oriented Workload Evaluation and Redistribution). In Phase 1, the HMI requirements for one specific application, a weapon selection task, were defined.

Under an F-16 Mid Life Update (MLU) contract from Lockheed Martin, colour display formats for the Fire Control Radar and the Horizontal

Situation Display pages of the Multi-Function Displays (MFDs) were tested in the F-16 Mock-up. A follow-up experiment was conducted on the NSF. The aim was to compare the two remaining colour coding configurations and a monochrome baseline configuration. One of these colour configurations is currently used in the F-16 MLU cockpit, the other was developed by NLR in close co-operation with the RNLAF.

Pilot performance and safety were addressed in a project carried out on behalf of the Netherlands Ministry of Defence, resulting in information relevant for both the Polish Air Force and the Netherlands Armed Forces. This project was performed by NLR, the Netherlands Aeromedical Institute and the Polish Air Force Institute of Aviation Medicine. The main goal of the first year of this collaboration was to collect the information required to design a pilot debriefing facility.

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

A human factors expert participated in the AGARD Working Group on Human Performance Modelling. An initial version of an expert system, named HOMER, was developed. This system queries potential users of human performance models about what they are trying to do before offering advice about models.

Operator Performance and Workload Measurement

Research on the development of a practical set of measures for evaluating operator performance, mental workload and situational awareness was continued. It included activities on data acquisition and interpretation issues, as well as a further development of the in-house analysis software package HEART (Human Factors Evaluation, Analysis and data Reduction Techniques).

A dual gaze-tracking system was implemented in the RFS to allow real-time measurements to be made of the Eye-Point-Of-Gaze (EPOG) of both pilots. NLR co-ordinates the European Union's VINTHEC project (Visual INTeraction and Human Effectiveness in the Cockpit) which is aimed at the development of a methodology which uses EPOG to assess the pilot's situational awareness. EPOG measures were taken in a simulator study on free flight concepts. Dedicated studies investigated the potential of using pupil diameter, eye blink frequency and scanning entropy as complementary measures for operator performance.

Work on brain activity measures concentrated on their potential to complement EPOG techniques. Among the measures considered for implementation are spontaneous EEG measures, as well as Event-Related (De-)Synchronization (ERD/ERS) and task-irrelevant probe techniques. Routine application of brain activity measures is foreseen in the future.

Human Factors of Pseudo Motion Cues in Flight Simulators

A collaboration programme was started with DERA in the area of motion cueing in flight simulation. The collaboration is supervised by the ANNSC (Anglo-Netherlands-Norwegian Steering Committee), working group VI (Aeronautics). The goal of the programme is to establish the effects of pseudo motion cues, as generated by a g-seat and possibly a helmet loader, on the execution of control tasks in a flight simulator. Experiments were conducted at DERA and in the NSF at NLR. Maximum commonality between the experiments was aimed at. A preliminary analysis of the data of the NLR experiment shows a clear effect of the pseudo motion cues on the execution of the control task. Task performance increases when pseudo motion cues are added and increases further when platform cues are present.

Training and Selection

As part of the project ECOTTRIS (European Collaboration on Transition Training for Improved Safety), the compatibility of airlines' automation philosophies with the automation as applied in aircraft has been investigated. An inventory of the automation in 'glass aircraft' has been created. A questionnaire, distributed among 'glass cockpit' pilots, was used to investigate to what extent airlines prescribe pilots to use this automation. The questionnaire was also used to investigate the skills that glass cockpit pilots currently require and to find out whether they consider their knowledge and skills sufficient to fly glass aircraft under difficult situations.

For the PHARE PD/3 programme the Internal Operational Clarification Project (IOCP) training was developed, implemented and delivered. This concerned the on-the-job training at NARSIM with the modified PD/1 system. Specification of the Computer Based Training for PD/3 controllers was continued. The implementation of this training is carried out at NLR.

The forthcoming European legislation in JAR-FCL (Joint Aviation Requirements - Flight Crew Licensing) includes a requirement for the assessment of skill proficiency on non-technical skills. A study was started at the request of the RLD and the JAA Project Advisory Group on Human Factors (JAA-PAG) with the goal to indicate possible ways to comply with the requirements of JAR-FCL. The study, which was carried out in co-operation with the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR), the University of Aberdeen and IMASSA, relates to JAR-OPS and Crew Resource Management training in general.

Human Factors in Aircraft Maintenance

Activities on human factors in aircraft maintenance continued in the European ADAMS (Aircraft Dispatch and Maintenance Safety) consortium and in a national study for the RLD. The activities in the ADAMS project included taking an inventory of existing human factors issues in aircraft maintenance. A Human Error incident analysis tool was evaluated and improved, and the contents of a European Human Factors Guide for Maintenance was discussed. Identified issues were related to both the JAR-145 and the draft version of the JAR-66. Recommendations to include human factors in both these requirements were listed.
The first phase of the RLD project, the identification of the human factors issues in line maintenance, was completed. In this project, information was collected at three aircraft maintenance organizations of the Netherlands, and the results were compared to the outcomes of the European investigation.

Human Factors Validation and Certification

NLR participated in the steering committee of a EUREKA-supported project on Cockpit Certification requirements for Human factors in Cockpits. An international workshop was organized with the purpose of eliciting proposals for research and implementation of regulations more adapted to the modern generation of flight decks.

The JAA/FAA harmonization committee on cockpit certification was supported by expert advice on design and evaluation procedures with respect to human factors. A major result was that procedures should be an integral part of the HMI review and certification process. At present, the regulations treat both aspects independently. The NLR CODEP (Cockpit Operability and Design Evaluation Procedure) methodology for the review of cockpits was selected as a possible candidate for defining regulations.

CODEP was further developed by using it in a human factors evaluation of the F-16 MLU cockpit in the NSF. Apart from describing this cockpit interface, the aim was to gain experience in executing the procedure.

Human Factors of Airport Hindrance

The Ministry of Transport was supported with subject matter expertise to assist the scientific basis of the GES project (*Gezondheids Evaluatie Schiphol*) that addresses hindrance and possible health implications of exposure to high density air traffic. NLR analysed and commented questionnaires and participated with a member in the scientific committee.

Human Factors of Aircraft Incidents

NLR participated in the HUFAG (Human Factors Advisory Group) with the aim to disseminate knowledge and expertise within the national aviation community, together with partners from KLM, KLS, IFALPA, VNV (Union of Netherlands Airline Pilots), the Aeromedical Institute and RLD. Meetings were organized and accident reports analysed and commented at the request of the safety organizations responsible for accident investigation.

Military Support

Human Operator Training and Familiarization

Training and simulation research was carried out under two Research and Technology Projects (RTPs) of the European Co-operation for the Long Term in Defence (EUCLID): RTP 11.1 on Simulation based training system concepts and RTP 11.2 on Simulation techniques. The latter was concluded.

As part of the RTP 11.1 programme, a study was conducted into the training values of high fidelity (high-end) simulators compared with lower fidelity (low-end) simulators. This included an investigation of the training effectiveness of the motion system on three fighter simulators, of which the NSF was used in the F-16 Mid-Life Update (MLU) configuration.

A second study within the RTP 11.1 programme involved a controlled training experiment to investigate the training of advanced manoeuvres (aerobatics). Two simulator configurations based on Personal Computers (PCs) were designed to accommodate ground school lessons and to support advance manoeuvre training on the aircraft. PC-based simulation indeed appeared to be capable of improving ambitious skill acquisition processes like aerobatics training by yielding quicker learning and better final performance.

In the RTP 11.2 programme, NLR co-operated with Aermacchi of Italy and Thomson Training & Simulation of the UK to establish the requirements to cueing systems for flight simulators (both for rotary and for fixed-wing aircraft). In the context of this programme several experiments were conducted in three simulation facilities including the NSF and in a light jet trainer (Aermacchi MB339C). Several operational flying tasks were used and a number of evaluation procedures were developed to assess the effectiveness of the cueing systems.

The selection of flying tasks was critical and it proved to be a challenge to design flying tasks that were operationally relevant but would not allow individual pilots too much freedom in executing the manoeuvres. Apart from this, the evaluation techniques that were developed and evaluated, as well as the area selected for the flight tests, also put a constraint on the selection of the flying tasks.

The mental workload was clearly higher in the real aircraft than in any of the simulators, as deduced from heart rate measurements.

Aircraft Accident Investigations

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

The RNLAF did not experience any serious aircraft accidents in 1997. NLR support was therefore aimed at the preparation for accident investigations. This mainly involved maintaining the necessary level of technical skills, and further development of Accident Investigation Manuals. Because a number of new aircraft and helicopter types have become operational in the RNLAF in recent years, the collection of a basic level of type specific information on these platforms was initiated.

NLR assisted the RNLAF in the parameter selection and the evaluation of analysis software for the crash-survivable flight data recorder to be incorporated in the F-16 MLU configuration.

Flight Test Support

NLR assisted the RNLAF during various flight tests with the F-16, with transport aircraft and with helicopters. The support concerned the F-16 Mid-Life Update Operational Test & Evaluation programme carried out at Leeuwarden Air Force Base, among other things. Existing instrumentation for the F-16 was maintained. Preparations were made for F-16 MLU instrumentation to be developed and installed.

Tactical Recce System Replacement
NLR supported the RNLAF in the process of defining and selecting new reconnaissance equipment to replace the present Orpheus system. The support included refinement of the requirements. Tests were carried out with candidate sensors, to evaluate their performance under operational conditions.

Certification of Military Aircraft
Various new F-16 configurations were analysed and the RNLAF was supported in test programmes. The analysis for the certification of the Navigation and Targeting pods that were acquired by the RNLAF was started.

The Royal Netherlands Army was supported in the certification of the Sperwer Remotely Piloted Vehicle.

Integrated Self Protection
NLR carries out investigations into the feasibility of an integrated smart self-protection system. Such a system should improve the performance of available countermeasure equipment such as jammers, radar warners and decoy dispensers while reducing the workload of the pilot. This National Technology Project (NTP) is carried out in co-operation with the Physics Laboratory of TNO.

Support of Military Operations
NLR supported the RNLAF with the analysis of the properties and performance of threat weapon systems and of RNLAF weapon systems. Models and other tools used for weapon system performance analyses were extended. NLR provided assistance in national and international field trials with regard to performance of electronic countermeasure systems for fighters, helicopters and transport aircraft.
New instrumentation, STF (Seeker Test Facility), used for the evaluation of the effectiveness of Infrared decoys, was fielded, and new instrumentation for the assessment of Electronic Countermeasure Effectiveness, ETF (ECM Test Facility), was developed. Support was provided in operational training for fighter aircraft and ground based air defence systems (including MAPLE FLAG) and instruction of RNLAF operational personnel, the Netherlands Royal Military Academy, the NATO Tactical Leadership Programme (TLP) and the NATO School in Oberammergau. For various ground-based air defence systems, evaluations of system performance were carried out. Also add-on equipment to be used for training was improved.

Military Flight Support
Support has been provided to the RNLAF on the tactical and operational use of fighter aircraft and on the safety analysis of airshow flight demonstration programmes for the Lockheed Martin F-16 and Pilatus PC-7 aircraft.
A preliminary version of the aerodynamic model of the Pilatus PC-7 aircraft has been constructed. This model is used for the safety analysis of airshow programmes. Work has been continued on the validation of the model, and discrepancies with respect to flight tests were investigated.

NLR provided support in the F-16 Mid-Life Update Operational Test & Evaluation programme

For noise abatement the PC-7 aircraft of the RNLAF are operated with a reduced propeller speed of 1825 r.p.m. Corrections with respect to the charts of the aircraft's flight manual, representing start, climb and cruise performance for the original propeller speed of 2200 r.p.m., have been calculated.

V/SHORAD

NLR participates in the NATO feasibility study (Very) Short Range Air Defence Systems (V/SHORAD) as a subcontractor to Fokker Space. NLR contributed in Command and Control and Target Sensor working groups.

Simulator Component Usability

Under contract to the Royal Netherlands Navy, NLR completed an investigation of the present status, maintainability and functionality of the Lynx Full Mission Flight Trainer (FMFT) hardware and software as well as giving advice on the future exploitation. The emphasis was on the computer complex and visual system.
A report was written and presented to the Joint Executive Committee (JEC) of the Joint Lynx Simulator Training Establishment and the Naval staff involved.

Aircraft Operations

Research Aircraft

Fairchild Metro II

The Metro II research aircraft, in addition to being used in several research programmes, performed flight inspections of the radio navigation aids in the Netherlands under contract to the LVB.

In the framework of the National Remote Sensing Programme (NRSP II) 'Remote Sensing for Precision Agriculture', managed by the Wageningen Agricultural University, a number of flights have been made with the CAESAR optical scanner. The capabilities of CAESAR for agricultural applications have also been demonstrated to potential customers. To support a basic research programme, a few flights have been dedicated to the investigation of the possibilities of state-of-the-art commercial digital cameras.

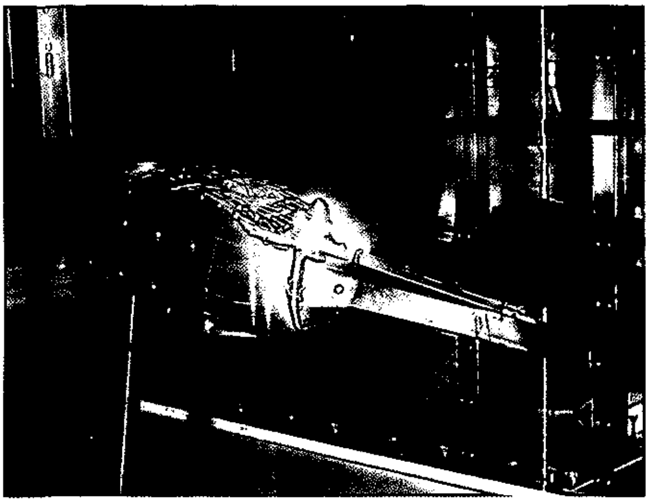
For the EU project EURICE (European Research on Aircraft Ice Certification), the Metro II aircraft has been equipped with a data collection system for obtaining data on icing conditions in the atmosphere. A number of flights have been made with this system with the primary goal to measure the distribution of the sizes of supercooled droplets in clouds in the Northwestern part of Europe and to look especially for the existence of Supercooled Large Droplets. As part of the same flight campaign German and Spanish research institutes have made similar flights in other parts of Europe.

Cessna Citation II

A number of flights have been made with the Phased Array Universal Synthetic Aperture Radar (PHARUS), under contract, with the purpose to obtain technical system data, familiarize potential users with the type of data and obtain radar data.
A ground test has been performed as part of a project for the evaluation of the use of spectrometers for identifying gas emissions by jet engines.

In the framework of the Future Aircraft Systems Testbed (FAST) project, activities have started to prepare the Citation for several large European projects dedicated to the integration of aircraft and Air Traffic Management in the near term in Europe. An experimental Primary and Navigation Display system has been installed in the cockpit. A dedicated Flight Test Instrumentation console for the operation and monitoring of the experimental system was realized.

For the measurement of drag caused by standing water on the runway, tests have been performed on a specially designed flooded section of a runway at Cranfield airfield in the UK. For this test the Citation has been equipped with accelerometers, wheel speed sensors, data registration and video equipment. The tests were part of a project of the European Commission aimed at improving the airworthiness requirements for aircraft operations on contaminated runways.



NH90 helicopter model in the DNW-LST wind tunnel

Helicopters

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

NLR participated in the European Union's Fourth Framework projects HELIFLOW (Improved Experimental and Theoretical Tools for Helicopter Aeromechanic and Aeroacoustic Interactions) and RESPECT (Rotorcraft Efficient and safe Procedures for Critical Trajectories).

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

Support to the RNLAF in the improvement of the CH47-D Chinook Avionics Control & Management System (ACMS) was continued. A study was conducted to assess the feasibility of a ballistic protection application to the transport helicopters of the RNLAF.

A specification of a standard helicopter flight test instrumentation system has been defined. A familiarization study has been conducted in applying NLR's FlighLab computer code, capable of predicting and analysing helicopter flight performance and handling quality characteristics.

Under contract to the Royal Netherlands Navy (RNLN), wind tunnel tests were executed on a model of the new Amphibious Transport Ship (ATS) in the DNW-LST. Flowfield visualizations and measurements were performed in the vicinity of the flight deck.
In the framework of the RNLN Lynx helicopter mid-life update extension programme a Forward Looking Infrared (FLIR) system has been installed. On-ground and in-flight vibration measurements were performed on a modified suspension system.

A theoretical study concerning the prediction of the wind environment of hovering and slowly/low flying helicopters for the Netherlands Ministry of Defence was continued.

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

Transport and Environmental Studies

Policy Analysis

Under contract to the government, a stakeholder analysis regarding the possible use of new metrics for aircraft noise exposure was carried out. Furthermore, a study into the development of the future air transportation structure was performed.

Air Pollution

Under contract to the European Commission, the study AEROCERT (Aircraft Environmental Impacts and Certification Criteria), into options for possible improvement of the existing certification procedures for emission of noise and exhaust gases was started. AEROCERT is carried out by DERA of the UK, the Aeronautical

Research Institute (FFA) of Sweden, the Loughborough University of Technology of the UK, DLR of Germany and NLR, the project co-ordinator.
NLR contributed to the EC-sponsored thematic network on Identification of Aircraft Emissions Relevant for Reduction Technologies (AERONET).
In co-operation with Resource Analysis of the Netherlands and MVA of the UK, NLR was involved in the further development of AERO, a computer model for 'Aviation emissions and Evaluation of Reduction Options'.
Under contract to the International Air Transport Association (IATA), NLR started a study into operational measures to reduce aviation emissions.
Supported by of the Netherlands government, NLR is involved in the realization of a report on 'Aviation emissions and the global atmosphere' which is realized by the Intergovernmental Panel on Climate Change. In co-operation with the US Federal Aviation Administration (FAA), NLR as Co-ordinating Lead Author is responsible for the chapter on Air Transport Operations and the Relation to Emissions.

Noise Exposure

Noise exposure was calculated for actual situations at several airfields in the Netherlands.
Under contract to the government, the actual noise exposure around Amsterdam Airport Schiphol was analysed and checked against the permitted noise budget.
Under contract to several airports, the noise exposure predicted for the next year was calculated.
Preliminary studies into the environmental consequences of additional infrastructure were performed.

Monitoring of Environmental Aspects

Under contract to the Netherlands Ministry of Housing, Physical Planning and the Environment, NLR has operated a noise monitoring system in the surroundings of Geilenkirchen Airbase. Under contract to the Netherlands Ministry of Transport, and under contract to the LVB, NLR worked on the extension of functionality of the Flight track and Aircraft Noise Monitoring System (FANOMOS). The extended FANOMOS will perform the following functions: track and noise monitoring, calculation of noise exposure and matching of information on noise, and recording of flight tracks, complaints and flight plans.

Accident Investigations

Throughout the year, the Netherlands Bureau for Accident and Incident Investigation was supported in the investigation of an accident with a vintage airliner, in 1996. NLR's support in 1997 mainly concerned component and systems investigations, and the reconstruction from radar data and analysis of the flight path. Based on the reconstructed flight path and through the use of a simple simulation model, an analysis of the degraded aircraft performance characteristics and handling qualities was carried out. The results of this analysis, which proved pivotal in understanding the chain of events, were presented by NLR at a public hearing about the accident.

Third Party Risk Analysis for Airports

A third party risk analysis was carried out for the airport of Eelde as part of the procedure to obtain government approval for the intended extension of the runway. Another third party risk analysis was carried out for the airport of Rotterdam, to be used in decision making on the future development of the airport. Under contract to the Netherlands National Institute of Public Health and the Environment (RIVM), third party risk calculations were carried for Amsterdam Airport Schiphol. This work was part of the annual national review by the RIVM of the state and development of the environment. In support of a Netherlands government working group tasked with the preparation of a government policy of third party risk around airports, NLR continued the development of a model and the conducting of trial third party risk calculations for regional airports. In the ongoing project on the development of third party risk calculation methods and models for military airbases under contract to the Netherlands Ministry of Defence, a data definition study was completed.

Facilities and Equipment

NLR Air Traffic Control Research Simulator (NARSIM)

The air server of NARSIM, which generates and controls the simulated air traffic, has been upgraded. Work was started to provide four-dimensional navigation capabilities and Advanced Flight Management functions to the simulated aircraft. In the BRITE/EURAM (Basic Research in Industrial Technologies for Europe/ EUropean Research on Advanced Materials) project PATIO (Platform for ATM Tools Integration up to Pre-Operation), NLR is responsible for the development of the Air Traffic Generator system. This system will be based on the NARSIM air server and extended with PATIO related interfaces. The PATIO project, carried out under contract to the European Union, aims at the development of a European ATM validation platform.

The NARSIM platform is being prepared for the PHARE Demonstration 3 (PD/3), planned to include running an operational experiment in a 4D ATM environment, including datalink and negotiation features between pilot and air traffic controller.

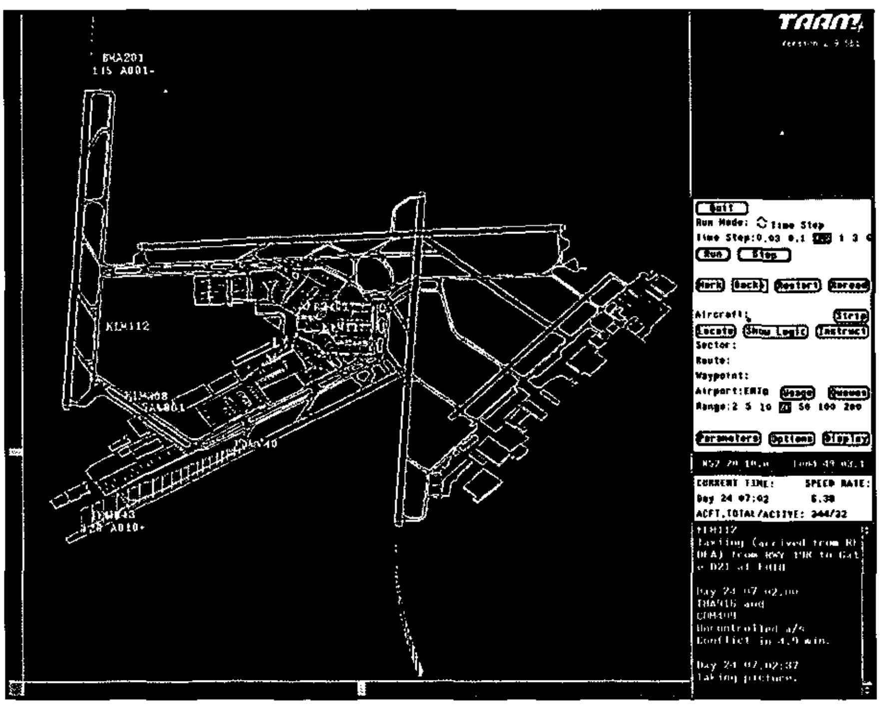
NARSIM was further upgraded to support the PD/3. For this a start was made to integrate several PHARE Advanced Tools such as the Negotiation Manager, the Arrival Manager and the Trajectory Predictor on the NARSIM demonstration platform. An advanced Air Traffic Generator (ATG) was developed to support PD/3 and PATIO projects. The combination of these tools enables research into advanced ATM concepts to reduce delays, enhance safety and efficiency with minimal environmental impact to be carried out.

NARSIM was moved to a new building, and five new ATC console combinations were installed.

Total Airspace & Airport Modeller

NLR has available a Total Airspace & Airport Modeller, (TAAM®), a workstation-based tool for the simulation of airspace and airport operations. It provides both fast-time and real-time modelling capabilities in a gate-to-gate model simulating in detail: push-back, runway taxiing, terminal, en-route airspace and down again in one seamless application.

Work with TAAM was conducted to support policy decisions for the Future Netherlands



Traffic displayed by Total Airspace & Airport Modeller (TAAM)

Airport Infrastructure (TNLI) and to analyze the impact of a fifth runway at Amsterdam Airport Schiphol, as well as new parallel runway options. Results indicated punctuality figures of the airport and sector load.

A number of 'calibration runs' were executed to verify the modelling using real-life data.

Traffic Organization and Perturbation Analyzer (TOPAZ)

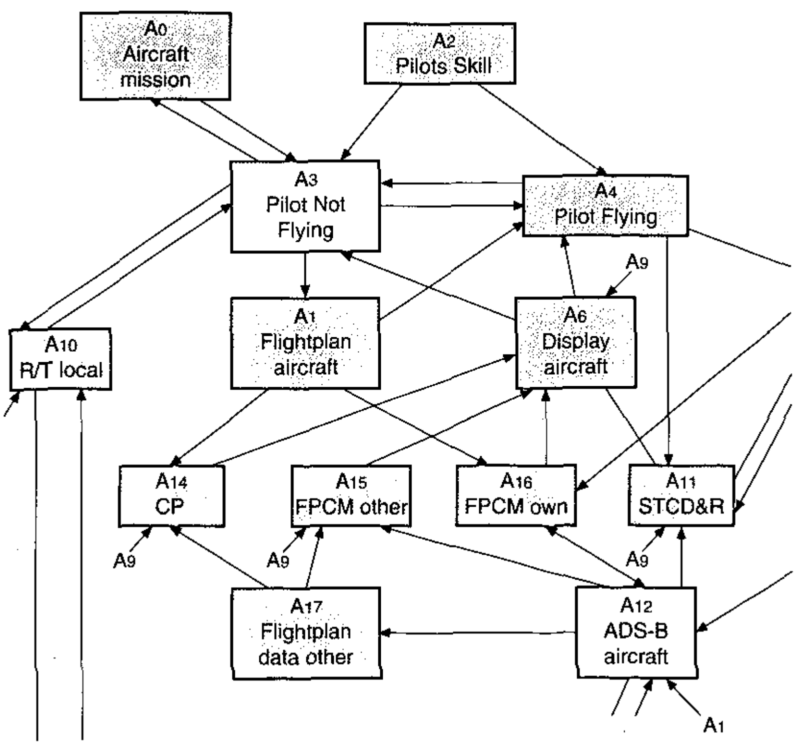
The Traffic Organization and Perturbation Analyzer (TOPAZ) facility saw its first operational year to assist in safety assessment studies. In comparison with other safety critical activities, Air Traffic Management (ATM) is by far the most complex. In contrast to traditional ATM design approaches, TOPAZ emphasizes an overall validation approach that views safety as the result of complex interactions between all ATM elements.

Research Flight Simulator

Modifications were made to the Research Flight Simulator (RFS) for a multitude of simulation experiments and configurations. The cockpit was equipped with two 13" Hitachi displays providing the lateral and vertical navigation displays as was required for the Free Flight experiment. A start was made with replacing the model board visual system by a computer-generated imagery system. Until the procurement of a new advanced visual system, the Evans and Sutherlands ESIG 3000 AT/GT image generator of the NSF will be used in the RFS.

To support flexibility during experiments, two Generic Control Panels were designed and placed in the cockpit for controlling the various experimental displays, in addition to the Display Control Panels.

The modification of the simulation software structure of the RFS, to harmonize the NSF and RFS simulation software environments, is almost finished. A large part of the aircraft models, avionics, hardware system drive laws etc. have been ported to the new real time simulation program and software development environment



Schematic produced by the Traffic Organization and Perturbation Analyzer (TOPAZ) for ATM design using a new Unix host computer system. At the end of the year, the validation tests of the Boeing B747-200/400 model neared completion. With a new RFS Interface Node linked to the host computer, the RFS infrastructure has been completely modernized.

In the next few years it is foreseen that the RFS will undergo a major upgrade of systems. A study has been started to collect user requirements and to make a realization plan taking into account the operational constraints due to simulation experiments on the current facilities.

National Simulation Facility (NSF)

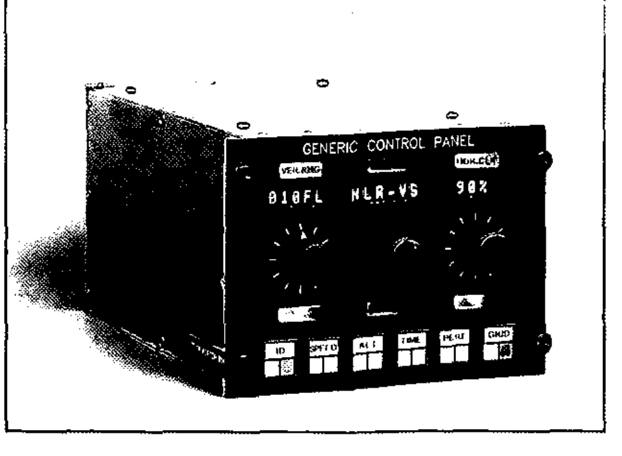
The F-16 MLU cockpit was equipped with Colour Multi-Function Displays enabling experiments within the F-16 MLU co-development projects to be carried out. To enable the video sources symbology, Maverick and Radar to be mixed on both displays, two switch boxes and two RGB Synchromasters were procured. Also for the F-16 MLU projects, the software of the Electronic Warfare Management System was changed by the manufacturer to comply with the simulation requirements of the NSF.
Further enhancements have been made to the software development program for more flexible and customized programming. The Flight Simulator Interface System (FSIS) software has been updated for more structured control of all computer systems linked into one simulation session. A MIL 1553B interface was one of the capabilities that were added to the FSIS.
The NSF was equipped with Vitaport and a point-of-gaze measurement system, similar to the systems used in the generic mock-up system. The point-of-gaze measurement system is used in combination with the head-tracker of the NSF visual system.

Generic Mock-up

The mock-up system was equipped with a displacement side-stick and pedal assembly for a pilot-in-the-loop evaluation of helicopter models. Helicopter-specific cockpit displays were developed and implemented in the mock-up. The standard F-16 throttle was used, rather than a specific collective lever. The available out-of-the-window-view was also suitable for this evaluation.

Future Aircraft Systems Testbed

The further development of the Citation Future Aircraft Systems Testbed (FAST) was mainly aimed at preparing the aircraft for three large multi-national projects (i.e. PHARE PD/3, AATMS and EOLIA), which will include experimental flights with the Cessna Citation II research aircraft. A flexible system architecture and cabin lay-out have been designed in order to enable the aircraft to be used in the various projects with minimal adaptations of the cabin equipment and lay-out. A number of essential components of this architecture (computers, displays and interfaces) were acquired. An important milestone of the FAST project was the design and implementation of a third crewmember position, which was installed in the cabin of the Citation. This facility is particularly aimed at the conduct of experiments with advanced Flight Management Systems in interaction with future Air Traffic Management concepts and environments. Also, experimental Primary Flight and Navigation Display systems, aimed at guiding the aircraft in four dimensions (position and time) along curved trajectories, were implemented. A preliminary version of the control algorithms required for this purpose was completed. In addition, work was carried out on an integrated instrumentation system. The design of a central 'Flight Test Instrumentation' console, from which all sensor systems and data collection systems in addition to the experimental systems can be monitored and controlled, was completed.



Generic control panel to be placed in the RFS cockpit

3.3 Structures and Materials

Summary

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

The scope of these activities was affected by the termination of Fokker Aircraft. In connection with this, NLR acquired the former Fokker Test Department, making NLR the major supplier for the testing of structures and systems for the Fokker Aviation Group.

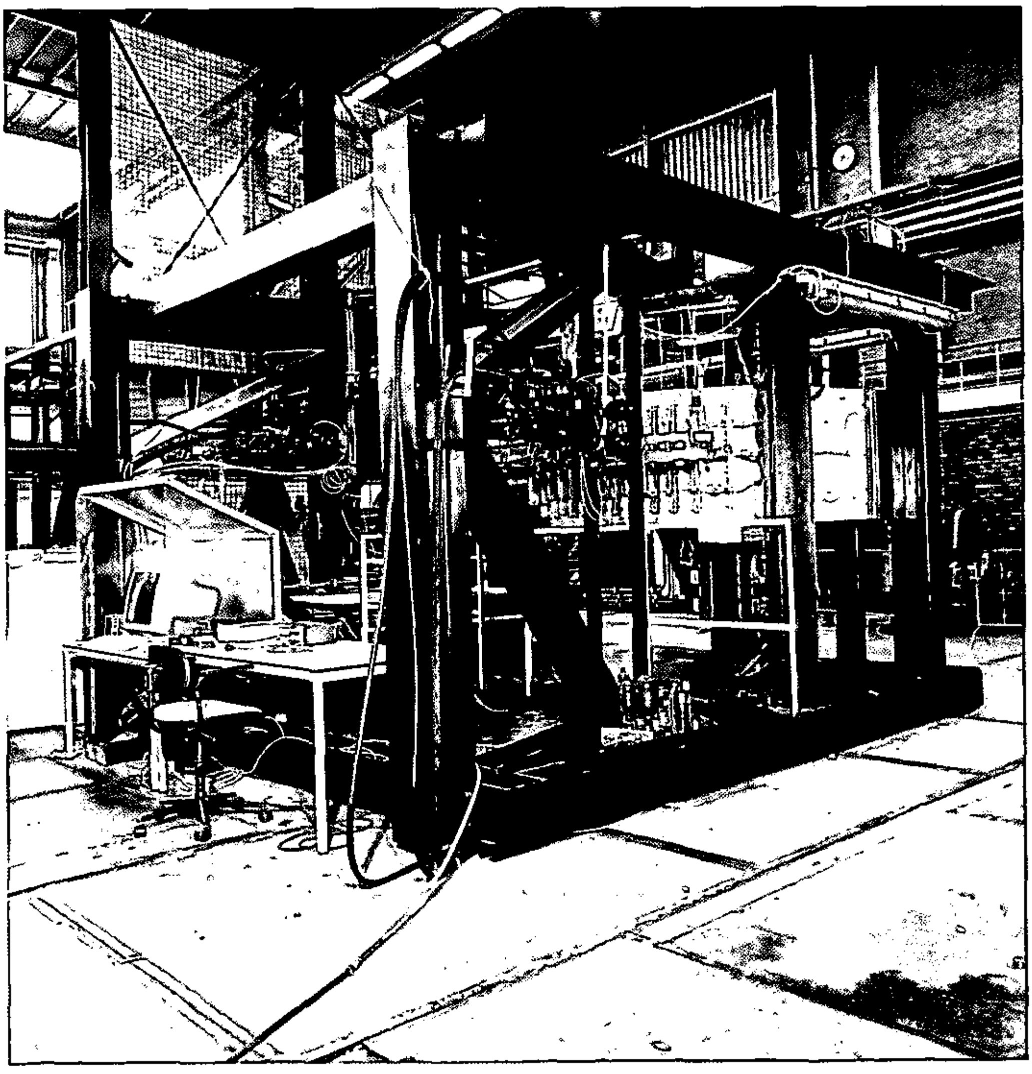
An important development was the start of new projects under the Fourth Framework Programme of the European Commission.

Discussions with industrial partners in the Netherlands were held aimed at participation in the Engineering and Manufacturing Development phase of the US Joint Strike Fighter (JSF) programme.

Loads and Fatigue

Aircraft Loads and Certification

The design criteria for continuous turbulence in current airworthiness requirements are not applicable to non-linear aircraft, equipped with active control systems. Under contract to the Netherlands Department of Civil Aviation (RLD),



Fatigue test on a large cargo door of a Fokker 60, at NLR Test House Schiphol

NLR has evaluated three simplified methods, so-called Deterministic Power Spectral Density (PSD) methods, and compared them with the Stochastic Simulation Method, whereby the design loads of the non-linear aircraft are obtained from response calculations in the time domain on turbulence patches with prescribed statistical properties. None of the deterministic PSD methods showed sufficiently reliable results.
NLR has 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.

Also under contract to RLD, NLR is preparing a Manual on Aircraft Loads, containing explanatory information on aircraft loads in general, with particular reference to the loading conditions specified in current airworthiness requirements. An educational tool, a gust response model, for the calculation of gust loads on a simplified aircraft model has been completed as part of the Manual.

Under contract to the US Federal Aviation Administration (FAA), through RLD, NLR participates in the FAA's Flight Loads Programme. An analysis of aircraft centre-of-gravity acceleration data obtained with so-called fatigue meters installed in Fokker F-27 and F-28 aircraft has been carried out, and published as an FAA report. NLR participates in the analysis of flight loads data supplied by NASA, to determine required sampling rates for on-board aircraft loads/flight data recorders.

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

As part of NLR's programme of basic research, an investigation was started into the applicability of 'Neural Networks' to derive aircraft loads from measured flight parameters.

Load and Usage Monitoring
The Fatigue Load Monitoring programme of F-16 aircraft of the Royal Netherlands Air Force (RNLAF) has been continued. The RNLAF has procured new, advanced fatigue load monitoring equipment for the F-16s, based on specifications made by NLR. Load measurements will be carried out in each aircraft of the fleet. Quantities measured include strains in five different structural locations and a number of engine usage parameters. At the end of 1997, about 55 F-16s had been modified for the new equipment. The Central Logistic Ground Station has been installed at NLR. This station was connected to four ground stations located at the squadrons, and monitoring was started. For storing and analyzing the measured data, a relational data base computer program has been selected, and the application for the F-16 data base was begun to be written.

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

For the RNLAF, the preparation of a load measuring programme for the C-130 Hercules fleet was begun. For the Royal Netherlands Navy and the Portuguese and Spanish armed forces, load monitoring was being carried out on Lockheed P3 Orion aircraft.

Gas Turbines and Failure Analysis
Methods to analyze the life of gas turbine components under service loading are being developed.

Under contract to the NIVR, a multi-disciplinary project was initiated to determine the service life of gas turbine components by thermo-mechanical modelling. The objective is to compute the service life of turbine blades by numerical analysis, and to establish the effects of various coatings on service life. The effect of the presence of cooling channels is also taken into account. The analysis started out by determining the heat transmission to the blades by CFD analysis, followed by computing the temperature distribution in the blades. Subsequently, the thermal stresses are computed, and a life prediction is calculated. Identical finite element grids are used to calculate the temperature distribution and the thermo/mechanical stresses, both for shell and solid elements. Modelling tools were developed and successfully validated with tests on cooled and uncooled tubes performed in house and with tests on blades described in the literature.

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

Thermal Barrier Coatings (TBCs) applied by Electron Beam Physical Vapour Deposition (EB-PVD) are in service on internally cooled first- and second-stage turbine blades in the hot sections of gas turbines. NLR evaluated sections of CF6-80 blades coated with these TBCs in the burner rig under thermal cyclic, high temperature and corrosive conditions. The blades were made available by KLM Royal Dutch Airlines and coated by the Interturbine Coating Centre and other suppliers. This project, sponsored by the Ministry of Economic Affairs' agency Senter, formed part of the cluster project EB-PVD Technology Development.

The failure of an industrial gas turbine was investigated and found to be caused by thermal mechanical fatigue cracking of the first turbine nozzle guide vanes under the influence of a large number of start/stops and one or more flame-outs.

Analysis of an F-16 Nose Landing Gear (NLG) piston failure led to an improved Non Destructive Inspection procedure, which resulted in the rejection from service of three NLG pistons. Re-inspection and destructive verification of these NLG pistons by NLR revealed the presence of several fatigue cracks in all three pistons at the same location as in the failed one.

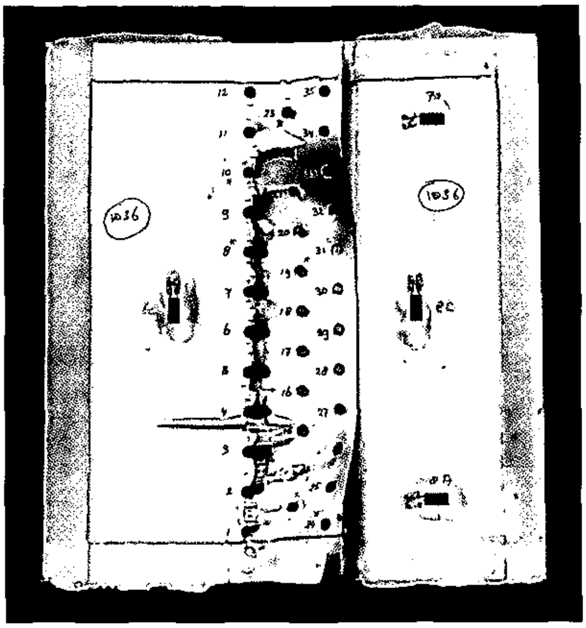
During inspection, an elevator hinge bracket arm of the Pilatus PC7 was found fractured. The main fracture and multiple secondary cracks emanated from a bolt hole. The inside of the hole had no corrosion protection and made contact with the installed steel bolt. Microscopic and metallographic examination showed that the fracture and the multiple secondary cracks were caused by intergranular corrosion. The combination of a steel bolt with the aluminium bracket results in galvanic effects which will at least contribute to the corrosion. To prevent this corrosive attack, it was recommended to install the steel bolt in the bracket with adequate sealing.

Several non-aerospace service failures were examined, including an aluminium cast four-blade ship propeller of which three blades separated during operation. Although the fracture surfaces were severely corroded and covered with sea acorn and other sea organisms, small patches with striations, indicative of fatigue, were found. Since no initial defects were noted, high loads which occur during start-up of the propeller were held responsible for fatigue crack initiation and propagation.

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-sponsored by the US Federal Aviation Administration (FAA).

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



Fracture of a GLARE lap joint

In the field of crack growth in metal structures, a collaborative programme with the Indonesian aircraft manufacturer IPTN was started.

Under contract to SAAB Military Aircraft AB, static strength, fatigue, and damage tolerance analyses were executed for a part of the SAAB Gripen canard. This analysis was part of the certification of a new version of the Gripen fighter aircraft.

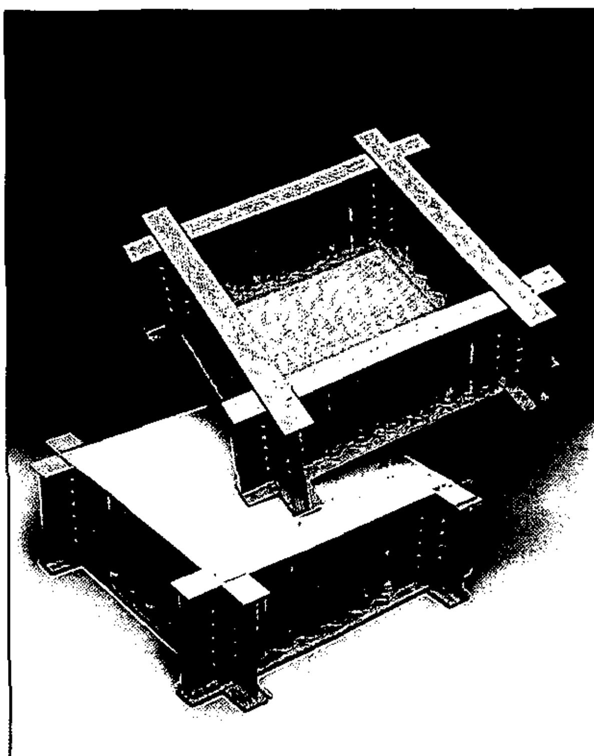
A collaborative programme with the Portuguese Air Force, for the assessment of the severity of their aircraft usage using advanced load monitoring and damage tolerance analysis methods, was continued.

Structures Technology

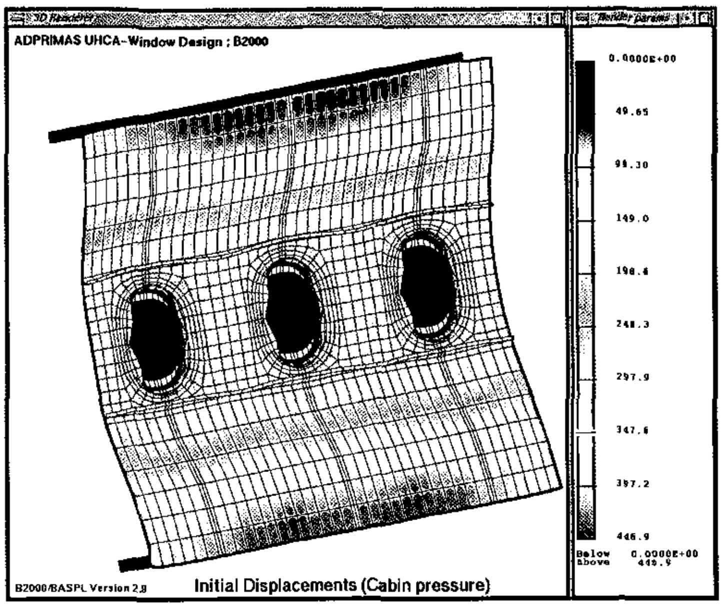
Design and Design Methods for Composite Materials

The design of aircraft structures made of composites such as carbon fibre/epoxy presents a major challenge because of the anisotropic and heterogeneous nature of the material. Moreover, impact damage is often non-detectable, but may reduce the strength considerably. Under contract to the NIVR, design methods for the prediction of strength and of residual strength in case of damage are being developed. Part of the work is carried out in GARTEUR (SM) AG 22, 'Design Methodology for Damage Tolerant Composite Wing Panels', under NLR leadership. A parallel EUCLID (European Co-operation for the Long term In Defence) study was completed, focusing on the transferability of residual strength data obtained with small, structure-relevant specimens to full-scale components, and on the prevention of damage by the use of protective layers. Methods for inspection and repair of damage were also developed and evaluated. The work will be continued in multinational programmes such as EDAVCOS (Efficient Design and Verification of Composite Structures) of BRITE/EURAM and the three-nation military programme DAMOCLES (Damage Management of Composite Structures for Cost Effective Life Extensive Service) with the UK and Sweden.

The expertise gained in the areas of design and design optimization and of fabrication technology for composite structures has been used extensively in several BRITE/EURAM projects. In APRICOS (Advanced Primary Composite



Generic helicopter subfloor structures for the European programme CRASURV (Crash Survivability of Composite Aircraft Structures)



Displacements in window structure in a GLARE fuselage panel modelled with B2000 for European programme ADPRIMAS (Advanced Primary Metallic Aircraft Structures)

Fuselage Structure), a one-piece freight door has been designed, to be followed by a door hinge, and in CRASURV (Crash Survivability of Composite Aircraft Structures) subfloor structures for helicopters and commuter aircraft were designed. Within the framework of a national technology programme, components made of composite materials for helicopter landing gears were designed for SP Aerospace and Vehicle Systems. In this case, the advantages over metals are not only low weight, but also lower production costs and natural resistance to fatigue and corrosion.

Low-cost manufacturing techniques have been developed for non-aerospace customers, with spin-on opportunities for the aerospace industry which is now focusing strongly on affordability. An example is the development of a 57-metre-tall carbon-fibre mast for a yacht, designed with the B2000 optimization code.

Although GLARE, a glass fibre/metal laminate, is strictly spoken not a composite but a hybrid material, design optimization methodology for composites is at present being used to design a window section of a GLARE fuselage in BRITE/EURAM programme ADPRIMAS (Advanced Primary Metallic Aircraft Structures). The brittleness of fibre reinforced composites poses problems when impact energy needs to be absorbed, such as in case of a bird impact on the leading edge of a wing. A composite leading edge structure is being developed based on an innovative stretchable composite skin concept, a design which will be evaluated within the framework of GARTEUR Action Group (SM) AG-22, 'Design Methodology for Damage Tolerant Composite Wing Panels'.

Structural Validation and Certification

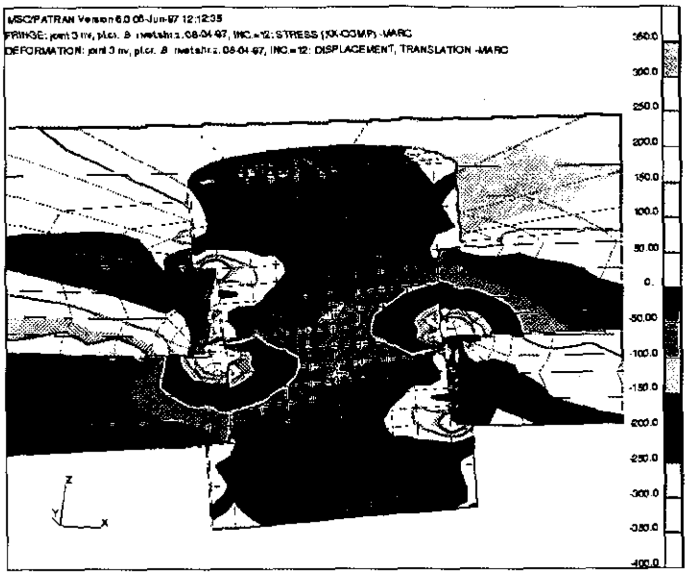
The final evaluation of a structural design as well as of newly developed design methodology requires full scale component testing. Fokker's design of a composite horizontal stabilizer as well as the underlying design methodology is being evaluated in a static and fatigue test programme on a major part of the load carrying

Full scale fuselage panel made of GLARE structure. After the successful completion of a static loading programme up to Design Limit Load, the test article was brought in a saturated condition by exposing it during a nine-month period to a hot/wet environment of 70 degrees C and 85% humidity. For this purpose a climate chamber of 20 m was built around the stabilizer. The stabilizer is loaded by means of twelve actuators. The first 22,000 flights have been completed.

A technology project for Urenco Aerospace for the development of a composite helicopter drive shaft was initiated. This project will also be concluded by subjecting full-scale components to a validation programme under environmental conditions.

In BRITE/EURAM programme SMAAC, preparations were made to test full-scale fuselage panels for Airbus and Alenia aircraft. For ADPRIMAS, similar test are being prepared for fuselage panels made of GLARE by Shorts. The panels will be tested in a specially developed fuselage panel test set-up, in which both bi-axial in-plane loads and transverse loads simulating the cabin pressure can be applied. A helicopter troop seat, designed and built at NLR as an option to retrofit crashworthiness into helicopters, was tested while occupied by an instrumented dummy passenger at the TNO Centre for Crash Safety.

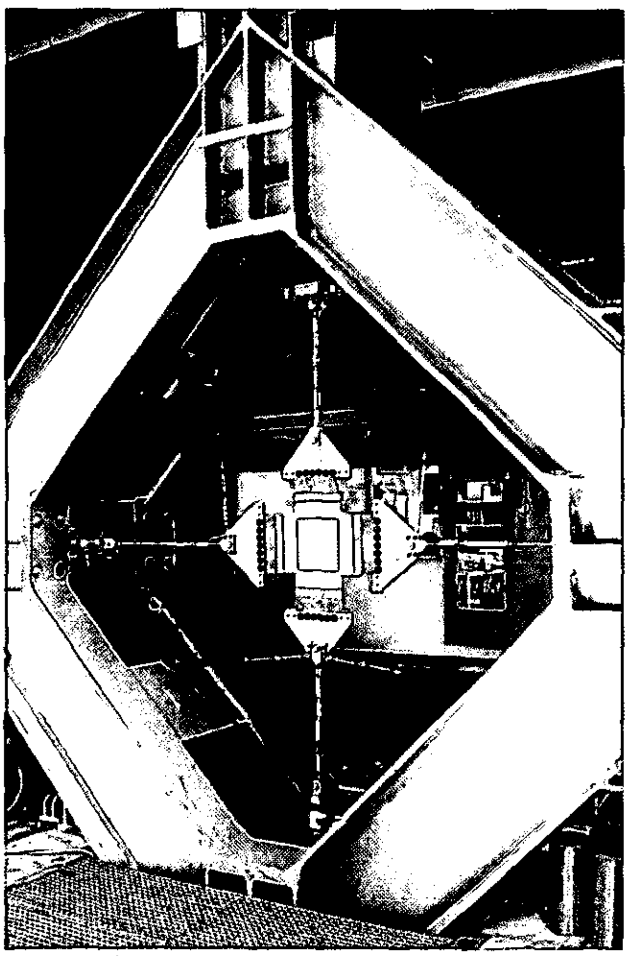
Computational Mechanics
Within the framework of the NIVR Space Technology Programme, numerical models have been developed to optimize active damping of vibrating structures, a topic of particular interest to space applications. Active damping is achieved by adding actuators to the structure, with a weight penalty that must be minimized. The same topic is addressed in co-operation with international partners in the GARTEUR Action Group investigating active control of vibrations. Damping of vibrations, and noise, becomes increasingly important for the Royal Netherlands Air Force and Navy, with the introduction of a range of new helicopter types, including Chinook helicopters with improved vibration characteristics. NLR is monitoring the information on this issue provided by the manufacturer. The present helicopter fleet is planned to be operated beyond its original service life, during which modifications are carried out and new equipment will be installed, actions which have a strong relation to the analysis and control of vibrations. Damping is a subject which is also related to the suppression of noise, for which NLR has developed coupled structure/fluid models.



Calculated stresses at a rivet in a joint

Optimization of aircraft design has been studied in BRITE/EURAM programme MDO (Multi-disciplinary Design Optimization) in a co-operation between three divisions of NLR. The effect of involving aeroelasticity already in the preliminary design phase was studied in co-operation with the major aircraft manufacturers in Europe. In GARTEUR (SM) AG 21, 'Multi-Disciplinary Wing Optimisation', a study is taking place under NLR leadership, focusing on an aircraft design generated in co-operation with the Delft University of Technology with the ADAS (Aircraft Design and Analysis System) design code. Structural optimization exercises have been carried out with B2OPT, an optimization module of the B2000 finite element code developed at NLR. In particular, the APRICOS freight door, the ADPRIMAS window structure, landing gear torque links and a carbon fibre mast of a yacht were all designed with the help of this optimization code.

Investigations in the areas of crash and impact are part of NLR's work aimed at improving the safety of aircraft and operations. The major objective of BRITE/EURAM programmes CRASURV and HICAS (High Velocity Impacts of Composite Aircraft Structures) is to develop computer codes to model crash scenarios and bird impacts on composite aircraft structures. NLR contributes with the design of suitable and innovative structures, and with the development of material models. For the RLD, a computer code is being developed to model the collision of an aircraft with approach light structures near runways. The code will be validated by comparison with test data obtained with wing sections hitting realistic approach light structures at 140 km/h. In co-operation with TNO, material data are being developed to support the upgrading of TNO's computer code MADYMO for the modelling of crashing vehicles made of composite materials.



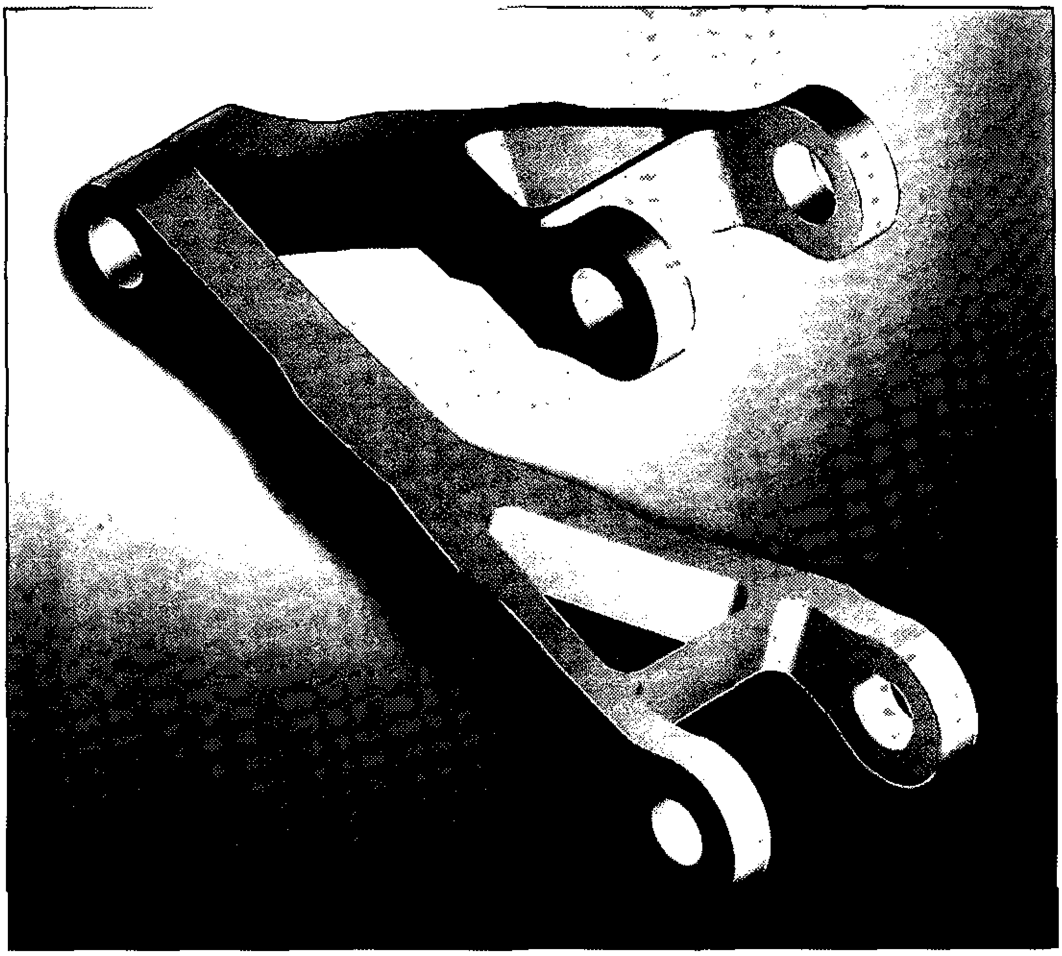
Bi-axial test of a GLARE lap joint

The PATRAN/B2000 interface for thermal elements was extended, and the thermal elements of B2000 were tested and modified. So far, steady state analyses were carried out using B2000, while transient analyses were carried out using MARC.

Development work in the area of computational mechanics was all carried out for the B2000 finite element code, a highly modular code featuring an accessible database that enables new algorithms, finite elements, material models, and optimization strategies to be implemented very easily. In addition to NLR, the Delft University of Technology and Twente University operate and contribute to the code. The aeronautical research institutes DLR of Germany and CIRA of Italy also use the code. NLR plays a co-ordinating role in the continuing development of B2000.

Evaluation and Characterization of Materials and Processes

Traditionally, materials and processes are being evaluated at NLR for their mechanical properties or the effect they may have on these properties. New aluminium alloys for aerospace applications (C188), and for yachts (such as ALUSTAR) were characterized. The need for environmentally friendly coatings has resulted in several evaluation programmes of paint systems for the KLM and the RNLAF, and of new systems to replace cadmium-based coatings on steel components. Research was initiated to study the effect of the stretching of aluminium alloy 2024 on the fatigue properties. If successful, this method may lead to fabrication cost reductions due to the elimination of several heat treatment cycles. Under contract to the NIVR, several projects were started for the Glare Technology Programme. The mechanical properties of riveted joints connecting GLARE fuselage parts is being investigated in an APERT co-operation programme with Indonesia and in ADPRIMAS. The influence of corrosion on Multi Site Damage (MSD) is evaluated for riveted joints connecting aluminium fuselage parts in SMAAC. Fractographic techniques to discover failure modes in composite materials are being developed in GARTEUR Action Group (SM) AG-20, 'Fractographic Aspects of Fatigue in Composite



Torque link design for composite landing gear

Materials'. Several programmes to characterize material systems were carried out to support the landing gear project, the drive shaft project, APRICOS and CRASURV.

Fabrication Technology

Several new techniques for the manufacturing of complex structural components were mastered, developed and applied at NLR in the past several years. Resin Transfer Moulding (RTM), a relatively new and promising technique, allows components of complex shapes with concentrated load introduction points to be produced. In this technique, carbon fibre formats are assembled into dry preforms before being placed in the moulds and injected with resin. This makes possible three-dimensional fibre architectures, for instance by stitching, which are less vulnerable to damage than two-dimensional laminated structures made with prepregs. Improvements of the damage tolerance of stiffened panels by stitching were studied under contract to NIVR, using a newly acquired stitching machine. A candidate structure for space application to be made as a pilot project with RTM was selected in co-operation with Fokker Space. RTM is also being used to fabricate the SP Aerospace and Vehicle Systems landing gear components and the freight door and hinges for the APRICOS programme. For Fokker Special Products a conceptual study was carried out for the development of a missile launch tube with RTM.

Thermoplastic materials are valuable because of their short fabrication time leading to limited production costs, and the potential to recycle the material after use. The development of the double diaphragm technique for the fabrication of a main undercarriage wheel door, carried out earlier for Fokker for PEI material was repeated for the new PPS material, which has improved chemical resistance.

Other affordable manufacturing techniques are being developed, for instance to build a mast for a yacht. Techniques using only ovens and vacuum have potential for use in the aerospace industry. The traditional prepreg/autoclave technique has been used extensively in CRASURV to build helicopter and commuter subfloor structures.

Facilities and Equipment

Test House Schiphol

NLR has broadened its facilities and capabilities in structure and system testing of aerospace/non-aerospace applications by acquiring the complete Fokker Ground Test department.

The main activities of the Test House are:

- Design, development and construction of:
  - test arrangements for structures and system tests
  - prototypes and mock-ups
- Evaluation, development and certification tests on structures and systems.

By this acquisition NLR acquired a wide range of facilities, from test benches and actuators to load control and data acquisition systems, extending the existing capabilities.

Construction Testing and Instrumentation Equipment

Laser displacement measuring systems were introduced for contactless measurements of specimen behaviour during structural tests.

The Autolog data acquisition system with up to 400 channels has been upgraded.

Materials Research Equipment

The scanning electron microscope (Zeiss DSM) was equipped with an automatic rotation system.

The grinding/polishing equipment for the preparation of microscope specimens has been modernized.

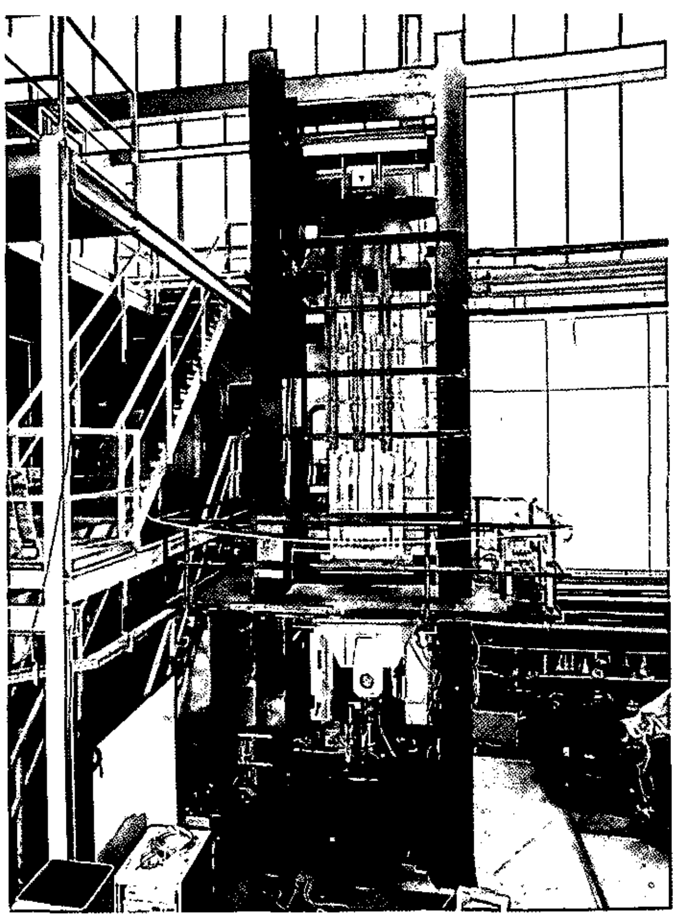
Fabrication of Fibre Reinforced Materials

For the Resin Transfer Moulding equipment a new data acquisition system was acquired.

New mould materials were introduced, and 3D production techniques using a stitching machine were evaluated.

Load Monitoring Equipment

Both the hardware and the software of the data acquisition systems for the flight load monitoring programmes for the Royal Netherlands Air Force and the Royal Netherlands Navy, among others, have been extended and modernized.



Fokker 60 wing panel test at the NLR Test House Schiphol

3.4 Space

Summary

A Loop Heat Pipe experiment has successfully flown on the Space Shuttle. Loop Heat Pipes are being developed to be used as integral thermal control components for future large communication satellites. The Test and Verification Equipment (TVE), developed mainly by NLR, has been applied as Attitude and Orbit Control System (AOCS) Test Equipment for the XMM and Integral spacecraft of ESA's Horizon 2000 programme. The TVE hardware consists of standard workstations and hardware specially developed to interface with the spacecraft buses, to stimulate sensors and to monitor actuators. The TVE Test Software has been built on top of NLR's PROSIM simulation tool, and provided with satellite dynamics models and graphical user interfaces for real-time test control. The AOCS Electrical Model has been successfully tested using the TVE.

Sloshsat FLEVO is a small satellite, being developed to investigate the interaction between spacecraft manoeuvres and liquids in partially filled tanks. The design satisfies the NASA Flight Safety requirements for launch by the Space Shuttle. An International Working Group supports the design of the satellite and experiment scenarios.

Two BioBench Microscopes functional models, of a high-magnification research microscope and of a stereoscopic dissecting microscope, were delivered as part of the Laminar Flow Bench Technology Study of ESA. Both microscopes were designed for use in a GloveBox or BioBench.

A Speech-I/O-equipped Advanced Crew Terminal (SPACT), an Advanced Crew Terminal (ACT) extended with a speech interface, was successfully developed. It provides the crew with a versatile support tool that could even be used in hands-and-eyes-busy situations. The SPACT project team obtained the opportunity to perform a flight test on the Russian Space Station Mir. The use of digital video systems is increasingly being considered for telescience/teleoperation in aerospace applications. User aspects of digital video have been studied in support of the development of a Dutch video system for the Microgravity Science Glovebox.

Improvements made to workstation technology for interactive remote operations using a small satellite and for remote moon operations included new image compression algorithms and user interfacing technology.

To investigate remote operations in aerospace applications, a satellite communication network simulator has been installed and evaluated, with the use of Internet, ISDN and ATM technology for the ground segment.

The Architectural Design delivery and review of the Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA) took place. In conjunction NLR reviewed the concept of computer-based training for robotics and payload operations in space.

RAPIDS, a low-cost ground station based on a Personal Computer, developed for local reception of optical and radar remote sensing data, has been demonstrated.

RAPIDS groundsystem, providing rapid access to Earth observation data at low cost, demonstrated at NLR Noordoostpolder

Quasi-lossless data compressor methods have been selected and implemented for use with remote sensing data.

The National Point Of Contact (NPOC) for the distribution of satellite remote sensing data transferred a part of the data distribution to a new company, Geoserve BV.

NEONET, the Netherlands Earth Observation Network, providing facilities for searching and retrieving Earth observation data and information, was further enhanced.

NLR participated in the Spatial and Spectral Scales of Spaceborne Imaging Spectroradiometer data study.

Research on the theory of radiative transfer models applied in optical remote sensing of vegetation canopies, conducted during a period of fifteen years, was compiled, resulting in body of fundamental knowledge of the relations between properties of objects and remote sensing signals.

Loop Heat Pipes

A Loop Heat Pipe (LHP) is a two-phase thermal control system that uses the latent heat of vaporisation of an internal working fluid to transfer heat from evaporator (heat source) to condenser (heat sink). The circulation of the working fluid is driven by capillary pressure gradients in a wick with very small pores. Advantages of LHPs are: high heat transport capability over long distances with a low mass, insensivity to adverse tilts up to several metres, tolerance of complicated layouts (because the transport lines are small-diameter tubes) and ease of incorporating flexible sections into the transport lines. The LHP is related to the Capillary Pumped Loop (CPL), which shares most of these features with the LHP, but requires extensive preconditioning prior to start up and is susceptible to depriming. LHPs are currently baselined as integral thermal control components for the next generation of large communication satellites. They are an enabling technology for deployable thermal radiators. Their ability to function in almost any orientation facilitates ground testing. The small diameter of the transport lines permits easy routing within the spacecraft.

To demonstrate LHP technology in orbit, the Loop Heat Pipe Flight eXperiment (LHPFX) has been developed by a team consisting of the US members Dynatherm (prime investigator), several US government laboratories (NASA, Ballistic Missile Defense Organization, USAF Phillips Lab & Wright Lab, Naval Research Lab, U.S. industry (Hughes), and NLR as the only non-US participant.

The LHPFX was successfully flight-tested as a Hitchhiker experiment on board the space shuttle Columbia, when 213 operating hours were accumulated. Tests consisted of numerous start-ups, step power changes from 15 to 400 Watts, 18 hours of low-power (20 W) steady state operation, 49 hours of high-power (200 W) steady state operation, and temperature control tests using a built-in thermostat. Loop operating temperatures ranged from -27 to +66°C. The lowest sink temperature was -34 °C. All objectives of the flight were met or exceeded, the LHP functioning flawlessly throughout the test programme.

Test and Verification Equipment

A new-generation of Test and Verification Equipment (TVE) has been developed for use in the integration and testing of Attitude and Orbit Control Subsystems (AOCS) of spacecraft. Built under contract to the European Space Agency (ESA), the TVE is used as the standard equipment for functional testing and validation of spacecraft attitude control systems of ESA spacecraft XMM (X-ray Multi-Mirror mission) and INTEGRAL (International Gamma-Ray Astrophysics Laboratory). The AOCS test equipment projects for these satellites are carried out by NLR under contract to Matra Marconi Space UK.

The XMM and the INTEGRAL are both missions within the framework of ESA's Horizon 2000 scientific programme.

Two sets of test equipment have been produced for the XMM satellite: one for attitude control subsystem testing at MMS-UK and one for

spacecraft system testing at DASA Dornier in Germany.
A third system is being produced for the INTEGRAL satellite. This system will be used for AOCS subsystem level tests at MMS-UK and AOCS spacecraft level tests at Alenia Spazio in Turin, Italy.

The TVE hardware consists of a Front End and standard workstations running the TVE Test Software. The TVE Front End is a modular VME system. It has interfaces to the spacecraft On Board Data Handling bus, the Modular Attitude Control System bus and the Stimuli and Monitoring equipment. The TVE Test Software built on top of NLR's PROSIM simulation tool, and XMM satellite dynamics software are running on two parallel workstations. The TVE Test Software supports a number of vital functions, such as the routing of telemetry and command data, the AOCS simulation data and the stimuli and monitoring data. The TVE Test Software provides the graphical user interface with the MACS bus spy, the telemetry monitoring and the global datapool monitoring in real time.
To complete the XMM AOCS test equipment project, an extensive effort of software development and validation testing has been carried out. Test scripts for the integration tests were developed to test the correct functioning of the Front End modules, the Remote Terminal Unit, the Stimuli and Monitoring electronics and the Power Distribution Unit. The interfaces with the electrical/optical support equipment for simulation of the sun acquisition sensor and the star tracker were tested. Integration tests with the software developed such as the TM/TC (Telemetry/Telecommand) database, have been carried out. Real-time closed-loop tests demonstrated the performance of the total XMM AOCS test equipment. Acceptance tests of the test equipment were prepared and carried out at the customer sites of MMS-Bristol and Dornier-Friedrichshafen.
MMS-UK has successfully applied the TVE in the XMM project Electrical Model test campaign, with good correlation between simulated performance and test results. The TVE user interfaces are powerful and user-friendly, and the mission definition language supports simple and quick development of user test sequences. The open 'Datapool' architecture and the access of test scripts to the Datapool, Simulator data and on-board data facilitate problem diagnosis.

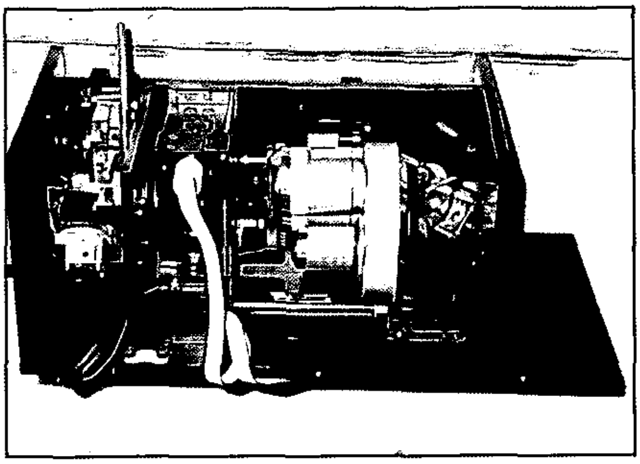
Payloads

Sloshsat FLEVO

Sloshsat FLEVO (Facility for Liquid Experimentation and Verification in Orbit), a small satellite to be launched by the Space Shuttle, is being developed under contract to ESA and NIVR by a team of NLR and Fokker Space of the Netherlands, Verhaert and Newtec of Belgium, and Rafael of Israel. The purpose is the investigation of forces exerted upon a manoeuvring spacecraft by liquids in partially filled tanks. Work on Sloshsat FLEVO was continued. The Flight Safety review with NASA has been successfully concluded in a meeting of NASA, ESA and NLR, where all questions could be answered satisfactorily. The Critical Design Review (CDR) was also held. An internal review revealed that a number of components needed a more detailed design: the experiment tank instrumentation, the interface with the thruster system, and the data handling system. Following the CDR, a meeting of the International Working Group of scientists has been held to discuss the usefulness statement of the Sloshsat FLEVO design and the responsibilities during the generation of experiment scenarios. The members of the Working Group have been assisted with the detailed design of the control algorithms. After consultations between NLR, NIVR and ESA it was agreed that ESA would monitor the project from a greater distance, to simplify the experiment control and to minimise the documentation.

Biobench Microscopes

NLR delivered and preliminary demonstrated the BioBench Microscopes functional models at Fokker Space. The models concern a high magnification Research Microscope and a stereoscopic Dissecting Microscope, both applying S-video imaging. The final flight versions of the microscopes are planned to be used for cell biology research in micro-gravity during space flights, for example in the International Space Station. The models are being



Functional model of BioBench Research Microscope

developed for ESA, as part of the Laminar Flow Bench Technology Study managed by Fokker Space, which awarded the BioBench microscopes contract to NLR. Both microscopes are designed for use in a GloveBox or BioBench. The Research Microscope working functional model, including all optics and video cameras, and some electronics, occupies a volume of only 26 x 14 x 12 cm^3. This includes a top section for electronics of 5 x 14 x 12 cm^3, which may be further reduced. The essential optics and cameras of the Dissecting Microscope fit in a volume of 28 x 16 x 13 cm^3. Six times zooming is possible, with a maximum field of view of 14 mm.

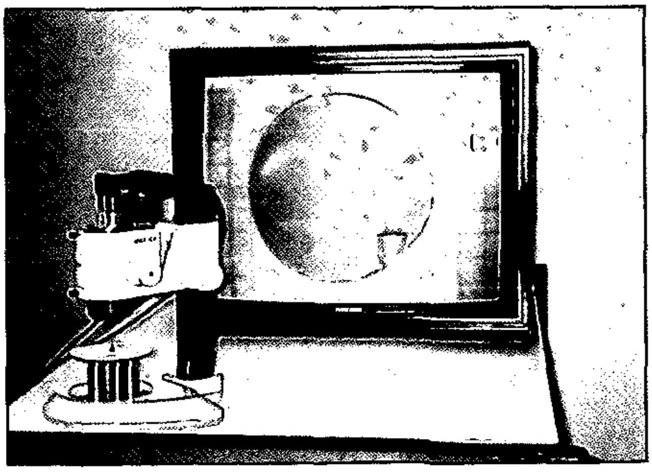
Utilization

Speech Interface

The SPACT (SPeech I/O equipped Advanced Crew Terminal) project is aimed at extending the Advanced Crew Terminal (ACT) with a speech interface. The project was carried out under contact to ESA and NIVR. NLR was main contractor and Origin Nieuwegein BV, TNO Human Factors, Trinity College of Dublin, Ireland, and Institut Dalle Molle d'Intelligence Artificielle (IDIAP) of Switzerland were subcontractors. The ACT software is used in a laptop computer providing the crew with experiment-specific support. This support ranges from on-line multimedia documentation (text, graphics, photographs and video clips), via on-line availability of crew procedures to on-screen payload operation panels. These present a graphical display on the laptop screen, on which experiment information is visualized and which is provided with buttons that can be 'mouse-clicked' to issue commands to the payload. Successful implementation would provide the crew with a versatile support tool that could even be used in hands-and-eyes-busy situations. The SPACT project team obtained the opportunity to perform a test on the Russian Space Station MIR.

Digital Video Systems

The use of digital video is increasingly being considered in telescience/teleoperation for aerospace applications. Digital video systems are being applied in small experimental satellites, new facilities for the International Space Station and exploration missions. User aspects for digital video were considered in support of the development of a Dutch video system for the Microgravity Science Glovebox being developed by Bradford Engineering. NLR contributed to the analyses of various options for the on-board digital video disk recorder and the digital video compression for communication. In addition general system design support has been provided reusing available experience in the building of space qualified systems.



Functional model of BioBench Dissecting Microscope in preliminary test set-up

Workstations
Activities to improve workstation technology for interactive remote operations have been continued using a scenario involving a small satellite and a scenario involving remote Moon operations. The activities included the study of new image compression algorithms and user interfacing technology.

Data Network
As part of an on-going effort to evaluate the use of remote operations for aerospace applications, a satellite communication network simulator has been integrated into a teleoperation set-up. Experience with the use of Internet, ISDN and ATM technology for the ground segment has been extended in various experimental set-ups. Experimental support for an internet-based microgravity database service has been continued.

Space Robotics

Mission Preparation and Training Equipment
The development of the Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA), which started in 1996, aims at first delivery (Assembly Mission) in 1999 and final delivery (Servicing Mission) in 2000. The Architectural Design delivery and review took place. ERA will be used to support assembly operations and servicing support on the Russian segment of the International Space Station. These operations will be prepared, planned and supported with the MPTE, and operators will be trained with it. The EuroSim software, a joint development of NLR, Fokker Space and others, will be used for real-time simulation and visualization.

In conjunction with the development of the MPTE for the ERA, NLR reviewed the concept of computer-based training for robotics and payload operations in space.

Computer vision can support remote robotics operations. As part of the 'Validation of Vision Processing Tools study', a testbed has been completed under ESA contract, in which NLR contributed the ERA-related algorithms.

Remote Sensing

Low-cost Ground Stations
In a co-operation with two British partners, NLR is developing a Personal-Computer-based ground station for local reception of data from the European Remote sensing Satellite (ERS) Synthetic Aperture Radar (SAR). NLR has developed the SAR data processor QSAR of this station named RAPIDS (Real-time Acquisition and Processing – Integrated Data System). RAPIDS, including QSAR were optimised. The European Space Agency (ESA) has agreed to giving demonstrations in a number of countries. In December, a demonstration was given at NLR Noordoostpolder. Preparations were made for the marketing and exploitation of RAPIDS.

Data Compression
As part of the development of a quasi-lossless data compressor, suitable methods have been selected and implemented. The performance evaluation and the consequences for an Application Specific Integrated Circuit were studied. Hyperspectral data can be decorrelated in the spectral and/or spatial domain. The purpose of a planned hyperspectral mission is to acquire accurate measurements in narrow spectral channels over a broad spectrum. Consequently, the decorrelation process must not corrupt the measured spectral channel values. Forward and inverse transformation of spectral data must not introduce errors, which requires a reversible transform.

A new transform method, the wavelet transform, has been investigated for data compression. This transform separates the signal into low-frequency and high-frequency components, each being half the size of the original signal. The low-frequency component can be subject to a subsequent wavelet transform decorrelation step. This process can be repeated up to the desired number of decorrelation steps. For example, the size of the smooth component of a 1024x1024 image after four decorrelation steps is only 0.4% of the original size.
A wavelet transform step consists of applying two filters and sub-sampling. The type of the filter to be applied depends on the nature of the data. Data generated by short-memory systems

may be well served by short filters like Haar, other data are better served by longer filters. Three well-known wavelet transform filters have been implemented as examples of short, average and long filters: the Haar, the 3-5 and the 9-7 filter.

National Point Of Contact

For many years the National Point Of Contact (NPOC) of NLR has been responsible for the distribution of satellite remote sensing data. Because of technological and commercial developments, the data distribution has been partly taken over by the company Geoserve BV, which from September 1997 has become the official distributor of SPOT and Radarsat data. NPOC remains the official distributor for Eurimage, and distributes data from, among other things, Landsat, ERS, J-ERS and several Russian sensors.

Netherlands Earth Observation Network

The prototype information system NEONET (Netherlands Earth Observation Network) was further enhanced. NEONET provides facilities for searching and retrieving Earth observation data and information. In particular, it supports Dutch users by providing access to data from current and future European earth observation missions ERS-1/2 and ENVISAT. Preparations were made for the Design and Implementation Phase of NEONET. During this phase the Core Facility and the Application Facility will be realized by several consortia under contract to the Netherlands Remote Sensing Board (BCRS) and the Space Research Organization Netherlands (SRON). The contract for the NEONET Core Facility was awarded to NLR and subcontractors Origin and ICT Automatisering. The Core Facility will provide transparent access to data and information holdings of Dutch service providers. It will also connect to the European infrastructure, CEO (Centre for Earth Observation) currently being realized by the European Commission. As part of the CEO Enabling Services, NLR will set up a Middleware Node.

Spaceborne Imaging Spectroradiometer

Under contract to ESA and in co-operation with DLO-Staring Centrum, the Royal Netherland Meteorological Institute and Strasbourg University, a study has been performed into the use of future advanced satellite sensors, like a PRISM (Processes Research by an Imaging Space Mission) imaging spectrometer, to determine important parameters of dynamic processes on the Earth's surface and their effects on the climate. NLR participated in this SASSSIS (Spatial and Spectral Scales of Spaceborne Imaging Spectroradiometer) data study by providing project management and carrying out calculations with the OSCAR radiation interaction model.

A member of the NLR staff prepared the PhD thesis 'Theory of radiative transfer models applied in optical remote sensing of vegetation canopies'. This thesis treats the research on radiation interaction models of vegetation and the atmosphere that NLR has conducted as part of its Basic Research programme during fifteen years. The purpose of this research is to gain fundamental knowledge of the relations between properties of objects and remote sensing signals.

Facilities and Equipment

The NLR robotics laboratory has been enhanced with remote robot control. The results have been demonstrated during the IAF exhibition when the set-up at NLR Noordoostpolder was controlled from Turin, Italy via an ATM telecommunication set-up. Further integration of robot vision has been continued.

The integration in the robotics laboratory of a large-screen visualization system to support astronaut training activities was completed, and experiments on the analysis of human factors were started. NLR integrated a torque-phase sensor in the robotics laboratory for experiment payload handling. The development of Failure Detection, Isolation and Recovery technologies was continued.

3.5 Informatics

Summary

The development, production and life-cycle support of information systems concerned such areas as: air traffic management; command, control and information; process and product improvement; and simulation, training and virtual environments.

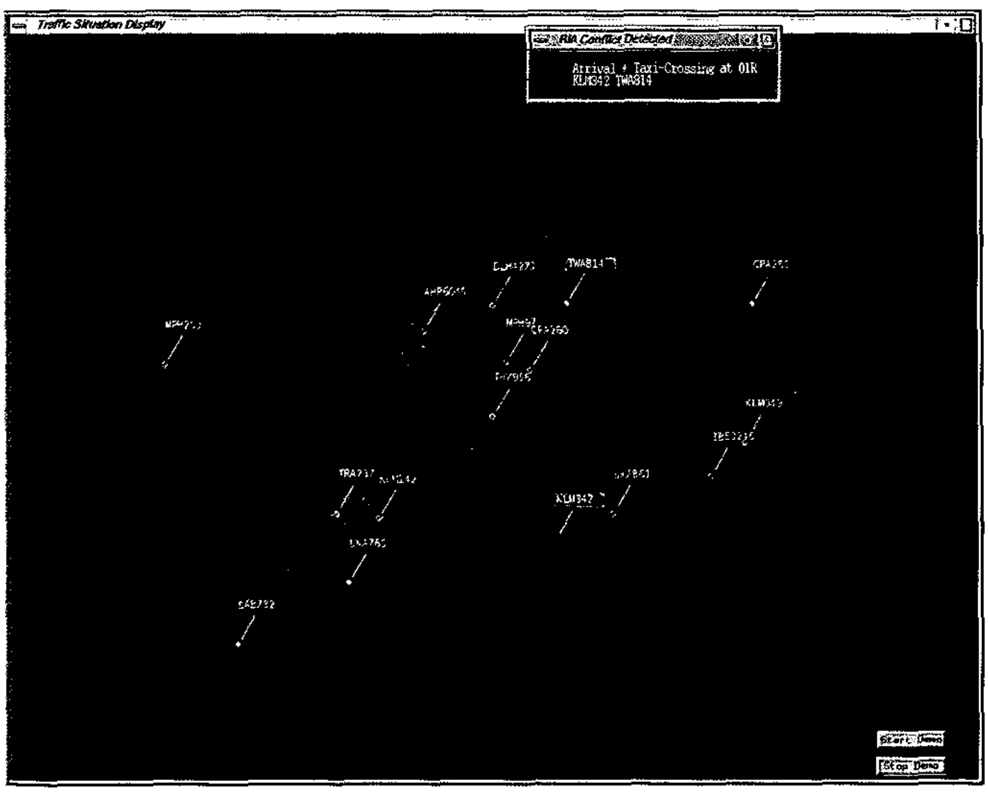
In the field of *decision support systems for airport applications,* NLR supported operators, regulatory authorities and policy makers. Models to help reduce the impact of air transport on the atmosphere and software to assist in the allocation of runways were implemented in operational systems. The development of decision support tools for surface traffic management and of a guidance function for supporting pilots was continued.

In the field of *planning for air traffic flow management,* NLR introduced a system architecture based on the Common Object Request Broker Architecture (CORBA) for the application of optimization algorithms, of real-time rerouting models and of mathematical techniques from operations research.

In the area of *surveillance,* NLR continued the development of radar data processing systems for civil and military use. NLR supported four sites that evaluated NLR radar trackers and provided assistance in tuning and evaluation.

In the area of *consultation, command and control,* NLR has continued to support several national and international customers. Existing information systems were upgraded and modernized, and technology development under the auspices of the Western European Union was continued.

The modernization of the Operational Management Information System, in use since 1983, was started. The Mission Support System/CAMPAL based on a commercial-off-the-shelf hardware platform was upgraded for semi-operational use. Under a EUCLID Programme, NLR has continued work in the area of decision support, planning and tasking.



Sequencing tool that assists controllers in the assignment of plans and sequences for departure traffic, under nominal and bad weather situations

Under a programme of the Western European Armament Group, NLR has continued work on *multi-sensor data fusion*.

In the area *reliability, availability, maintainability, safety and certifiability*, the support to designers and operators of aircraft and space systems and to aviation authorities was continued. NLR continued investigating the applicability of knowledge-based systems for fault detection, isolation and recovery of the RNLAF's F-16 aircraft.

For the Netherlands Department of Civil Aviation (RLD), the development and validation of accident location models was continued.

For the LVB, NLR continued work on a model for determining tactical separation minima. For the RLD, NLR has undertaken a collision risk analysis for aircraft during independent parallel approaches.

Under contract to the RLD, an investigation into the relation between the software development process and certifiability of systems containing software was continued. Under contract to Fokker ELMO, certifiable software was being developed for an airborne embedded application, with parts conforming to the highest level of the RTCA standard.

Process and product improvement activities concerned the Continuous Acquisition and Life Cycle Support (CALS) of systems of the Netherlands armed forces. Electronic means for storage, exchange and presentation of information for life cycle support of the Patriot missile were demonstrated; the application was delivered on CD-ROM.

Under contract to supercomputer manufacturer NEC, NLR has continued the development of the software package SPINEware, a tool for the development of working environments that provide users with one single virtual computer giving transparent access to the resources of a computer network.

NLR's facility based on SPINEware for Computer-Aided Control Engineering, ISMuS, and its facility for software development, ISEnS, were applied in various European projects.

Task leader in information technology in the EU project for multidisciplinary design, analysis and optimization of aerospace vehicles (MDO), NLR realized the framework with SPINEware and assisted the project leader British Aerospace to integrate the tools in it. On the basis of the results of the MDO project NLR was asked to participate in the preparation of the ENHANCE project for aeronautical concurrent engineering, for which the *extended enterprise* is the major concept.

In the area of *simulation, training, visualization and virtual environments*, the development of a Netherlands High Performance Computing and Networking centre for flow simulation was continued.

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

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

The use of NLR's *computing facilities* with the powerful supercomputer, an NEC SX-4 with 16 processors of 2 GFLOPs, showed considerable growth for both computing and information management. NLR's computing centre is one of four HPCN centres in the Netherlands that are members of an association that provides the Netherlands scientific and industrial community with access to top level high performance hardware and software.

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

Decision Support Systems for Airport Applications

NLR continued to increase its ICT and mathematics support to operators, regulatory authorities and policy makers on airport environmental monitoring and decision support. The development of information systems for noise abatement and environmental monitoring was continued.

Monitoring

To support air traffic controllers in allocating runways at Amsterdam Airport Schiphol, and to enable the allocation of runways to be analysed for environmental reporting to aviation authorities, NLR has continued the development of concepts and systems. The main effort was directed at the conversion of two pilot systems available at Air Traffic Control The Netherlands (LVB) into operational systems.
The Runway Allocation Assistant pilot system was installed at Schiphol Approach to validate requirements and to perform an operational evaluation. This system provides advice to the air traffic controllers in the allocation of runways to aircraft, based on noise considerations, runway availability, and traffic and weather conditions. Many of the validated requirements have been implemented in the operational system. The second system is the Runway Use Inspection system which provides information to ATC authorities on the actual allocation of runways in comparison to preferential runway use.

Planning

According to the Eurocontrol study 'ATM strategy for 2000+', the current Air Traffic Management organization and concepts will not be able to cope with the expected air traffic growth unless advanced concepts and operational procedures are implemented. Information and communication technology (ICT) research and development, integrated with expertise in air traffic management and airport issues, has been identified by international bodies as providing potential for increasing capacity while maintaining safety.

Within the MANTEA (MANagement of surface Traffic in European Airports) project, NLR provides a tool to assist controllers in the assignment of plans and sequences for departure traffic. The departure sequencing tool proposes optimal runway usage and Standard Instrument Departure (SID) allocations under nominal and bad weather situations. Constraint satisfaction methods are used to model airport regulations such as wake vortex separation and overlaps in SIDs. A distributed open architecture based on the Common Object Request Broker Architecture (CORBA) was developed to facilitate a novel way of co-operative planning by controllers, starting at the runway and planning backwards through time, ending with the establishment of a start-up time. To assure plan achievement during the execution phase, monitoring and replanning functions are part of the architecture.

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

Increased simultaneous aircraft movements and increasing use of intersecting runways and runway crossings cause a large potential for conflicts and a greater need for tower controller decision support. To demonstrate integrated use of tower controller planning expertise with ICT, NLR has developed a Runway Incursion Alert (RIA) demonstrator that provides assistance to controllers in the tower. The RIA architecture consists of a knowledge-based control component that reasons about information provided by a surveillance function and an advanced human-computer interface to obtain and display information from and to controllers. RIA will help in acquiring knowledge about the use of artificial intelligence for runway conflict detection. Based on the NLR Engineering X-pert system Toolkit (NEXT), RIA will be used for further experimentation and applied research into the tuning of operational procedures, aiming at the optimization of safe ground movement capacity. Especially under low visibility conditions, RIA promises to support ground and tower controllers in maintaining safety at high throughput for sustained periods.

Research on the scheduling of aircraft landings has been continued to support planning for airport harmonization and integration with air traffic management. Scheduling aircraft landings is the assigning of a runway and a landing time to aircraft. NLR has developed an algorithm for this problem, which will enable the air traffic controller to react quickly to changes in the operational environment, so that aircraft landings can be scheduled dynamically and flexibly.

Planning for Air Traffic Flow Management

In the framework of the TOSCA-II (Testing Operational Scenarios for Concepts in ATM) project for Eurocontrol, a study was carried out on Multi-Sector Planning (MSP). NLR developed a mathematical model for MSP. The systematic insight that was gained from modelling together with the results obtained by an expert-based study have led to the identification of a system of the governing dimensions for the description of operational concepts for MSP. The study supports the development of the future European Air Traffic Management System (EATMS).

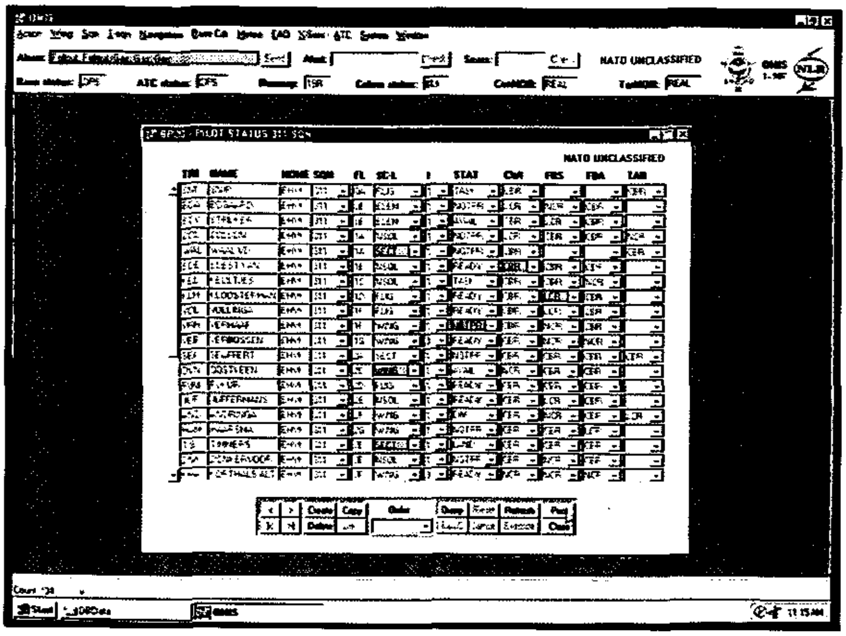
Surveillance

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

ARTAS (ATM surveillance Tracker and Server)

The final version of the tracker software was delivered to main contractor Thomson-CSF Airsys ATM and subsequently installed at each of the evaluation sites Schiphol, Beek and Toulouse.
The formal test and qualification of the tracker, which includes the measurement of all the relevant tracker performance measures, was nearly completed. Tracker evaluation and tuning support was given to the evaluation sites. Reported problems were fixed and changes to the tracker were implemented. The tracker Phase 3 Formal Qualification Test (FQT) was passed, concerning mainly the redundancy features of the tracker.
After several months of evaluations, the LVB decided to use ARTAS to supply track data to the Amsterdam Airport ATC (AAA) system.
The Portuguese administration ANA was the first administration that was not involved in the ARTAS development to have an ARTAS system installed, in Lisbon. Several other systems are

Demonstration of ATM suRveillance Tracker And Server (ARTAS)



User interface of new Operations Management Information System (OMIS)

planned to be installed. The first ARTAS system was officially transferred from Eurocontrol to LVB at Schiphol by the Eurocontrol EATCHIP Programme Leader while LVB Schiphol and Eurocontrol Headquarters were connected through a live video connection.

LVB Support for ARTAS Tuning and Evaluation

The tuning of the ARTAS tracker at Schiphol was adapted, after an analysis of specific problems in the Schiphol Terminal Movement Area (TMA). Tuning and evaluation support will be continued.

ARTAS2 Feasibility Study and Prototype Implementation

Work started on the feasibility of integrating aircraft-derived data, such as on-board position, speed and heading, that is sent via Automatic Dependant Surveillance (ADS) or Mode-S, into the existing ARTAS tracker (ARTAS would then become the acronym for ATM surveillance Tracker and Server). The ARTAS2 feasibility study is executed under contract to Eurocontrol. NLR is responsible for the tracker-related part, whereas Thomson-CSF Airsys ATM is responsible for the overall system study and the sensor-related part. For the tracker part, the goal is to demonstrate, by means of an ARTAS tracker prototype, a tracker performance at least as good as that of the existing ARTAS tracker, while incorporating the aircraft-derived data. Initial simulations showed promising results.

Quality Assessment Facility for Radar Tracking

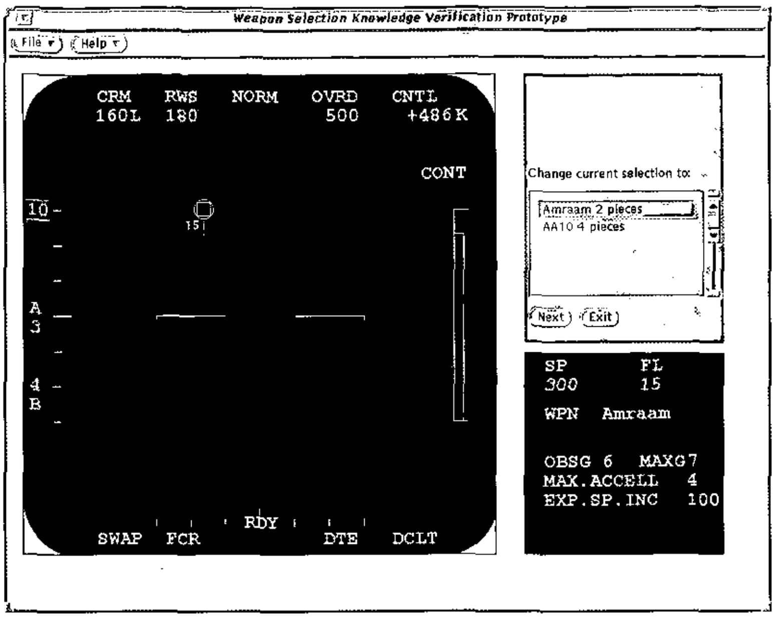
The work on quality assessment for multi-radar tracking, under contract to Eurocontrol, has been continued. A new design for a tracker quality assessment facility has been introduced, in close co-operation with Eurocontrol, based on the experience gained in using the existing tracker quality assessment facility MTRAQ. This new design includes a highly dynamic user interface, extended result presentation facilities and the use of Commercial Off The Shelf (COTS) products to speed up the development process. Based on this design, NLR has generated a prototype for the analysis of track accuracy performance.
A prototype, demonstrated to Eurocontrol and intended users, has proven its feasibility.

Consultation, Command and Control

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

Operations Management Information System

Under contract to the RNLAF, NLR has started the modernization of the Operations Management Information System (OMIS), which has



Pilot Oriented Workload Evaluation and Redistribution (PoWeR) tool

been in use at Volkel Air Force Base since 1983. OMIS supports the RNLAF in the preparation of aircraft for missions to be flown. In particular, OMIS assists in the communication of all necessary information between control centres and units.
The new system, OMIS-2, is a redesign based on OMIS. It is being implemented using fourth generation Commercial Off The Shelf (COTS) software development tools from Oracle. The target hardware platform is a network of PCs running under Microsoft Windows NT. The system has a new Windows NT-like user interface and is based on a client-server computing concept as opposed to the original OMIS, which performs centralized computing. The application of multiple replicating Oracle database servers provides failsafe operation of the system. OMIS-2 is intended to run on the future information processing infrastructure of the RNLAF.

Mission Support Systems
Within the framework of a support programme funded by the Ministry of Defence for the Hellenic Air Force (HAF) on mission support systems, representatives of the HAF received training on the system. A geographical data set, enabling Greek map data to be used on the MSS/Pandora mission preparation system, was prepared. Additionally, two extensions to the programme, related to output capabilities of MSS/P (Combat Mission Folder, and Data Transfer Cartridge capabilities), have been defined and approved by the Ministry. These upgrade the MSS/P up to a level suitable for semi-operational use.

Upon request of the RNLAF, improvements of the MSS/C software related to improved maintenance of scenario information have been designed and implemented. The resulting improved software release was transferred to the Wing Mission Planning section of Volkel Airbase.

Decision Support, Planning and Tasking
NLR has continued work in the EUCLID (RTP 6.1) programme 'Advanced Information Processing for a Command and Control workstation', in the area of decision support, planning and tasking. NLR research has focused on artificial intelligence techniques for time-critical planning and replanning. Results have been implemented in a demonstration system for the allocation of sorties and artillery to prioritized targets in a military peace enforcement scenario. Two applications have been implemented: aircraft and helicopter resource allocation for close air support (RACAS) under severe time constraints, and artillery allocation in a land battle environment. The RACAS facility will be integrated with terrain analysis and other C^3I facilities to form a demonstrator.

A follow up to the EUCLID (RTP 6.5) Crew Assistant project, the Pilot Oriented Workload Evaluation and Redistribution (PoWeR) project is aimed at gathering knowledge and experience concerning Crew Assistant applications.
A Weapons Selection Tool has been developed as a national precursor to an international co-operation with Defence Evaluation and Research Agency (DERA). In close co-operation between specialists in military operations research, human factors and knowledge engineering, applications knowledge was acquired and represented in such a way that it can be re-used. Reasoning with the knowledge is carried out through a combination of a weapons simulation model and rule-based reasoning.

Multi-sensor Data Fusion

Under the research and development programme of the Western European Armaments Group (WEAG), NLR has continued its co-operation with Signaal and other parties in the Netherlands and in France. An advanced multi-sensor data fusion architecture was designed to produce a near-real-time observation of a dynamic military situation. From a helicopter with simulated sensors and from other positions, sensor data are obtained. Data are numerically fused at low level, and subsequently reasoned about, using artificial intelligence, to infer information about military units and intentions. The design and implementation of the near real-time system have been completed. NLR's contributions were mainly in the area of heliborne fusion of moving target indicator data and electronic support measures data, in the area of global ground-based and heliborne data fusion, which combines heliborne data fusion information with Signaal's ground-based fusion, and in the area of situation assessment, in which five knowledge sources reason both separately and co-operatively about content and intentions of military units. Integration of the implemented parts was begun.

Knowledge Discovery in Databases

Under contract to the Royal Netherlands Navy, a data mining algorithm has been designed to discover implicit relations in databases. The algorithm is based on genetic programming. Analysis was performed to counter an important bottleneck in mining algorithms, which normally pose a very large number of queries to the database. Several techniques have been proposed to handle these queries efficiently.

Reliability, Availability, Maintainability, Safety and Certifiability

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

Decision Support for Reliability and Maintainability

A new element in the continuing support to the RNLAF, the applicability of knowledge-based systems for the improvement of fault detection, isolation and recovery of the F-16 aircraft was investigated. The project was focused on line maintenance and the reduction of unnecessary removal of equipment from the aircraft. Current practice in debriefing, fault detection, isolation and recovery was investigated, as were logs of F-16 fire control radar maintenance activities at all Netherlands air bases. Two demonstration systems have been developed to demonstrate the applicability of rule-based expert systems and case-based reasoning to alleviate problems in line maintenance. Other improvements relating to the RNLAF communications and information exchange via personnel and computing infrastructure were identified as well. A cost-benefit analysis was carried out to provide the RNLAF with a ranked list of possible improvements and associated cost.

Safety

For the LVB, NLR continued the development of a general model to determine tactical separation minima. The model is general in that it is applicable to both an ADS (Automatic Dependant Surveillance) environment and a radar-controlled environment. The model was first applied to the latter environment involving an operational scenario of traffic at nearly opposite directions. Using this as a reference case, the model was then applied to the same operational scenario in an environment with surveillance based on ADS. This was used to determine combinations of parameters of an ADS environment that would support the same tactical separation minimum as did the radar-controlled environment.

NLR continued to contribute to the Mathematicians Drafting Group of Eurocontrol for Reduced Vertical Separation Minima (RVSM) above Flight Level 290. A series of working papers were prepared dealing with various aspects of RVSM, such as monitoring requirements, the global system performance specification, modelling of aircraft height-keeping deviations and a graphical tool set for analysing aircraft height-keeping measurements.

A preliminary hazard analysis has been carried out in order to assess the environmental risk of contamination of IJsselmeer water due to an airport in the Dutch Markermeer. The research has been carried out for the benefit of the discussion on the Future Netherlands Airport Infrastructure (TNLI), in co-operation with government departments *Bouwdienst Rijkswaterstaat* and *Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA)*. The hazard analysis focused on two accident scenarios: uncontrolled jettonising of fuel and crashing of aircraft carrying dangerous goods and/or large amounts of fuel. The risk of occurrence of these two accident scenarios has been estimated for several airport locations and route structures, and a number of traffic and transport scenarios. Risk reducing measures have also been identified.

Safety and Certification

NLR continued an investigation, carried out for the RLD, into the relation between the software development process and certifiability of systems containing software. A special research topic was the reuse of software. Reuse is encouraged by both customers and manufacturers to reduce development costs and cycle time for new systems. New or different operational use of software, however, requires rigid certification procedures. The study examines the reuse of software in the framework of the DO-178B guidelines.

Validation

Under the EU's Fourth Framework programme, NLR and its Phare-X partners completed the GENOVA (GENeric Overall Validation of ATM) project. One work package dealt with the development of a validation strategy and plan whereas another investigated a number of organizational and technical issues related to the validation environment. A final report was produced summarizing the main results and providing recommendations for further work.

Network Management of ATN Systems

To gain experience with network management for an Aeronautical Telecommunication Network (ATN), Eurocontrol initiated the Network Management Centre (NMC) for the Trial Infrastructure (ATIF) programme. NLR delivered an initial set of network management tools to Eurocontrol as part of the ATIF/NMC contract, and developed an ATN on-line monitoring tool that remotely observes the execution of ATN systems.

Process and Product Improvement

Continuous Acquisition and Life-cycle Support

Fokker Services and NLR, under contract to the RNLAF, have investigated the feasibility of the implementation of Continuous Acquisition and Life-cycle (CALS) applications for the Integral Weapon System Management of the Patriot guided missile weapon system. The first part of the investigation has provided an overview of possible CALS applications that the RNLAF considers relevant, such as automated information systems, including security aspects and Interactive Electronic Technical Manuals (IETMs). In the second part, a study was carried out into improvements of the maintenance engineering process and the configuration management process for the RNLAF using the World Wide Web for automated distribution and review of Engineering Change Proposals. In addition, the study addressed the RNLAF implementation of the Field Data Collection System (FDCS) to support maintenance engineering and life-cycle support for the international Patriot missile system partners. Finally, to demonstrate the feasibility of implementation, national manual data were merged into an existing electronic technical manual using the Standard Generalized Markup Language and hyperlinks. The application was delivered on CD-ROM.

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

Optimization and Frameworks for Process and Product Improvement

MDO Framework

In the BRITE/EURAM project MultiDisciplinary Design, Analysis, and Optimization of AeroSpace Vehicles (MDO), NLR led the Information Technology task. A prototype MDO Framework has been jointly realized by the Task partners NLR, British Aerospace (BAe), Daimler-Benz Aerospace (DASA), DERA, Saab, and DUT. The Framework is to be delivered to the MDO Consortium (consisting of nine European aircraft manufacturers, three institutes, and two universities) at the end of the project. The prototype is based on the SPINE software developed by NLR for NEC. The Framework includes SPINEware mechanisms for single tool invocation by drag-and-drop, and for tool chain building and invocation; the TOSCA component, developed by BAe, supports the specification and invocation of optimization cycles.

The range of tool invocation mechanisms is required in different stages of an MDO activity. Initially, only single tools will be invoked. Then, when the best tools for the problem solution have been found, and a series of tools have performed adequately for analysing various design points, a chain of tools will be built to form a supertool. Finally, when some optimization cycles have been carried out successfully, and the number of optimization cycles is of the order of ten or more, it may be useful to capture the process in a specification of fully automated optimization cycles, including iterative constructs. For trouble shooting and extended investigations, the single tool invocation and tool chain invocation remain valuable instruments.

NLR has performed a surface shape optimization using an early version of the Prototype Framework 'ismo'. The merit of the design was represented by a weighted combination of drag and mass. In the optimization, the structures and aerodynamics disciplines were contributing. The surface shape variations were represented by up to 17 design variables. In eight optimization cycles, the design was improved by reducing the drag by 72 counts, at the cost of six tonnes of weight increase.

Optimization in Flight Control

The GARTEUR Action Group (FM) AG-10 'Multi-variable optimization techniques for experimental and conceptual design' concluded with the publication of reports on optimization problems, methods, and techniques in flight mechanics. The research focused on the design of an interface between mathematically formulated optimization problems and existing numerical routines to help users choose an optimization method suitable for their problem.

Middleware for Computer Networks

Under contract to NEC, the development of SPINEware, a general tool for the development of working environments for specific application areas, was continued.
SPINEware has been adapted to be capable of being announced as an official NEC product. For this, SPINEware has been extended with a tool-chaining facility and prepared for the PC.

SPINEware has proved to enable enterprises to accumulate, conserve and exploit know-how and to support enterprises in quality management of computer applications. SPINEware also supports the realization of the virtual enterprise and the extended enterprise.

Computer Supported Collaborative Work

Work in the EU project MULTICUBE, in which industries and research organizations from Telecommunication, Aerospace and Automobile sectors collaborate, was continued. Alenia Aerospazio, CASA Espacio and NLR have set up Computer Supported Collaborative Applications to support spacecraft design via broadband connections, using multimedia systems and high performance networking based on the Asynchronous Transfer Mode (ATM). Distributed Interactive Simulation (DIS) and Teletesting sessions were set up to demonstrate the advantages of modern high speed communication facilities. In the DIS sessions, simulation packages such as EUROSIM and DECAP are combined with visualization packages such as VISTA. In the Teletesting sessions, the NLR Robotic Arm Simulator was incorporated. These user sessions were held at the 48th International Astronautical Congress (IAC) in Turin, Italy.

In the SPOCK project, partly funded by the German telecom industry, the potential of tele-co-operative, computer-supported work was also demonstrated using high-speed ATM connections. In this project NLR and DNW, together with other European aeronautical partners such as DASA, DLR and CIRA, exchanged and compared interactively data from Computational Fluid Dynamics (CFD), wind tunnel measurements and flight testing.

Extended Enterprise

NLR participated in the AEREA Working Group on Supercomputing and Networking. The main activity of this Group was the definition of an Extended Enterprise concept for AEREA, the so-called AEREA Common Computing Centre (ACCC), considered important as the industry is organizing itself in the same way. NLR participated in the preparation of the ENHANCE project for aeronautical concurrent engineering, for which the extended enterprise also is a major concept.

Working Environments

Facility for Control Engineering

The facility for control engineering, ISMuS, has been extended with the generic simulation tool EuroSim and with the tool TRACE for the simulation of constrained robotic manipulators.

NLR contributed to the development of the EuroSim facility, an engineering simulator built by a Dutch consortium, led by Fokker Space & Systems. NLR has been responsible for the Software User Manual, for the Demonstration Model, for the System Test Plan, and for the independent System Test.

Facility for Software Engineering Process and Product Improvement

The working environment for software engineering, ISEnS, was extended with an improved user interface, with Internet pages providing help, with additional software engineering information and with links to useful external software engineering sites. The tools for analysis and design were customized to make them more easily useable. A number of source templates were added to improve source code maintainability. In addition, a number of public domain tools for source code production, inspection and documentation were added. Conversion tools were added to facilitate the incorporation of design diagrams into documentation. To support software configuration management in projects, electronic forms for change requests were introduced.

ISEnS was made available on more platform types to enable project-specific, tailored software engineering working environments to be made. For a number of projects, ISEnS was tailored to incorporate project-specific tools.

Facility for Statistical and Risk Analysis

A working environment, ISTaR (Information System for Statistical and Risk analysis), has been developed for activities in the fields of statistical and risk analysis. ISTaR currently contains commercial software tools (Matlab, PV-Wave) and software tools developed by NLR. Examples of the latter are PAROPS and PARSAM for the statistical analysis of data on the independent usage of parallel runways for landing. ISTaR has been used in a number of projects, and is under continuous development. It uses state-of-the-art methods, techniques and tools in statistical and risk analysis. The development will continue through integration of additional commercial software tools (e.g. SPSS, S-Plus, Statistica or SAS) and software developed by NLR (e.g. Accident Location Modelling tools).

Simulation, Training, Visualization and Virtual Environments

NLR maintained its proficiency in the computationally intensive areas of the visualization of existing or future situations. For space applications, test systems, including satellite simulation software, were developed and supported during satellite tests.

Flow Simulation and Solvers

In the NICE project, partially funded by the foundation HPCN (High Performance Computing and Networking), which aims at the development of flow simulation applications on HPCN platforms, is co-ordinated by NLR. Several third parties used the HPCN centre for Flow Simulation (HFS) for CFD design problems supported by the NICE partners.
In the NICE project, the flow solver ENSOLV has been parallelized with do-loop parallelization over the blocks in the domain. By inserting parallelization directives in only five places, over 99% of the code was parallelized by the NEC SX-4 preprocessor. The speed was increased by a factor 7.1 on eight processors, and the flow solver reached a speed of 4.5 Gflop/s. The parallel ENSOLV code and tools for performing load balancing and speed-up estimating are made available through the working environment for Computational Fluid Dynamics, ISNaS.

Also in the NICE project, parallelization of the unstructured flow solver Hexadap on the NEC SX-4 continued. For time-accurate simulations, the adaption part of the simulation method has been parallelized. For sufficiently large problems the speed-up was a factor 4.5 on seven processors.

Experiences in NICE showed that in industry there is a growing demand for optimization in the design of products and processes. Several software tools for numerical simulation, such as CFD solvers, that include possibilities for optimization analysis are commercially available. However, as optimization involving CFD simulation is extremely computationally expensive, the performance of commercial software is often far from sufficient, even on high-performance platforms such as supercomputers.

NLR's expertise on high-performance computing and its in-house developed CFD solvers, specifically tuned for optimal performance on NLR's supercomputer, the NEC SX-4, provided the basis for the development of high-performance optimization tools. The tools have been applied to the design of aerofoils and of air heaters for large rooms.

A generic software tool for design optimization has been developed. The structure of this tool allows several CFD solvers to be easily integrated. The optimization tool uses the CFD solver that is specifically suited for the CFD problem considered, and for execution on NLR's NEC SX-4 supercomputer. The optimization tool has been successfully used in the design of an industrial air heating system and in the geometric design of an aerofoil.

A generic software tool for design optimization has been developed. The modular structure of this tool allows several CFD solvers to be easily integrated, and the tool uses the CFD solver that is specifically suited for the considered CFD problem and optimized for execution on the NEC SX-4 supercomputer. Recently, the optimization tool has been successfully used in a number of design optimization studies.

Vehicle Simulation

Work under the SIMULTAAN R&D programme, initiated by the foundation SIMNED, partly funded by the foundation HPCN (High Performance Computing and Networking), and executed by the SIMNED partners NLR, TNO-FEL, Siemens Nederland, Fokker Space, Hydraudyne Systems & Engineering, and DUT was started. In SIMULTAAN, existing knowledge and products will be combined with tools to be developed, to arrive at a permanent infrastructure in the Netherlands for real-time simulation that involves complex high performance computing and networking.
NLR participates in almost all parts of SIMULTAAN, but the responsibilities and major contributions of ICT and modelling are: the design and implementation of generic and complex behaviour models and the design and implementation of a generic scenario management tool. Instantiations of the behaviour model

will be made for specific classes of vehicles, such as planetary rovers, trucks, cars, tractors and caterpillar tracked vehicles.

Automatic Debiting Systems

The Ministry of Transport is planning to introduce automatic tolling systems on the main roads leading to major cities. The Ministry has formulated strict requirements to the performance of the Automatic Debiting Systems (ADS). A number of international consortia have offered proposals for an ADS. Computer simulations are used to test whether these proposed ADS systems satisfy the requirements. For this purpose a simulation facility has been developed by the University of Amsterdam in co-operation with the software house CMG. NLR has supported the consortia in the development of simulation models for their ADS systems in the evaluation phase. In this work NLR has utilized the experience obtained in sensor modelling and simulator development for aeronautics and spaceflight. NLR has also provided support to the Ministry in the reviews during the evaluation phase. NLR has assisted the University of Amsterdam in the ongoing development of the simulation environment and in strategic studies for the Ministry concerning the feasibility of alternative chipcards in the ADS systems.

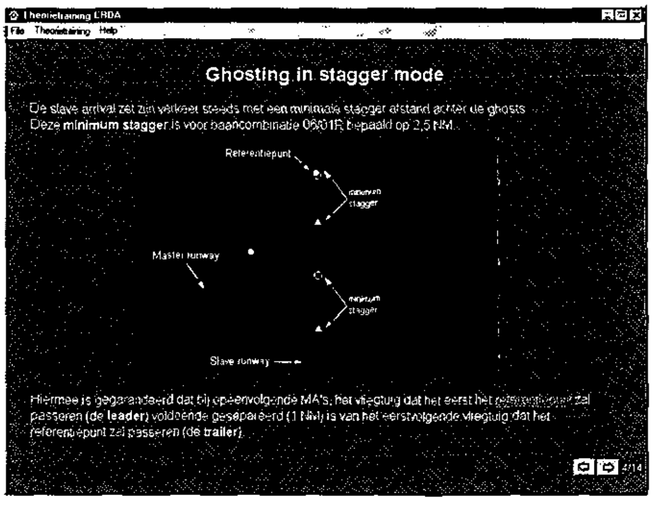
As part of these activities, a statistical model was developed for the analysis of simulation results. The analysis dealt with statistical questions of how to set up a simulation, what confidence to place in the resulting System Quality Factors, how to test the reliability requirements for an ADS, and if and when to stop the simulation.

Visualization, Synthetic and Virtual Environments

In the area of three-dimensional visualization, NLR software for 3D object manipulation, rotation, translation and zooming was adapted to comply with Open GL. This enables users to use a large variety of platforms, including UNIX workstations and PCs under NT. Important applications were in the visualization of grid generation around an aircraft configuration using a multi-block domain modeller. In addition, efficient Postscript output to file or printer has been established.

Training and Simulation

In order to support air traffic controller effectiveness and to decrease controller workload, new ATC tools are being developed in a variety of international projects. Training is required to familiarize air traffic controllers with these new tools. NLR has investigated the feasibility of computer-based training on PCs instead of classroom training. The Converging Runway Display Aid was used as a basis for developing a part of a training course, using a commercial authoring environment for developing both theory training and simulation training material. To support European astronauts in operating the European Robot Arm (ERA) on the Russian segment of the International Space Station, NLR



The Converging Runway Display Aid was used as a basis for developing part of a training course has started the Mission Preparation and Training Equipment project. Software Requirements and Architectural Design activities were carried out. The MPTE system will consist of advanced hardware and software, which will enable simulation, preparation, validation and training of missions with the ERA arm to be performed.

As part of the EUCLID RTP 11.7 programme on training simulation combining real and simulated systems, a feasibility and conceptual design study was carried out into weapon system simulation in flight.

Test Systems for XMM and INTEGRAL Satellites

Test and Verification Equipment (TVE) has been further developed for the X-ray Multi-mirror Mission (XMM) satellite's Attitude and Orbit Control System (AOCS) and put in use for Electrical Model testing at Matra Marconi Space in Bristol (UK). An analogous system has been delivered to Dornier of Friedrichshafen, Germany, for integration in the satellite test system. For the INTEGRAL satellite, the development of a compatible TVE has been started (see also Capita Selecta).

Robotics Simulation and Control

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

The specification of the Exception Handling, or Failure Detection Isolation and Recovery (FDIR) system, was completed. Threshold values were determined for a number of parameters. Initial tests on communication failure detection were successfully performed. Support was provided to the generation of procedures for diagnosis and recovery, and to the realization of a design change which had the objective to make manual control a major control mode instead of a back-up control mode for situations where automatic control fails. Requirements for the ESF were formulated such that no false alarms result when it is integrated with the On-Board Software.

Funded by the Netherlands Agency for Aerospace Programmes (NIVR) and in co-operation with the Delft University of Technology, a study on observer-based, and identification-based FDIR schemes for a robotic joint was performed. The focus was on the detection of degraded performance, in the context of predictive maintenance.

For the ERA evolution programme, simulation of dynamic contact is an essential topic. Funded by NIVR, experimental studies were defined to obtain a validated mathematical model for the simulation of control laws of a robotic manipulator. The studies were carried out in the hardware environment in NLR's Robotics laboratory. These experimental studies support further development of NLR's simulation environment TRaCE (Trajectory and Constraint Evaluation) for the simulation of robotic manipulators that are in or come into contact with their environment. A new graphical user interface was designed to prepare TRaCE for inclusion in ISMuS.

In close co-operation with University of Groningen, investigations have been carried out into efficient representation of dynamical systems subject to inequality constraints. Systems of these form include robotic manipulators and flight control systems, and are common in aerospace. The investigations have led to a PhD thesis on 'Unilaterally constrained dynamical systems', that has been defended successfully.

Computing Facilities

The NLR Computing Facilities are distributed over NLR Amsterdam and NLR Noordoostpolder, allowing NLR to be considered as one Extended Enterprise. Both internal and external users can be provided access to computing facilities and to a lot of other theoretical and experimental facilities. The basic infrastructure, the computer network, includes a high speed data communication network, a large 32-GFLOP/s, UNIX-based supercomputer (an NEC SX-4), several other UNIX-based servers and a non-UNIX mainframe. The communication network, based on TCP/IP and ATM (Asynchronous Transfer Mode) protocols, connects these facilities and workstations, X-terminals, PCs and terminal equipment for experimental facilities such as wind tunnels, flight simulators, ATC simulator and space simulators. The number of NLR stations connected increased from 1310 to 1533. Via international networks NLR is connected to users and partners all over the world. Besides the usual support of E-mail and Internet use, the Computing Facilities were integrated in and gave support to a large number of projects, including a variety of EU projects.

The computer networks of the two sites of NLR are connected by a 34 Mbps ATM link. In both sites, segmented networks provide the users with high communication performance. The ATM backbone of the NLR network is fully operational. A start was made with improving user access to facilities by providing high-speed Ethernet and ATM connections from the workplace to the NLR backbone.

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

The use of the computer facilities showed considerable growth, not only for computing, but also for information storage and retrieval.

The file server provides to all UNIX systems and PC servers in the network a file system for daily use and backup. The total size of the files stored on this server increased from 155 GB to 240 GB. The number of systems that use the fileserver for automatic backup also increased rapidly. To accommodate projected growth, an upgrade of the file server facility has been implemented. This upgrade provides a doubling of the file server capacity and a four-fold growth path for the near future.

The support structure for PCs at NLR includes central PC servers. Rapid growth made it necessary to improve the support structure for the PC users and the robustness of the PC-based part of the computing infrastructure. An investigation of the possibility to use Windows NT for the central PC servers was started.

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

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

3.6 Electronics and Instrumentation

Summary

In the area of *avionics*, NLR studied the potential interference to airborne GPS (Global Positioning System) receivers and the potential disturbances of ILS (Instrument Landing Systems) signals due to multipath reflections from buildings, under contract to the RLD. On behalf of the RLD, NLR participated in Working Groups of the European Organization for Civil Aviation Equipment and the Radio Technical Commission for Aeronautics.

Under the EU's Fourth Framework Programme, NLR participated in the project Generic Avionics Scalable Computer Architecture.

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

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

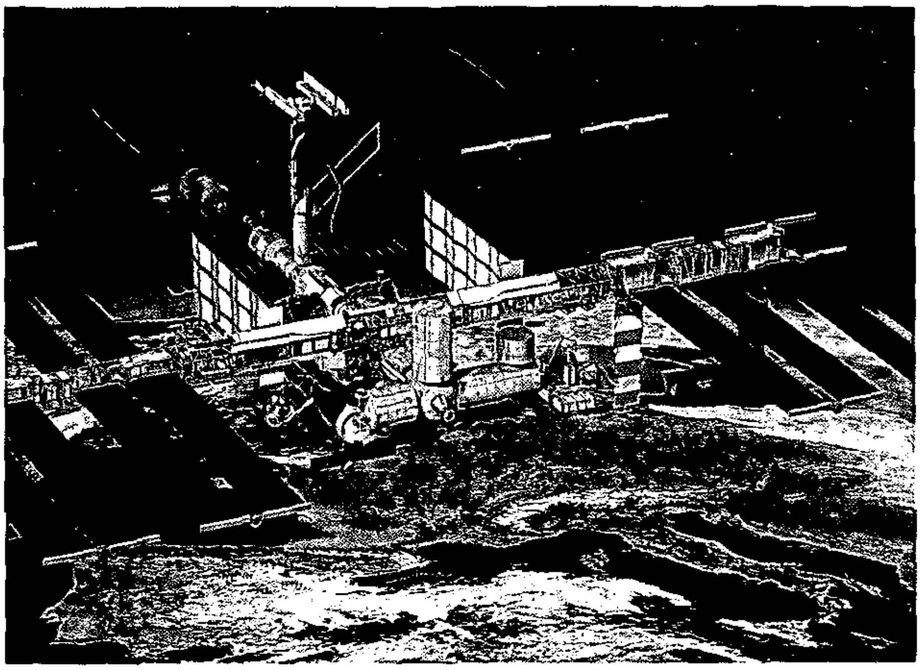
The programme 'Training simulation combining real and simulated systems' of EUCLID was successfully completed.

NLR provided support to the RNLAF in several projects, including studies concerning tactical Data Links and possible system architectures for a future armoured vehicle.

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

NLR carried out several studies concerning Synthetic Aperture Radar (SAR) in co-operation with national and international partners. Work on the Phased Array Universal Synthetic Aperture Radar (PHARUS), a fully polarimetric airborne SAR, was continued. An end-to-end forest monitoring system comprising both airborne and spaceborne SARs was studied. NLR contributed to the study of a spaceborne SAR, mainly dedicated to the global monitoring of land surfaces and ice. NLR participated in the EUCLID programme Space SAR Technology.

Artist's Impression of Weapon System Simulation In-Flight (WaSiF)



Artist's view of the International Space Station (© ESA/Ducros)

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

The upgrade of the UN FAO's Africa Real Time Environmental Monitoring Information System was completed.

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

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

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

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

Under the EU's research programme Advanced Propulsion Integration Aerodynamics and Noise, NLR developed a Multiplexer/demultiplexer system for signal transfer.

In the area of *instrumentation*, NLR supported flight testing for the certification of new braking materials and in thrust reverser tests by Fokker Aviation.

The ESA Parafoil Technology Test Vehicle made the first successful fully autonomous landing, controlled using NLR sensors.

Processing of GPS flight test data showed the smoothed differential code tracking mode worked reliably for the 1–0.5-m accuracy class. In phase tracking mode, an accuracy of 0.15 m (3-D) was obtained, although the phase ambiguity algorithm has to be improved.

A Fourier Transform Infrared spectroscope for the measurement of engine exhaust emissions in flight was tested on the ground for CO, NO and NO_2.

The Non Stationary Measurement research programme to identify mathematical models of aircraft from flight test data was completed.

Under the European Research on Aircraft Ice Certification project, flight tests were carried out with the Metro II research aircraft equipped with special sensors.
Within the Eurocontrol Programme for Harmonized Air Traffic Management Research in Eurocontrol (PHARE), new software was implemented in the Experimental Flight Management System and tested on board the Cessna Citation II research aircraft.

Modern reconnaissance system sensors were integrated in the Medium Altitude Reconnaissance System of the RNLAF.

In the field of *facilities and equipment*, a new Open Area Test Site, annexed with a heliport, for NLR's EMC Laboratory was completed. The EMC laboratory was accredited by the Dutch Council of Accreditation for complying with the STERLAB criteria.

Two dedicated clean rooms (Class 100,000) were built for the production of flight and space equipment.

Large Liquid Crystal Colour Displays (LCDs) driven by new computers, were installed in NLR's research aircraft. The aircraft's satellite data link was upgraded.

The system for measuring, presentation and recording of shipborne parameters for flight tests with navy helicopters was completely renewed.

The Data Acquisition Equipment Calibration Laboratory successfully passed re-evaluation by the Dutch Council for Accreditation.

Avionics

Support to the Netherlands Department of Civil Aviation

Under contract to the Netherlands Department of Civil Aviation (RLD), NLR studied the potential interference to airborne GPS (Global Positioning System) receivers. The need to maintain GPS integrity is of considerable interest to the aviation community. One of its aspects is the requirement to operate when interference renders reception difficult. Interference contributes to the noise floor of the receiver and degrades its performance. An analysis was executed which assesses the vulnerability of airborne GPS receivers to interference from sources in the Netherlands.

Also under contract to the RLD, NLR was involved in development and evaluation of computational tools to predict disturbances of ILS (Instrument Landing System) signals due to multipath reflections from buildings. One of the subjects that were addressed was the calculation of shadowed parts of buildings, to facilitate the processing of geometrical models, which was demonstrated for the buildings around runway 06 of Amsterdam Airport Schiphol.

On behalf of the RLD, NLR participated in working groups of the European Organization for Civil Aviation Equipment (EUROCAE) and the Radio Technical Commission for Aeronautics (RTCA). NLR attended the EUROCAE WG 48 and RTCA Steering Committee 182 meetings and participated in the definition of Minimal Operational Performance Standards for an Avionics Computer Resource (ACR). The ACR will integrate several aircraft applications onto a single platform, providing the possibility of incremental certification. By segregating the applications (software), the certification effort will be limited to new or modified applications. The guidelines for a standard Application Programming Interface provide portability and re-use of application software. NLR also participated in Working Group 33 of EUROCAE, which develops requirements and test procedures to protect aircraft from electromagnetic interference due to High Intensity Radiated Fields. NLR was especially involved in calculating the electromagnetic environment in the Netherlands.

Additionally, under contract to the RLD, NLR worked on an overview of methods for fault detection. First, a classification of faults that can occur in an avionics system was defined. Based on the classification, several well-known methods for fault detection were evaluated.

Advanced Avionics Systems

Under the Fourth Framework programme of the European Union, NLR participates in the project Generic Avionics Scalable Computing Architecture (GASCA), executed with several European partners led by Dassault Electronique of France. The objective of this project is to define, build, demonstrate and validate an advanced avionics architecture to integrate several aircraft applications onto one computer platform. First, the requirements from airlines, aircraft manufacturers, avionics manufacturers and certification authorities were gathered. Based on these requirements the GASCA architecture guidelines were defined, following the Minimal Operational Performance Standards for an ACR. NLR was specifically involved in the definition of the guidelines for fault tolerance. Based on application requirements and resource availability, the applications are optimally distributed throughout the system. NLR developed a method and tool to help the integrator finding this optimal distribution. Furthermore, NLR was involved in the definition of the communication architecture of GASCA.

Flight Control and Display Module

Under contract to Fokker Elmo, NLR is involved in the development of the Flight Control & Display Module (FCDM), a safety-critical part of an avionics system that is being developed for next generation civil helicopters and fixed-wing aircraft. NLR provides assistance with the hardware development and has complete responsibility for the development of the flight-critical software. The hardware development support, consisting of schematics entry of the electronic circuit diagrams and the design of the printed circuit boards was completed. The software development includes software engineering, verification and validation, and certification. Part of the software has to conform to the highest software level of the applicable RTCA standard for airborne software, DO-178B. Several preliminary software deliveries were realized.

NH90 Mission System Development

NLR participates in the design and development of the Nato Frigate Helicopter (NFH) Mission System of the NH90 helicopter. A contribution to the Mission System Specification has been prepared. NLR will develop a software module that performs track-to-track associations of tracks from surface and subsurface vessels using information from sensors such as radar, Forward Looking Infra-Red (FLIR), Electronic Support Measures and sonar. The main goal of this module is to reduce the operator's work load. These associations have previously been done manually. Using this module, the operator only has to confirm or reject the suggestions made by the software. Functional evaluations and simulations were carried out in order to specify the behaviour of the module in more detail and to validate the design goals.

Training Simulation

The EUCLID programme 'Training simulation combining real and simulated systems' (CEPA 11, RTP 11.7) has been successfully completed. In this project, led by Daimler Benz Aerospace of Germany, an on-board training system for NATO fighter pilots, in particular for Air-to-Air missions, has been defined and specified (Weapon System Simulation In-Flight (WaSiF)). Such a system is expected to be embedded in the avionics suite of future aircraft, generating virtual targets on the pilots' displays and simulating a (hostile) tactical environment. In the project the functional and operational requirements for the system have been identified, described and reviewed. These requirements were the basis for the preliminary design. The way ahead for future developments was presented.

Support to the Royal Netherlands Air Force

NLR provided support to the Royal Netherlands Air Force (RNLAF) in several projects. In the field of Tactical Data Links, interoperability between platforms was investigated. For the future Multi Purpose Panzer Vehicle, possible electronic system architectures were investigated.

Under contract to the Netherlands Ministry of Defence, NLR started a research project into Smart Skin Array Technology. Smart Skin arrays can be classified as active phased array antennas of the conformal type using transmit/receive modules which are constructed in the form of thin flat layers. Smart Skins are especially suited for application with aircraft or ground-based platforms, where they are flush-mounted to the exterior of the vehicle. The Smart Skin technology is ultimately aiming at the improvement of the aircraft performance and the avionics system capability by integrating sensors, signal processors, signal and power distribution networks and associated control functions with a composite load-bearing skin structure to form an active interface with the flight environment. NLR's participation concerns the electromagnetic interaction of conformal antennas with the aircraft structure.

Synthetic Aperture Radar Technology

NLR continued its work on the Phased Array Universal Synthetic Aperture Radar (PHARUS), a fully polarimetric airborne SAR. The project is a co-operation of Physics and Electronics Laboratory (FEL-TNO), Delft University of Technology and NLR. Several flights were conducted with PHARUS on the Citation II research aircraft to collect data for Remote Sensing users. For the Netherlands Ministry of Defence, flight trials were conducted in the Freiburg, Germany, area. In addition, in co-operation with Fokker Space, FEL-TNO and ARGOSS (Advisory and Research Group on Geo Observation Systems and Services), a market study was carried out concerning the commercial exploitation of PHARUS.

In co-operation with Fokker Space (lead), FEL-TNO, the Agricultural University of Wageningen and the International Institute for Aerospace Survey and Earth Sciences, an end-to-end forest monitoring system was studied. The system, named RASIMHUTAN, comprised both airborne and spaceborne Synthetic Aperture Radar (SAR) systems to monitor protected forest areas and tropical forest plantations.

Under contract to Alenia, NLR contributed to the pre-phase A study of CLIMACS, a spaceborne SAR, mainly dedicated to the global monitoring of land surfaces and ice. CLIMACS is a multi-frequency SAR with a wide swath which can provide long term uninterrupted global monitoring of the Earth with a high temporal resolution. NLR was responsible for the definition of P-band and L-band instrument concepts and the associated initial performance assessment. In addition, NLR performed the preliminary design of the digital electronics and the calibration unit. Under contract to the NIVR an analysis was carried out of the feasibility of a frequency allocation for a spaceborne SAR operating in the P band. The results were discussed in the Space Frequency Co-ordination Group, the European Conference for Postal and Telecommunication Administrations and the International Telecommunication Union. In November 1997 the request for a frequency allocation was addressed on the World Radiocommunication Conference.

The EUCLID programme 'Space SAR Technology' (CEPA 9, RTP 9.3) was continued. NLR participates in the areas of Electronic Counter Counter Measures (ECCM), digital control and thermal analysis and control. The goal of the programme is to define and develop new technologies to be used in military spaceborne SARs. For the ECCM work package, jamming due to non-intelligent sources (so-called brute force jamming) was studied. For the digital control work package, a control concept for three antenna configurations was defined. This concept includes a smart central controller which calculates and distributes phase and amplitude settings for a large number, over 3000, of transmit and receive modules. A demonstrator system to prove the control concept has been defined. In the framework of the thermal analysis three concepts of a spaceborne SAR (S-band, X-band and combined S/X-band) were studied.

Mass Storage Device

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

A qualification model was built, which was used to validate the performance of the MSD under operational conditions. The required qualification tests were performed successfully. Three complete flight models for use in the Russian Service module were built, tested, and delivered. In the Columbus programme, the production, test, and delivery of two Engineering Models was started.

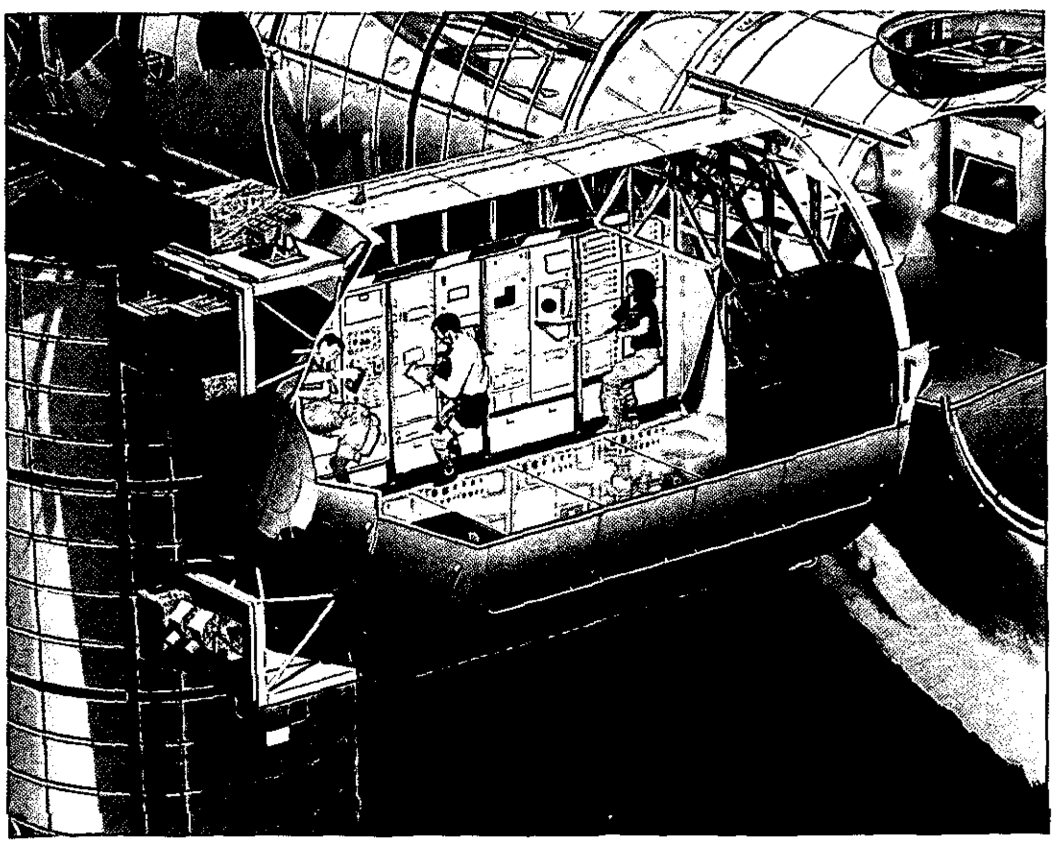
In addition, under an NIVR contract, a research programme was started to investigate the feasibility of the use of solid-state memories. This included radiation tests carried out at the facilities of Brookhaven National Laboratories of the USA. Potentially, a solid-state-based MSD is suitable to a wider range of applications.

Ground Stations for Space Applications
The ARTEMIS upgrade, denoted ARTEMIS III, has been completed under contract to the Food and Agriculture Organization of the United Nations. ARTEMIS is the Africa Real Time Environmental Monitoring Information System. Image visualization is now performed by using a SGI Indy Workstation, which exchanges data with the ARTEMIS computer, either automatically or interactively. The number of available features has been increased considerably.

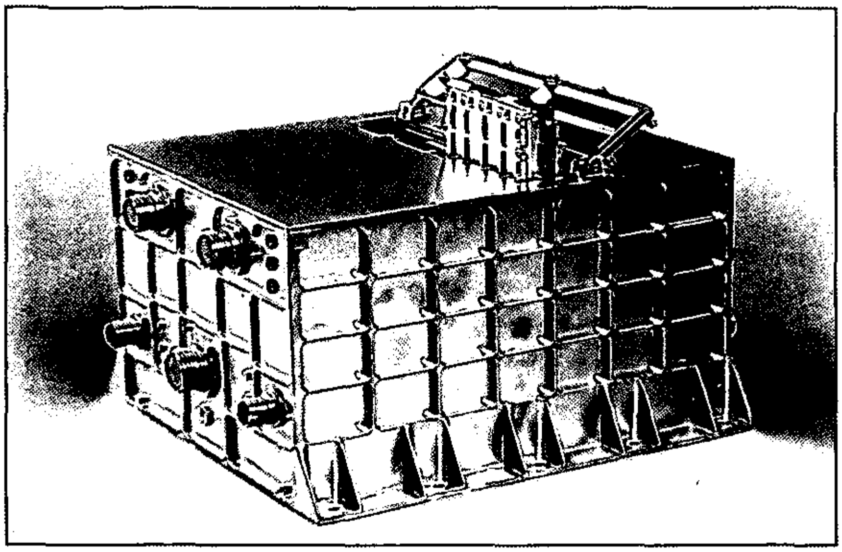
Electronics

Satellite Electronics and Ground Support Equipment

NLR has been involved in the ESA project Cosmic Dust Aggregation (CODAG) as a subcontractor of Fokker Space B.V. CODAG is an experiment to simulate the early phase of dust aggregation in protoplanetary disks. In a low pressure gas-dust cloud, micron-sized particles show random thermal motion. In the microgravity environment of the CODAG sounding rocket module, which will be launched on the MASER-8, the particles can be observed for approximately six minutes. The particles are observed with two subsystems: a Light Scattering Unit and a set of two high-speed microscopes. NLR has developed a major part of the electronics and the ground support equipment for CODAG. The electronics consist of a Service



Artist's view of ESA's Columbus orbital facility (© ESA/Ducros)



Control Post Computer (developed by Matra Marconi Space) with one MSD cartridge partly shifted out

Electronics Box, which controls the system during flight and has been equipped with telemetry and telecommand, and three subsystems to interface the various sensors and actuators. The ground support equipment mainly consists of several PCs which can monitor and command the module via a direct cable connection or via telemetry. The CODAG facility elements are derived from, and partly re-use the existing Cells In Space facilities.

Satellite Test Equipment

Under contract to ESA, the Stimuli and Monitoring electronics for the Attitude and Orbit Control System (AOCS) test equipment used for the Integral satellite, was developed, built, tested and delivered.

Miniaturization of Satellite Test Equipment

Supported by NIVR, NLR in co-operation with the Dutch industry HYMEC, has miniaturized a current/voltage source. A previous design, used for the X-ray Multi-Mirror mission (XMM) was further developed. This resulted in an miniaturized electronic circuit with improved temperature stability and accuracy.

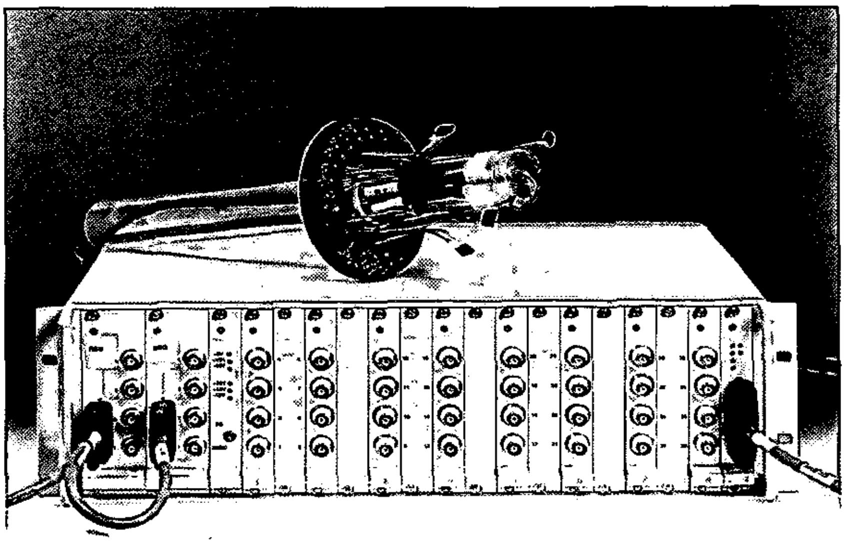
Temperature Data Acquisition System

Under contract to ESTEC, NLR continued the design and development of a Temperature Data Acquisition System (TEMPDAS) for ESTEC. The system will be mounted on a motion system inside the Large Space Simulator (LSS) which provides close simulation of in-orbit conditions. Two partners of ESTEC, IABG of Germany and InteSpace of France are also involved in the project.

In the current configuration the analog signals coming from the thermocouples are multiplexed and via Slip Ring Units transmitted to the control room where they are measured. 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-calibrating capability. NLR designs the hardware that measures the thermocouple signals inside the LSS (vacuum, with temperature ranging from –40°C to +50°C) and transmits the data digitally multiplexed via a MIL-1553B standard output over the Slip Ring Units to a PC. NLR also develops software, the service layer, for the PC to control the hardware. To eliminate Single Point Failures that lead to the loss of the complete system, redundancy plays a big role in the design.

NH90 Remote Frequency Indicator

NLR continued its support to Dutch industries in the design and development of avionics equipment for the NH90 helicopter. Under contract to BFGoodrich Aerospace of Zevenaar, the activities in the field of programmatic and technical co-ordination of all development activities, and executing analyses required for the delivery of the Remote Frequency Indicator, were continued.



Signal conditioning unit for wind tunnel instrumentation

NH90 Fuel Panels

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

Advanced Data Link Processor Unit

Under contract to Eurocontrol, NLR started the development of ADLP units (Advanced Data Link Processor), which provides intercommunication functions necessary to interface data link communication systems with a Mode S transponder. The ADLP acts as a data collector for ARINC429 avionics busses such as the Flight Management computer. After collecting and preprocessing, the data is transmitted to the ground via the mode S transponder. This function was also available in the predecessor of the ADLP called DLPU (Data Link Processor Unit). The ADLP has also the capability to interface with equipment using the IOS8208 (X25) protocol. This will allow aircraft to use the ADLP for setting up a save data link connection with a Mode S ground station. The ADLP will also carry a special application called Compact Positioning Reporting. This application will extract position information from the avionics buses and use a data compression algorithm to compress the latitude and longitude using just 19 bits for the resulting latitude and longitude. Another application of the ADLP is the dataflash protocol that sends information from air to ground on an event-triggered basis. This is an efficient means of downlinking information that changes occasionally. For example, a ground station can send a request for information to an aircraft when that aircraft is making a turn of more than 30 degrees.

Signal Conditioning, Wind Tunnel Instrumentation

NLR participated in APIAN (Advanced Propulsion Integration Aerodynamics and Noise), a Fourth Framework research programme of the EU. The APIAN experiments will be performed with a rotating model propeller equipped with a slip-ring assembly. This slip-ring assembly transfers the transducer signals from the rotating part to the data acquisition system. For the APIAN experiments, the capacity of the existing slip-ring assembly is too small. NLR was responsible for the design and development of a Multiplexer/demultiplexer system named Signal Transfer System (STS). The STS will extend the capacity of the existing slip-ring assembly by more than 40 per cent. Special measures are taken in the mechanical design of the rotating multiplexer electronics. Due to the high rotational speed (up to 10,000 rpm) of the propeller, the multiplexer is subjected to very high g-forces up to 6000 g. In 1997 the design was finalized and the production of two signal transfer systems was started.

Under contract to LABEN of Italy, NLR continued to develop and install the Safety System Sub-Assembly for the Automation System of the Italian Aerodynamic Plasma Wind Tunnel.

Instrumentation

Flight Testing and Flight Test Instrumentation

Flight Testing at Fokker Aviation

NLR played an important role in the relatively limited flight test activities at Fokker Aviation. Tests were part of accident and incident investigations, a consequence of legal actions or required for certification of system updates.
In the aftermath of the DC-9 Valuejet accident, a video system for certification of a smoke detection system in the cargo compartment of a Fokker 100 was delivered to Fokker for installation at a Fokker customer. To support thrust reverser tests, a Production Flight Test (PFT) system was installed in a Fokker 100 series aircraft. The Fokker 100 prototype 'Q1' was used for the certification tests of a new carbon braking material. This aircraft was also used for a number of engine verification tests. In both programmes a PFT system of NLR took care of the data gathering.

All these tests confirmed the conviction that, in spite of the end of the development of new aircraft in the Netherlands, a need for flight test instrumentation remains. The feasibility study into the required future capabilities of flight test instrumentation was continued. It focuses on smaller, easy to install flight test instrumentation with limited on board presentation and *in situ* data processing facilities.

Flight Testing ESA's Parafoil Technology Demonstrator

Instrumentation designed under a subcontract to Fokker Space for controlling the Parafoil Technology Test Vehicle (PTTV) was used in successful tests, demonstrating the feasibility of a controllable parafoil to safely land a space re-entry module. Four releases of the PTTV from a Transall aircraft of the German Army took place. In the last release a successful, completely autonomous landing was performed using the data from the NLR sensor systems (including a laser height measurement device, a fibre optic angular rate sensor, airspeed sensors and differential GPS) and controlled by the GNC-software of Dasa/Dassault implemented in NLR's on-board computer.

Measurement and Analysis Techniques for In-Flight Research

Position Reference System

The processing of the GPS data acquired during earlier test flights with Fokker aircraft was completed. The smoothed differential code tracking mode of operation worked fine and reliably for the 1–0.5-metre accuracy class. The use of GPS phase tracking data allowed the flight path to be reconstructed within 0.15 m (3-D), but the success rate of the current implementation of the technique to solve the phase ambiguities remains too low even after skilled operator intervenience. In co-operation with the Delft University of Technology, other, more promising algorithms than the one used at present have been tested. Initial results show that higher ruggedness and equal accuracy can be expected.

Engine Exhaust Measurements

The research programme for the validation in flight of engine exhaust emissions models was continued. In this first stage the work was concentrated on the selection of optical measurement methods for in-flight measurements of NO_x and CO concentrations. This work is performed with specialist support of the Netherlands Organization for Applied Scientific Research (TNO). In a ground-based set-up behind the engine of the NLR/TUD Cessna Citation II research aircraft a Fourier Transform Infrared spectroscope was tested in light emission and in light absorption mode. The light emission mode resulted in good measurements for CO and NO, but performed less well for NO_2. The results of two earlier ground tests were also analysed.

Mathematical Modelling of Aircraft

For many years the research programme to support the operational use of the Non Stationary Measurement method for the determination of mathematical models of aircraft from flight test data has been continued. A prerequisite for the successful use of this technique is high accuracy of the flight test instrumentation sensors and detailed knowledge of their behaviour including time delays. The method has been used for the evaluation of Fokker aircraft in applications were traditional methods were less successful and for the development of simulator models. Flight tests with NLR's Metro II research aircraft allowed the fine tuning of the method to be continued. This research programme was completed with the final reports on the successful implementation in the parameter identification process of a number of additional influences, for example dynamic fuel displacements. The reports describe the improved results for the identification of the aerodynamic model for both the clean symmetrical and the asymmetrical case in cruise conditions.

Support to the European Union

Aircraft Ice Certification

As part of the Fourth Framework programme of the European Commission, the European Research on Aircraft Ice Certification (EURICE) project is carried out by a consortium led by CIRA of Italy. The project is aimed at aspects of aircraft flying under icing conditions, ranging from meteorological data to incident/accident data bases and certification regulations. With emphasis on helicopters, several recommendations and practices for icing certification were analysed. NLR conducted a number of flight tests with the Metro II research aircraft equipped with a pod carrying special sensors to determine the properties of the atmosphere under icing conditions.

Airborne Air Traffic Management System

NLR's contribution to the Airborne Air Traffic Management System (AATMS) Fourth Framework project was in the preparation of the datalink facilities and the groundstation to be used in the coming evaluation and demonstration trials phase of the project. To this purpose use will be made of the PHARE Aeronautical Telecommunications Network (PATN). AATMS supported additional PATN developments and the implementation on the NLR ATC Research Simulator (NARSIM).

Multimodal Approach for GNSS-1

The Global Navigation Satellite System (GNSS) project Multimodal Approach for GNSS-1 in European Transport (MAGNET-B) is being carried out by a consortium led by Dassault Electronique. NLR started the preparation and prepared a validation plan for the approach flight trials with an NLR aircraft in the second part of the project. A laser tracker system will be used as the independent flight path reference.

Support to Eurocontrol

Automatic Dependent Surveillance

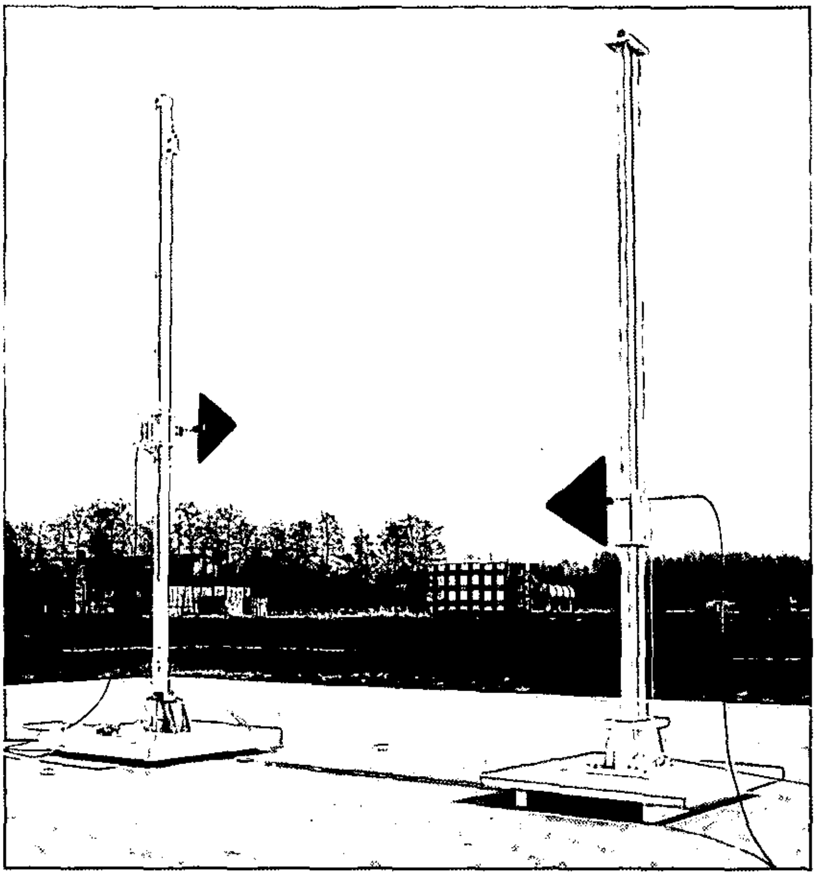
NLR participated in the European Automatic Dependent Surveillance (ADS) project, ADS-Europe 97, of Eurocontrol. In this project Eurocontrol, together with NATS (National Air Traffic Services Ltd) of the UK and DNA (Direction Navigation Aérienne) of France, provided the means to continue the use of the pre-operational ADS infrastructure that was built during the preceding ADS Europe project of the EU for the gathering of data from a number of commercial airliners equipped with Arinc-compliant ADS equipment. NLR was involved in the activities of the Project Management Team and the Project Management Panel.

Experimental Flight Management System

As a partner in the Eurocontrol Programme for Harmonized Air Traffic Management Research in Eurocontrol (PHARE), NLR takes part in the development, evaluation and demonstration of an Experimental Flight Management System (EFMS). A new software version was implemented and exposed to initial testing during a ground run and two flights on board NLR's Cessna Citation. After adapting the flight guidance module and the performance tables the system was integrated with new display systems.

Military Flight Test Support

For the qualification tests of helicopters on board navy vessels, the system for measuring, presentation and recording of shipborne parameters was completely renewed. Dedicated software, which was relatively complex to adapt, was replaced by a tailored application of COTS software, resulting in a flexible and easy reconfigurable system.



NLR's Open Area Test Site for EMC testing at NLR Noordoostpolder

New anemometer subsystems were developed for initial use on the new Amphibious Transport Ship 'Rotterdam'.

A contract for the development and installation of a flight test measurement system in an F-16 MLU was awarded by the RNLAF. The system will be able to record all MilStd 1553 Mux buses in a format compatible with existing RNLAF/ NLR replay systems and with the configuration used at Edwards AFB for F-16 MLU development testing.

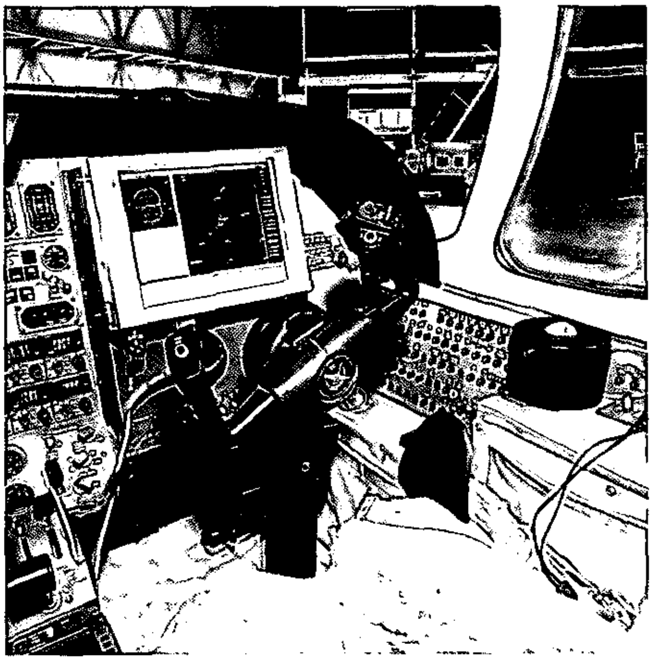
In preparation for the programme for the acquisition of a successor for the Orpheus reconnaissance system by the RNLAF, manufacturers were given the opportunity to demonstrate the performance of their daylight and infrared sensors on an operational F-16. In co-operation with these manufacturers, NLR integrated the sensors in the Medium Altitude Reconnaissance System (MARS) and supported the flight demonstrations.

Facilities and Equipment

Facilities for Environmental Testing

Both the Electromagnetic Compatibility (EMC) and the Vibration and Shock Test (VST) Laboratory carried out numerous measurements under contract to customers from the aerospace and non-aerospace industry. A new Open Area Test Site, annexed with a heliport, enabled the EMC Laboratory to carry out measurements on both small test samples (e.g. emission measurements according to the European EMC directive) and larger test samples like helicopters (e.g. radiated immunity tests).

The EMC Laboratory was accredited by the Dutch Council of Accreditation (RvA) according to the STERLAB criteria based on the criteria from EN45001 and ISO/IEC Guide 25 and the relevant criteria from ISO 9001/9002. NLR started to offer a complete package of environmental testing for its customers. A combined offer was made for tests at NLR's facilities for Vibration and Shock, Electromagnetic Compatibility, Temperature, Pressure and Humidity,



Navigation Display of the Experimental Flight Management System in the Cessna Citation cockpit

Thermal Vacuum, Thermal Cycling, Salt Spray, Fluid Contamination and Rain. In case NLR did not have the required capabilities, part of the testing was subcontracted to test facilities elsewhere (e.g. for fungus testing).

Computer Aided Engineering of Electronics

The NLR Infrastructure for Computer-based Electronics Systems development Tools was updated with a new set of CAE software tools 'WorkView Office' based on Windows95. Existing software tools for reliability calculations such as MTBF (Mean Time Between Failure) calculations and FMECA (Failure Mode Effect and Criticality Analysis) prediction were expanded and improved. Existing workstations were replaced by more powerful ones.

Prototype Production Facilities

Two dedicated clean rooms (Class 100,000) were built for the production of flight and space equipment and for the mounting of Surface Mounting Devices on PCBs, including coating activities for space electronics.

Instrumentation for Research Aircraft

For Air Traffic Management research and demonstrations two positions for pilots conducting the tests were created, one in the cockpit for the 'pilot flying' and one behind the cockpit for the 'pilot non-flying' or an observer. New, larger, LCD colour displays were installed and new computers were acquired, providing compatibility with display computers of the Research Flight Simulator.

The satellite Data 2 communication link was upgraded to Data 3 standards. Implementation of the PATN communication protocols is under way.

Facilities for the Acquisition and Processing of Measurement Data

A new receiver with tracking antenna was acquired capable of receiving telemetry data of rates of up to 6 Mbps. First use is foreseen for a F-16 flight test programme in early 1998.

A predesign was made for an easily reconfigurable data acquisition system for use on board helicopters.

To support the measurements for human factors research a third head/eye-tracking system was ordered. Calibration methods were further enhanced.

The Data Acquisition Equipment Calibration Laboratory, originally accredited for pressure calibration by the National Calibration Organization in 1985, successfully passed a re-evaluation process by the Dutch Council for Accreditation.

3.7 Engineering and Technical Services

Summary

To ensure the capability of manufacturing highly complex products, the development of new techniques has been given continued attention.
The use of finite element methods was extended, the Catia CAD/CAM system was upgraded, and new techniques in the field of rapid prototyping were studied.

Taking part in the AEREA Facilities Subcommittee for Workshops, NLR studied possible reductions of the lead time of designing and manufacturing wind tunnel models.

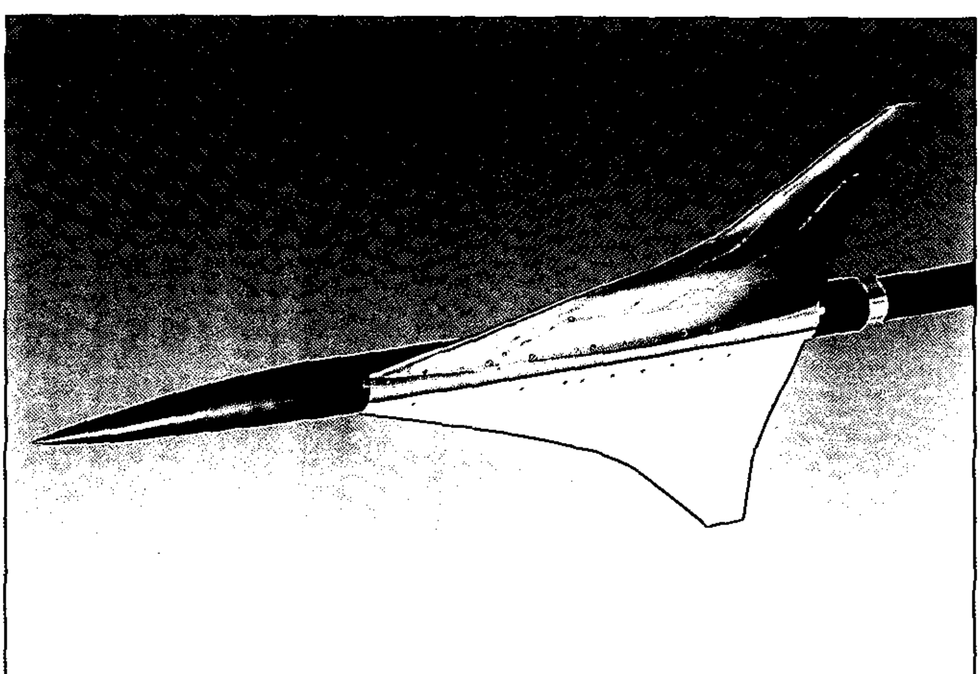
Various wind tunnel models, balances and other equipment were designed and manufactured.
For the cryogenic European Transonic Wind Tunnel (ETW) the work on a twin sting rig was completed, including two cryogenic three-component balances.

Fundamental research on strain gauge balances was continued. Analytical methods were developed, using finite element analysis tools, to predict the behaviour of balances at different load and environmental conditions.

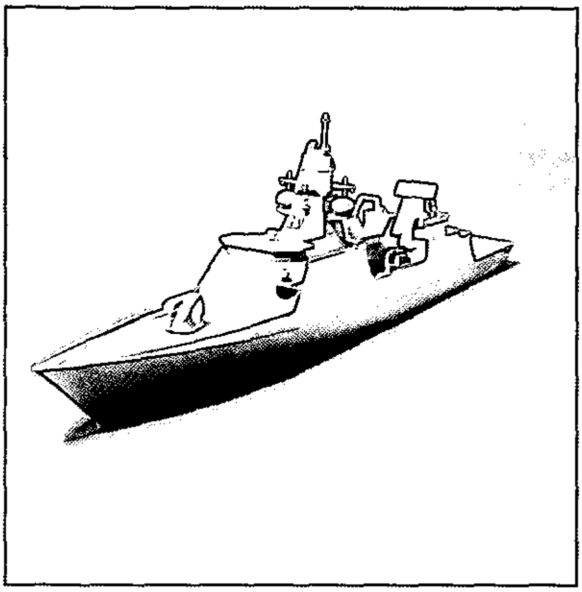
Wind tunnel models

For Fokker Services a model for the F-28-RE (re-engining) programme was composed from existing F-28 and Fokker 100 model parts, modified where necessary.
A new model of the Ariane-5 launcher with simulated jet propulsion was made, to be tested in the High Speed Wind Tunnel (DNW-HST).
The cryogenic model of the Fokker 100 aircraft to be tested in the European Transonic Wind Tunnel (ETW) was completed.
Work was started on a European study model for a supersonic transport aircraft (EUROSUP), and on a model of a launcher.
Various models of external customers were adapted for measurements in the DNW-HST.
Under the NH90 programme, configuration changes were made to the 1:10-scale low speed model for tests in the DNW-LST. Stereolithography was used as a new, and promising, technique to manufacture complex parts for the NH90 model in a very short time.

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



Scale 1:80 model of supersonic airliner (Eurosup) for tests in transonic (DNW-HST) and supersonic (DNW-SST) wind tunnels



Wind tunnel model of frigate

Apart from complete wind tunnel models, parts of models were made as contributions of NLR in international programmes. NLR contributed in the field of propeller research by manufacturing the propellers for a high speed model of the European Future Large Aircraft (FLA), and the propellers for the European propeller research programme APIAN (Aircraft Propulsion Integration Aerodynamics and Noise).

Wind tunnel equipment

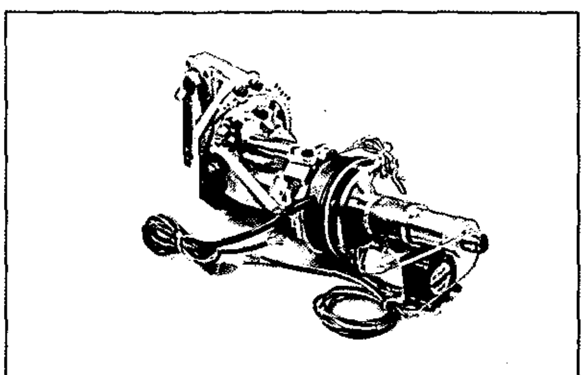
The work on the Twin Sting Rig (TSR) for the cryogenic European Transonic Wind Tunnel (ETW) was finished. Together with the TSR, two gauged flexures (three-component balances) for cryogenic use were developed and built. As with the development of the cryogenic wind tunnel model of the Fokker 100 mentioned above, the TSR project supplied very useful additional knowledge and experience in the complex field of cryogenic design.

As part of the European propeller research programme APIAN, propeller test rigs were developed for the LST and HST. Also for this programme, rotating balances were built.
In the second phase of the modernization of the HST, completed in the first half of 1997, the development of the new, carbon composite, fan blades was completed with the installation and testing of the blades in support of the strength analysis, both statically and *in situ* dynamically. Various other modifications to the DNW-HST were completed.
In support of DNW, two stings for the DNW-LST and a microphone grid for the DNW-LLF were made. A study was started on a new type of low-reaction air supply systems.

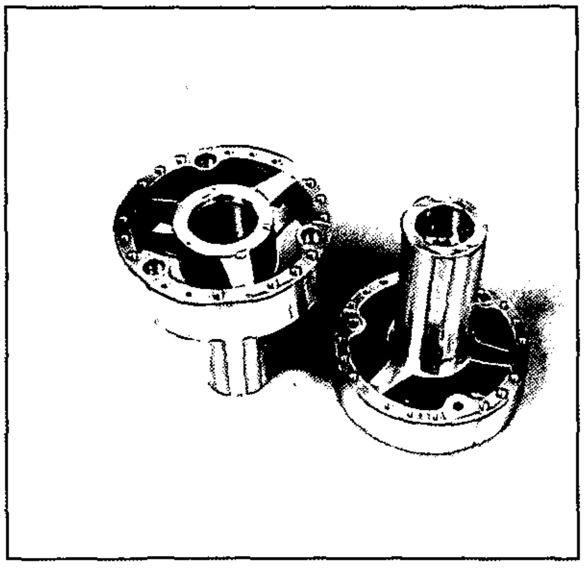
Strain Gauge Balances and Model Instrumentation

Basic research on strain gauge balances was continued. A study was made of the influence of the balance-sting connection on the nearest strain-gauge section of the balance. Second-order effects were studied using finite element analysis methods, in order to develop a prediction method for these effects on the behaviour of the balance. A cryogenic test box was acquired and tested for further investigations on cryogenic temperature effects.
The calibration method for rotating balances was studied and improved.

Various balances for several purposes were developed. They include the rotating balances for the APIAN propeller research programme and the gauged flexures for the cryogenic twin sting rig for the ETW mentioned above. A very slender, sting balance was designed for a supersonic transport aircraft study model (EUROSUP). Also, the development of a general purpose six-component sting balance for use in the DNW-HST was started. A pre-design study was made of a platform balance for possible future use in the DNW-HST.



Adjusting mechanism for ETW Twin Sting Rig



Rotating balance for European propeller research programme

Various Structures

In addition to models and wind tunnel equipment, several structures of very different nature were designed and/or manufactured.
Various modifications were made to a reconnaissance pod to be carried on an F-16 fighter aircraft, to enable the Royal Netherlands Air Force to evaluate sensors.

Adaptions of the fuselage panel test rig were designed to allow tests to be carried out on panels for several customers.
The top part of a Fokker 60 wing-to-fuselage frame was manufactured, to be tested in the Fokker 60 fatigue test rig at Schiphol.
An impactor was developed to enable impact resistance tests to be carried out on products *in situ*.

Various parts of consoles and racks were designed for NLR's research aircraft. The existing PHARUS pod was adapted for installation on the Metro II research aircraft.

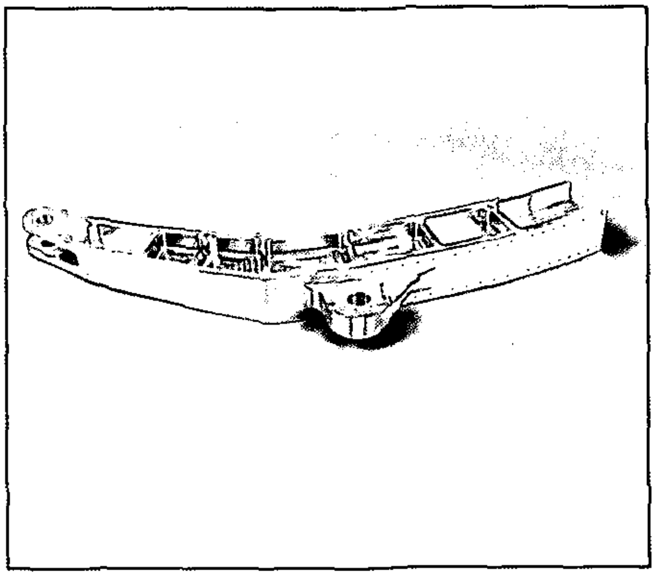
Non-aerospace Activities

Activities included the development of a medical cut-and-clamp tool, the strain-gauge instrumentation of a roller-bearing for a bearing loads-testing facility, and advisory support to a fan manufacturer. Production work, milling, was taken on to better utilize the workshop facilities.

Development of New Techniques

To ensure the capability of manufacturing increasingly complex products, the development of new techniques has been given continued attention. The use of finite element methods was extended in support of the design process.
The effect of temperatures down to cryogenic conditions on the accuracy of strain-gauge balances was investigated. For this purpose a cryogenic test box was acquired.
The Catia CAD/CAM system was further extended and improved, and upgrades of components were installed.
New manufacturing techniques in the field of rapid prototyping were studied and practised, notably high-speed milling, stereo-lithography and other layered manufacturing techniques.
Further efforts appeared to be required for the introduction of the newly acquired five-axis high speed CNC milling machine, to reduce lead-time and cost of the manufacturing of wind tunnel models and comparable products.

As a member of the Association of European Research Establishments in Aeronautics (AEREA), NLR participated in the Facilities Subcommittee for Workshops, discussing how to co-operate on the design and manufacturing of wind tunnel models.
A dedicated workshop was organized to discuss the challenge of how to reduce the lead-time of the production of wind tunnel models.



Structural part of Fokker 60

4 Internal and External Relations

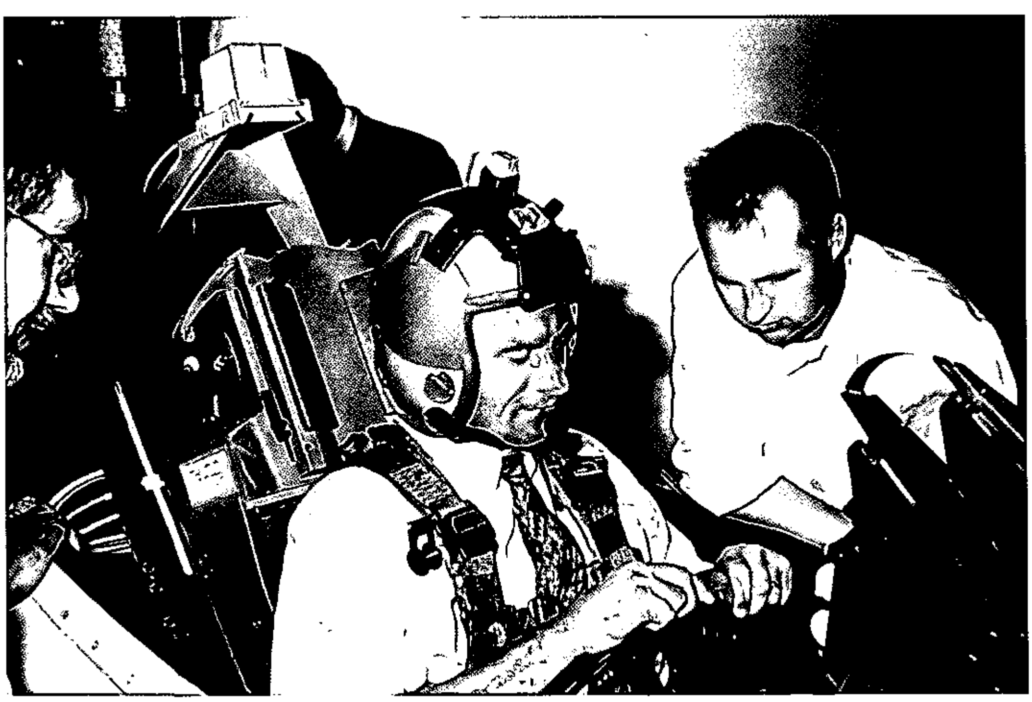
Many visitors showed interest in NLR activities. NLR participated in several airshows and exhibitions and organized various events.

Visitors from the Netherlands

- Mr. N. van Putten, Ministry of Economic Affairs
- Mr. J. van Walsum, Member of Parliament, D66
- Mr. J. Muller and Mr. P.H.M. te Riele, from Urenco
- Mr. C.J.M. Gresnigt, Director Flight Services of KLM
- Mr. J.P.M. Remmen, from the Netherlands Department of Civil Aviation (RLD)
- Gen.Maj. Ir. M.R.H. Wagevoort and members of the Royal Netherlands Air Force
- Mr. W. Pelt and Mr. W.C.J. Verberne, Department of Scientific Research of the Royal Netherlands Navy
- Lt.Gen. B.A.C. Droste, Commander of the Royal Netherlands Air Force
- Mr. S.G. van der Plas, Secretary General of the Ministry of Transport
- Mr. J. Fledderus, Director General Materiel of the Ministry of Defence
- Dr. J.C.M. Hovers, Chairman of the Board of Stork N.V.
- Mr. E. Hofstee and Mr. A. Kraan, from the Netherlands Department of Civil Aviation (RLD)
- Mr. H.R. Crince le Roy and Mr. M. van der Haer, from the Netherlands Department of Civil Aviation (RLD)

Foreign Visitors

- Mr. João Vaz, Brazil
- Members of AVIC and the Euro-China Center for Business Co-operation
- Mr. Durval H. Silva (Brazset)
- A delegation from the Israeli Air Force
- Mr. K.T. Dornbusch, American Ambassador in the Netherlands
- Dr. Sergey yu Boris, from the Gromov Flight Research Institute of Russia
- Mr. R. Smyth and Dr. A.N. Szodruch from Daimler-Benz Aerospace Airbus



Mr. J. Fledderus, Director General Materiel of the Ministry of Transport, who flew the National Simulation Facility NSF

Excursions

- Students of Industrial Management from the Zwolle College
- Students of the Zadkine College
- Members of the Aeronautical Study Society 'Sipke Wynia' of the Haarlem College
- Avionica students from the Amsterdam College and from the Delft University of Technology
- Members of the European Aeronautical Study Society *Euroavia*
- Students from the Study Society *Johannes Diderik van der Waals* of the Eindhoven University of Technology
- Students from the Delft University of Technology's Society for Space Flight
- Employees of Railconsult, from the Netherlands Railways
- Students from *De Leidsche Flesch*, Study Society for Science and Informatics

Exhibitions

- NLR participated in the exhibition at the celebration in the World Trade Centre of Rotterdam of the 50th Anniversary of the Netherlands Agency for Aerospace Programmes (NIVR), showing past and present NLR activities for NIVR.
- The NLR stand at the exposition 'The Instrument' held in Utrecht during three days was visited by many.
- NLR participated in an AGARD Exhibition held in Paris.
- At the Conference 'Rail Tech Holland 1997', NLR presented non-aeronautical activities at an exhibition called 'Lightrail'. Especially the work on noise measurements for high speed trains was showed.
- At the Maastricht Exhibition and Congress Center (MECC) NLR participated in the 'Materials Engineering Exhibition'.
- In the field of materials, NLR participated in the 'Journées Européennes des Composites' (JEC) held in Paris.
- The International Training Equipment Conference (ITEC) was held at Lausanne. In the stand of the Netherlands Industrial Simulator Platform (NISP), NLR showed its Pandora mission planning system and flight simulation capabilities.
- At the exhibition 'Tech-knowledge' in the Exhibition and Congress Center of Utrecht, NLR focused on the Forest Assessment and Monitoring Environment (FAME) project.

NLR contributed to the stand of the Netherlands Aerospace Group (NAG) at Le Bourget, Paris

- At the Open Days of the Royal Netherlands Air Force at Gilze Rijen, NLR was present with a stand.
- NLR contributed to the stand of the Netherlands Aerospace Group (NAG) at the Paris Airshow, Le Bourget.
- The Netherlands Defence Manufacturers Association (NIID) organized a symposium: 'Transatlantic Co-operation through Participation' in The Hague. During this event NLR showed its activities by means of pictures, video film and a demonstration of the ATC Tracker Development Facility 'Tradef'.
- Over 100,000 visitors came to Valkenburg Airbase to celebrate the 80th anniversary of the Naval Air Service (MLD) by attending airshows and demonstrations. NLR was present.
- NLR contributed to an exhibition held during the IAF Congress Space '97 in Torino, Italy.
- The Free Flight Symposium in Amsterdam, the AEREA Congress held at Toulouse and the 9th World Congress of the International Association of Institutes on Navigation, held in the RAI Congress Centre in Amsterdam were all completed by exhibitions to which NLR contributed.

Events

- Well attended New Year Receptions for NLR staff were held in both Amsterdam and the Noordoostpolder.
- Together with the Confederation of European Aerospace Societies (CEAS) a Symposium on 'Free Flight' was organized in the Marriott Hotel in Amsterdam. With a typical Dutch Breughelian dinner and a sightseeing trip to Haarlem the Congress was complete.
- Partners of the NLR board members visited the Noordwijk Space Expo.
- At NLR Amsterdam and NLR Noordoostpolder introductory meetings were held for new employees.
- NLR and the other Technological Institutes of the Netherlands (GTIs) congratulated the Royal Institute for Engineers (KIVI) at the celebration of its 150th anniversary via a huge slide projection wall.
- The Arbeitskreiz Belastungs Mechanik held a two-day meeting at NLR Noordoostpolder.
- The Innovation Centre, the Dutch Society for Precision Technology (NVPT) and NLR held a workshop at NLR Noordoostpolder.

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 1996 under the Programme for basic research and development of facilities of NLR;
- the preliminary Work Plan for 1998;
- the Programme for basic research and development of facilities for 1999;
- To the Boards of Directors of NLR and NIVR, on:
- the results of the work carried out by NLR in 1996 under the 'General Research Programme with a view to aircraft development in the near future' (ARP) of NIVR;
- the reports NLR submitted to the Committee to be considered for suitability as scientific publications.

Membership of the Scientific Committee

Prof.ir. C.J. Hoogendoorn in connection with his retirement has expressed his desire to resign, but to remain functioning as a member until a successor is appointed. Ir. Holwerda resigned in connection with his accepting a position with NLR.

At the end of 1997 the Scientific Committee was composed as follows:

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

Membership of the Subcommittees

In the course of 1997, the following members of the subcommittees resigned for various reasons: Prof.dr.ir. J.A. Mulder (Subcommittee for Aircraft Performance and Operations), Ir. H.B. Langeraar (Subcommittee for Aircraft Performance and Operations), Prof.dr.ir. J. Schijve (Subcommittee for Structures and Materials) and Prof.dr.ir. G.Y. Nieuwland (Subcommittee for Applied Mathematics and Information Technology).

Six new members were appointed in the Subcommittee for Structures and Materials.

At the end of 1997 the subcommittees were composed as follows:

Subcommittee for Aerodynamics

Prof.dr.ir. J.L. van Ingen, *chairman*
Prof.dr.ir. P.G. Bakker
Dr.ir. R. Coene
Prof.dr.ir. H.W.M. Hoeijmakers
Prof.dr.ir. F.T.M. Nieuwstadt
Prof.ir. E. Obert
Prof.ir. E. Torenbeek
Prof.dr.ir. P. Wesseling
Prof.dr.ir. L. van Wijngaarden
Ir. E.J. Bos, *secretary*

Subcommittee for Space Technology

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

Subcommittee for Structures and Materials

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

Subcommittee for Applied Mathematics and Information Technology

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

Subcommittee for Flying Qualities and Flight Operations

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

Subcommittee for Electronics and Instrumentation

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

Concluding remarks

The Scientific Committee's opinion, stated in its annual report on 1996, that a sufficient amount of activities existed to maintain research and development in aircraft technology, aeronautics and spaceflight at a high level and to continue requesting active support from the Netherlands government, was virtually subscribed to by the publication in December 1997 of the government's position concerning the restructuring and stimulation of the Netherlands aeronautical cluster.

The position of the government included the continuation of the usual support by the government departments to the activities of NLR and NIVR, while the government expressed its readiness to provide additional means for participation of Netherlands' industries and institutes in the development of the Airbus A3xx and, in anticipation, short term bridging projects. A decision on this was announced for Spring 1998. The government's arriving at such a decision, after having several consultancy agencies carry out studies, is gratifying the Committee; the fear initially existing that with the demise of Fokker Aircraft Company a larger than necessary annihilation of activities on bordering areas would occur, was dispelled. The Committee interprets the intention of a reorientation of NIVR included in government's position such that it is aimed at a maximum decisiveness and efficiency in the serving of the Netherlands industry and research community.

The Committee notes that the willingness to provide financial means for the A3xx and JSF projects should not be interpreted too narrowly. In addition to the jobs these projects may offer, there is work for other principals who already call in the Netherlands industry and knowledge infrastructure, contributing to the construction of a new position for the Netherlands aircraft industry.

The Committee regrets that the extension of the working area of NIVR, still advocated in 1996, has not been implemented. The interaction between the various aeronautical technologies and scientific disciplines applied in the areas of aircraft component production, maintenance and modification, aircraft operation and infrastructure and environment, can be highly productive. This holds both for

NLR, more often than before called in for design and other work, and for NIVR as manager of research and development programmes. In the reorientation of NIVR this may receive attention.

The Committee can agree with NLR's Work plans for 1998 and the planned programme for 1999. The Committee notes that NLR is frequently requested to take part in consortia that make research proposals in the European framework. The high rate of approval of these proposals is putting the basic research under pressure, because of the contributions required from the participants. Sufficient means must remain available for basic research, which has to provide the basis for contracts to be acquired in future. An alternative way of co-funding the European research, which fluctuates in amount, should be found. A subject of which the scope in the past few years has been and still is growing strongly, is the air transport system as a whole. Several aspects of Air Traffic Control, safety, capacity, physical and environmental limits play a role. Procedures and techniques that lead to greater safety must be implemented as soon as possible, and increasing the capacity, both in the air and on airports, requires much effort. Results on sub-areas that can contribute to solving capacity problems must be lifted from isolation and evaluated in integral large-scale research. This type of research requires considerable investments, which exceed the average investment budgets of NLR. The Committee advocates such integrated research to be made possible, since the results will enable the Netherlands to make a well-based strategy for the future, to the benefit of the Netherlands.

Concerning space flight technology, the Committee notes increasing interest from life sciences (biological, medical sciences) relative to physical sciences for experiments in space. Although NLR aims at developing generic experimental facilities, it is recommended to maintain good contacts with the user community, the experimenters. The trend is for ever more complex systems to be applied. To test these, larger and more complex experimental facilities will be required. To realize these, not only investments are required, but also a stable long-term policy. For the Netherlands to play a reasonably prominent position, partly as a consequence of the retreating role of ESA and the increasing importance of bilateral agreements and the tendency towards market division, the determination of a strategic position for the Netherlands seems to be indispensable. To reach agreement on this position, and to maintain a steady long-term strategy, a stronger concentration of the activities of the government departments would seem to be required. In this respect the Committee supports the view on a Space Technology Agency laid down in the report on future jobs for space technology by the Advisory Council for Science and Technology Policy (AWT). The Committee is of the opinion that a number of the tasks mentioned by the Council are carried out by NIVR.

6 International Co-operation

6.1 NATO Research and Technology Organization (RTO)

Introduction

On 26 July 1996, the NATO Council established the NATO Research and Technology Organization (RTO). On 21 November 1996, Ambassador Belanzino, the Deputy Secretary General, officially inaugurated the RTO.

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

The principal tools used to perform the mission are:

- development and maintenance of a co-ordinated long term strategy for NATO defence research & technology;
- ensuring the co-ordination and harmonization of Programmes of Work within the NATO R&T community;
- co-ordination of R&T programmes and activities between nations as well as within NATO as appropriate;
- provision of advice on R&T issues to senior NATO bodies;
- sponsorship of joint studies and research projects;
- conducting and promotion of co-operative research activities including tests and measurement campaigns;
- promotion and facilitation of information exchange regarding R&T amongst NATO member states;
- provision of assistance to member states for the purpose of increasing their scientific and technological potential, with special emphasis on Greece, Portugal and Turkey;
- provision of specific and general support for Partner nations.

The RTO is a NATO organization reporting both to the Military Committee and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and a Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, France.

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)

These Panels are made up of national representatives as well as generally recognized 'world class' scientists. The Panels also provide a communication link to military users and other NATO bodies. The scientific and technological work of the RTO is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organize workshops, symposia, field trials and training courses including Lecture Series. An important function of these Technical Teams is to ensure the continuity of the expert networks. Technical Teams also play an important role in formulating longer term plans.

The RTA, with headquarters in Neuilly, France, is responsible for carrying out the decisions of the R&T Board 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 other NATO activities, a small part of the RTA staff is located in 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.

For the co-ordination and communication with the nations, National Co-ordinators have been nominated in each nation. These National Co-ordinators play an important role in the organization of activities that take place in the various nations, such as holding symposia, meetings of the RTB, assisting with Lecture Series and the running of Consultant Missions.

Co-operation with nations in Middle and Eastern Europe was started under the Partnership for Peace programme. The RTO attached particular importance to this activity, especially as working together in the field of research is one of the more promising areas of initial co-operation. Contacts were already established under the AGARD Outreach programme and through symposia with Partners. This activity will be enlarged, paying in particular attention to those nations which shortly may become full NATO members.
The RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr. Theodore von Kármán, a leading aerospace scientist, who early on recognized the importance of scientific support for the Alliance Armed Forces. The RTO intends to capitalize on these common roots and to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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

Netherlands Participation in RTO

R&T Board

The Netherlands members of the RTB are

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

R&T Panels

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

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

National Coordinator

The national coordinator is Ir. L. Sombroek (NLR).

Highlights

The year 1997 has been a transition period. AGARD and DRG activities initiated in preceding years were continued under the auspices of the RTO.

Memorable events were an all-AGARD panel conference on 'Future aerospace technology in the service of the alliance' (Paris, April 1997) and the presentation of the AGARD study 'Aerospace 2020'.

The objectives of the study Aerospace 2020', presented in Paris, April 1997, were:

- to assess how emerging technologies may influence charges in aerospace systems and concepts of operation;
- to advise decision makers of the advantages the emerging technologies may have for NATO and for NATO nations, and to make them aware of the possible threats that new and readily available technologies may pose when acquired by potential adversaries;
- to recommend to the nations active pursuit, both individually and co-operatively, of the most promising aerospace technologies and to offer advice, where appropriate, on collective action.

With these two highlights the 45-year history of AGARD has been marked. The Secretary General of NATO, Dr. Javier Solana, attended the closing ceremony of the last ever AGARD conference, and formally terminated AGARD, the Advisory Group for Aerospace Research and Development.

6.2 The German-Dutch Wind Tunnel (DNW)

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

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

The Board of DNW

The Board of the Foundation DNW is formed by members appointed by NLR, DLR, and the German and Dutch governments. At the end of 1997 the Board consisted of:

Min.Rat Dr. H. Diehl, *Chairman*
Ministry of Education, Science, Research and Technology of Germany (BMBF)

Dr.ir. B.M. Spee, *Vice-Chairman*
NLR

Prof. Dr. A. Bachem
DLR

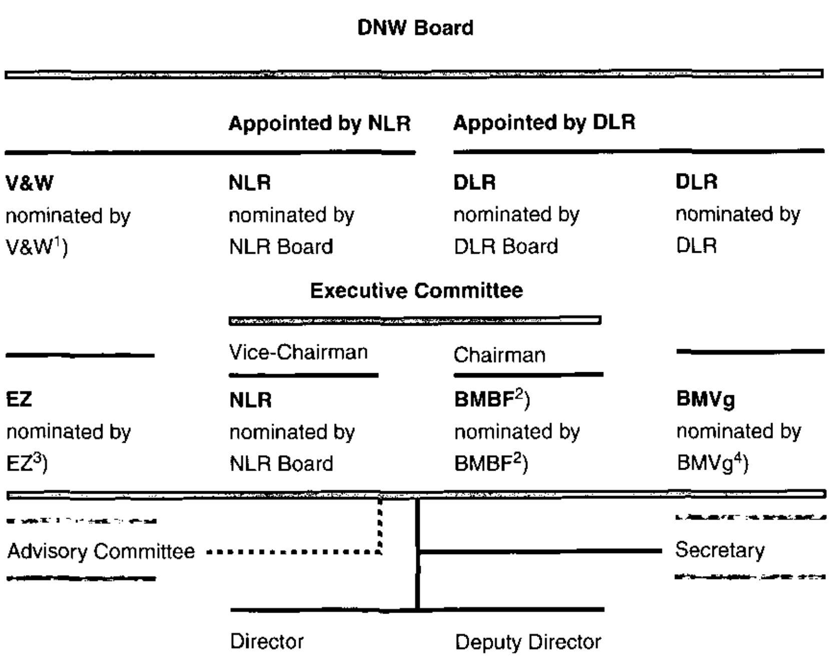
Min.Rat W. Brechtelsbauer
Ministry of Defence of Germany (BMVg)

Prof. Dr.-Ing. H. Körner
DLR

Drs. L.W. Esselman, R.A.
NLR

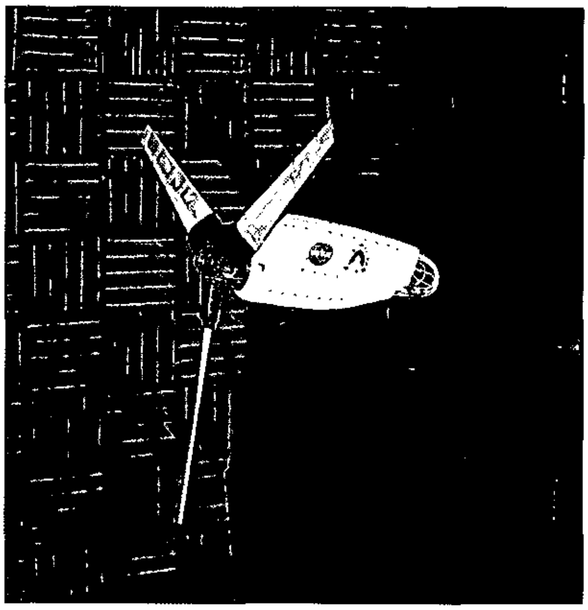
Ir. H.N. Wolleswinkel
Ministry of Transport of the Netherlands (RLD)

Secretary: Dipl.Kaufm. D. Smyrek



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

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



A tilt-rotor model for acoustic research

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 1997 the Advisory Committee consisted of:

Prof.Dr.-Ing. F. Thomas, *Chairman*
DLR
Dipl.-Ing. V. von Tein
Airbus Industrie
Dr.-Ing. J. Szodruch
Daimler-Benz Aerospace Airbus
Dipl.-Ing. B. Haftmann
Daimler-Benz Aerospace Airbus
Dipl.-Ing. A. Rauen
Daimler-Benz Aerospace
Dipl.-Ing. R. Birrenbach
Fairchild Dornier
Mr. Y. Richard
Eurocopter France
Prof.dr.ir. J.L. van Ingen
Delft University of Technology
Prof.ir. J.W. Slooff
NLR
Secretary: Dr.-Ing. G. Lehmann

The Board of Directors

The Board of Directors of the DNW consisted of:
Director: Prof.Dr.-Ing. H.U. Meier (DLR)
Deputy Director: Ir. C.J.J. Joosen (NLR)

DNW-LLF

Pending go-aheads for new aerospace programmes resulted in a low occupation by aerospace tests in the first half of 1997. During the second half of 1997 the occupation increased considerably, requiring sometimes even 1.5 shift per day in order to fulfil the needs of all customers.
In contrast to the aerospace industry a continuous and balanced business with the car/truck industry has taken place resulting in a 45% contribution to the total occupation.
Besides many standard projects some real highlights can be noted. One of the most challenging tests was a campaign with the so-called ELAC hypersonic transportation system. In order to study the low-speed characteristics of such an aircraft, a large model was designed and constructed by the Technical University of Aachen, Germany, and tested in the 8m*6m test section of the LLF. With different model configurations, with and without attached through-flow engine nacelles, modern measuring techniques like hot-film and hot-wire techniques and Particle Image Velocimetry (PIV) were applied. Together with the standard measurement of forces, moments, and pressure distributions a huge database covering the low-speed region was generated for further evaluation.

The first phase of a long awaited wind tunnel programme of the US Army and NASA was completed in 1997. Defined as a system check-out test, a tilt-rotor model was built-up and tested in the open-jet test section. It was the first time that this model was operated in a wind tunnel. This test also covered the operation of all subsystems throughout the whole test envelope in order to verify the reliability of the measurement data. Although the test was mainly aimed at assuring the proper overall system performance, some unique measurement results could be obtained including first PIV images of rotor tip vortices. The next phase will be performed in 1998 and will address the rotor acoustic properties of convertible rotorcraft like the V-22.

DNW-LST

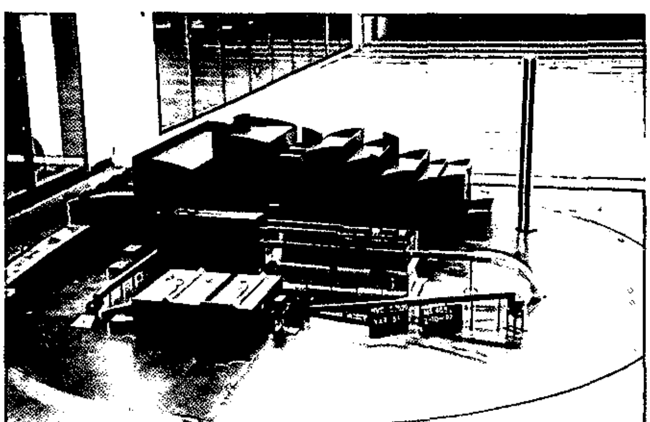
The DNW-LST was well used in 1997 for both aircraft related and non-aeronautical projects. Aircraft models tested included a trainer fighter aircraft and a 1:12 scale model of the CASA

C-295. Tests with the C-295 model were part of an extensive wind tunnel programme consisting of a total of six, separate entries in the DNW-LST. The test objectives included flap optimisation, drag reduction, stability and control characteristics in start and landing configurations, and the determination of the effects of thrust reversing and ice accumulation.

Besides buildings and ships, a part of the non-aeronautical tests were sport related: a yacht, sailing the Whitbread race, four-men bobsleighs and a world record challenging faired bicycle. Of the tests dealing with the airflow around and through buildings one concerned a modern waste incineration plant, recently put into use. The investigation was aimed to determine the effects of wind speed and wind direction on the performance of the forced draught of air-cooled heat exchangers. Moreover, the influence of nearby buildings was investigated.

DNW-NWB

In 1997 the NWB was well occupied with contract tests, most of them received from DLR. Along with more or less standard tests with new profiles and wing sections, a very complex test was performed at a fighter model. For this test the new measuring technique Global Doppler Velocimetry (DGV) was successfully applied the first time for determination of the external and internal flow at an air intake. DGV is a laser-based measuring technique and allows the three components of a flow field to be measured in parallel.



Scale model of waste incineration plant in the DNW-LST

6.3 The European Transonic Wind Tunnel (ETW)

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

In 1997, some co-operative test programmes were executed. Besides, a limited number of paid tests were executed successfully. The agreement to extend the Initial Operation Period, allowing the available funds to be better distributed over the coming years, was signed on behalf of the participating governments.

ETW Supervisory Board

At the end of 1997, the membership of the Supervisory Board was as follows:

France

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

Germany

Dr. H. Diehl	BMBF
Prof. A. Bachem	DLR
Dr.-Ing. H. Körner	DLR

United Kingdom

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

The Netherlands

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

Managing Director Operation of ETW was Mr. T.B. Saunders (UK). He was assisted by:

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

6.4 GARTEUR

The Group for Aeronautical Research and Technology in Europe (GARTEUR) was formed in 1973 by representatives of the government departments responsible for aeronautical research in France, Germany and the United Kingdom. The Netherlands joined in 1977, Sweden in 1992 and Spain in 1996.

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

The co-operation in GARTEUR is concentrated on pre-competitive aeronautical research. Potential research areas and subjects are identified by Groups of Responsables and investigated for collaboration feasibility by Exploratory Groups. If the subject is feasible, an Action Group is established in which parties (research establishments, industries or universities) from at least three GARTEUR countries participate.

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

The organizational diagram shows three levels: the Council/Executive Committee, the Groups of Responsables and the Action Groups. Via CARTE (*Group for Collaboration on Aeronautical Research and Technology in Europe*), Industrial Points of Contact in the Groups of Responsables and industry participation in Action Groups, GARTEUR has interfaces with the European Aerospace Industry.
In 1998, CARTE's role in GARTEUR will be taken over by the Industrial Management Group (IMG[3]) of the *Association Européenne des Constructeurs de Matériel Aérospatial* (AECMA).

GARTEUR Council and Executive Committee

At the end of 1997 the GARTEUR Council was composed as follows.

France

IGA F. Flori	DRET/SDEP *)
IGA J. Chéret	ONERA **)
ICA E. Lisack	DGAC/DPAC
ICA Ch. Mathieu	DCAé/STPA

Germany

Dr. W. Döllinger	BMBF *)
Dr. H. Diehl	BMBF
Dr. R. Haupt	DLR **)

United Kingdom

Dr. M.F. Steeden	DERA *)
S.I. Charik	DTI
Dr. D.E. Mowbray	DERA **)
Dr. J.B. Jones	MOD

Spain

Prof. E. Varela	*)
G. Moreno Labata	INTA
P. Garcia Samitier	INTA **)

Sweden

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

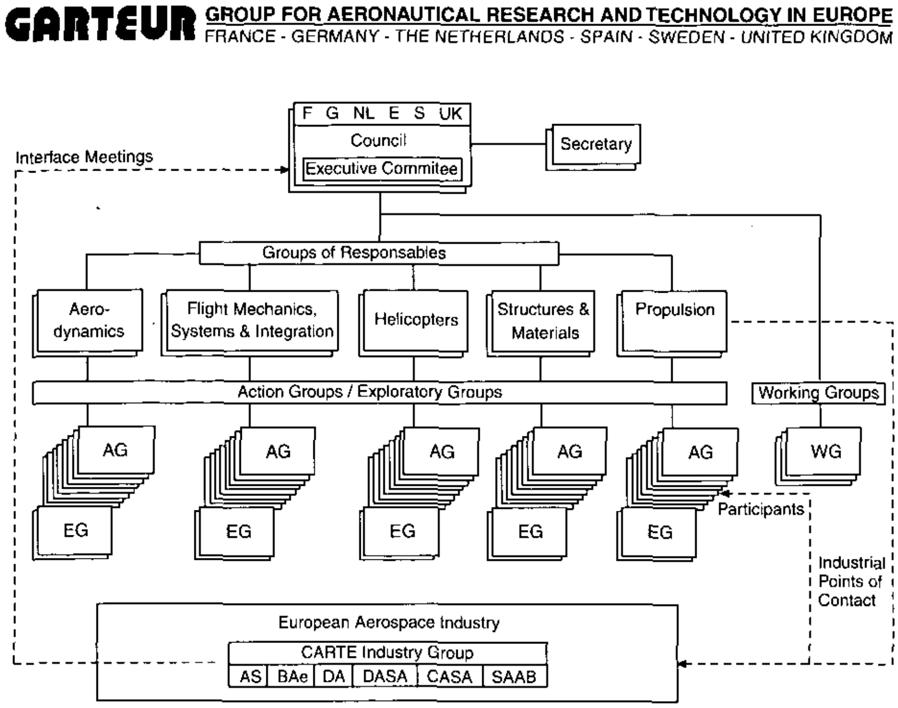
The Netherlands

J. van Houwelingen	NLR *)
Prof.ir. J.W. Slooff	NLR **)
Dr.ir. B.M. Spee	NLR

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

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

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



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

GARTEUR Development and Strategy

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

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

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

NLR Participation

NLR participates in all five Groups of Responsables. In 1997, twenty-four Action Groups were active; NLR participated in twenty of these.

6.5 Co-operation with European Research Establishments in Aeronautics

DLR/NLR Partnership

Background

A formal partnership agreement between DLR and NLR is in force since 1994. This partnership is based on the good experience obtained with the co-operation within the German-Dutch Wind Tunnel (DNW). The aim of the partnership is to strengthen the ties between the two establishments in order to make more effective use of the extensive knowledge and facilities available.

In order to guide and control this task, a Joint Executive Board was set up, consisting of representatives of DLR and NLR. The chairmanship rotates annually.

DLR/NLR Executive Board at the End of 1997:

J. van Houwelingen (*chairman*)	NLR
Prof. W. Kröll (*vice-chairman*)	DLR
Dr.ir. B.M. Spee	NLR
Prof.Dr. A. Bachem	DLR

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

A Programme Committee, in which both DLR and NLR were represented, was active.

The Programme Committee at the End of 1997

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

Facilities

The partners stimulate joint operation and use of existing research facilities. Furthermore, the partners exchange information on planned investments and where possible embark on joint or complementary investments. Potential facilities for co-operation are flight simulation equipment and wind tunnels. During a meeting of the joint Executive Board on 15 January 1997, a provisional agreement was reached. The incorporation of all of NLR's and DLR's aeronautical wind tunnels in the DNW organization became effective as of 1 July 1997.

Basic Research

The partners continued strengthening their collaborative efforts with respect to a number of basic research topics, such as aerodynamics (propulsion/airframe integration, computational fluid dynamics), structures, and simulation. The co-operation complements the co-operation within GARTEUR and often provides the nucleus for proposals for research projects under the Framework Programme of the European Union and the co-operation in the Western European Armament Group (WEAG).

Personnel Exchange

Ir. F.J. Abbink, Technical Director, spent most of his time with DLR in Germany, as Programme Director Aviation.

AEREA: Association of European Research Establishments in Aeronautics

Supported by the European Commission, the seven European aeronautical research establishments have developed a joint vision on future co-operation. The aim of this co-operation is to create an effective and efficient aeronautical technology base in line with the integration of industries and governmental responsibilities on a European level. On 11 October 1994 the research establishments formed an association, in order to realize the first steps in a process which ultimately should lead to setting up a union between regional centres. In the union, strong organizational ties should exist resulting in integrated management of joint activities, pooling of facilities and the creation of interdepencies and specialisation.

The parties within the association realize that the speed and outcome of this federative process will be highly dependant on the developments within the markets and the environment of the research establishments. Therefore, in 1994 the association started a modest action plan comprising facilities, basic research, acquisition and personnel exchange. The following phase is planned for 1998.

Organization

The Heads of Establishment Board is the highest body within the Association. At the end of 1997 the Heads of Establishment Board consisted of:

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

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

Facilities

The associates have established a policy of co-ordinated use of and investments in large facilities. This should result in a rational utilization of existing and future facilities for common European needs. A Facilities Committee prepares this common policy. Prof.ir. J.W. Slooff represents NLR in the Facilities Committee.

In the Subcommittee on Wind Tunnel Facilities, Prof. Slooff and Drs. De Graaff took part. This Subcommittee recommended actions to introduce measures to increase cost efficiency in the operation of wind tunnels by pooling resources including test rigs and equipment. Furthermore the topic of rationalization of the European wind tunnel capabilities was addressed.

A working group on High Performance Computing Networks further elaborated on a proposal for a European supercomputing centre and proposals for standardisation of software to facilitate co-operation. Ir. U. Posthuma de Boer represented NLR in this group.

An activity aimed at combining the capabilities of the workshops of the research establishments was continued, with Ir. J. van Twisk of NLR participating.

Furthermore, Ir. H.A.J.M. Offerman represented NLR in a group aimed at pooling flight simulation facilities.

Research

A Programme Committee has to propose and manage strategic multidisciplinary programmes. Prof. Slooff represents NLR in this Committee.

A joint AEREA test was conducted in the ETW. An action group on adaptive structures was established. AEREA also has exploratory groups on supersonic aircraft and new measuring techniques, as well as aero-acoustics. Two co-operations with NASA were established: on the environmental impact of aviation (Ir. Bekebrede participating for NLR) and on aviation safety (Drs. De Graaff being the chairman of the AEREA Exploratory Group). AEREA and NASA intend to co-operate on the US safety initiative.

A new concept of joint teams was developed, in which all capabilities of the AEREA partners on a specific research area will be integrated. Furthermore, a new methodology was developed to identify opportunities for future integration of research activities and facilities.

Personnel Exchange

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

Relations to the European Commission

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

6.6 Co-operation with Indonesia

Introduction

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

APERT 95

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

Organization

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

Indonesia

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

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

The Netherlands

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

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

Programme

APERT covers three areas, viz:

- Education.
  The main objective is to continue the co-operation between DUT and ITB.
- Laboratory Development.
  The main objective is to further improve the aerospace research capabilities and facilities in Indonesia.
- Joint Research.
  The main objectives are to increase the number of joint research subjects and to increase the number of participating institutes and industries.

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

Highlights

In the course of 1997 the KNAW authorized the APERT '95 Work Plan 1997. This is the final phase of APERT '95, which formally ended at the end of 1997.

On 15 December 1997 the governing groups met for the annual PPM (preliminary programme meeting) at NLR Amsterdam. During this meeting it was decided:

- As the Work Plan 1997 has not been concluded before the end of 1997, to finalize the programme in 1998.
- To continue this co-operation with Indonesia, but to adapt the APERT framework in order to comply with the Indonesian request to give priority to education and laboratory development.

Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Capita Selecta

1 Aeroacoustic Research for Reduced Aeroengine Fan Noise

Experimental and theoretical research has led to better insight into fan noise generated by turbofan aeroengines. Recent investigations in NLR's acoustic test facilities following flight tests have yielded improved intake liners. Aircraft industries and operators are introducing such novel liners to reduce fly-over noise.

Introduction

After the introduction of the jet-engined civil aircraft in the fifties, aircraft noise rapidly became a serious community problem. The main source of noise in the first generation of turbojet engines was the turbulent exhaust flow. The turbofan engine, with a fan-driven bypass airflow, was introduced in the early sixties. This engine type combines higher efficiency with lower jet noise through a lower jet speed. Since the introduction of the turbofan, fan noise has become of primary importance, although the jet noise component has never been insignificant. Fan noise is caused by unsteady aerodynamic interaction of rotor blades and stator vanes, and is radiated from the engine inlet and by-pass duct exhaust. The fans of current turbofan engines, with by-pass ratios H of about 6, contribute significantly to community noise loads at approach and take-off conditions. For future aircraft equipped with Very High Bypass Ratio (VHBR, $H \approx 9$) and Ultra High Bypass Ratio (UHBR, $H \approx 15$) turbofans, being developed for fuel savings and low noise emissions, fan noise will also be a major contributor, in addition to the airframe noise generated by the interaction of unsteady flow around the aircraft and components, in particular wings, slats, flaps and landing gear.

In current engines, fan noise is controlled by several passive technologies. These include optimizing the numbers of rotor blades and stator vanes, using the benefits of destructive interference of sound waves, maximizing the acoustic shielding of the rotor, reducing the fan tip speed, increasing the gap between rotor and stator, minimizing the in-flow distortion by careful aerodynamic design of the intake, and using passive acoustic liners in intake and exhaust ducts. At present, some turbofan engine design studies address the noise reduction potential of swept fan blades and vanes. Furthermore, research is carried out to control fan noise by active means, such as actuators on stator vanes and in the nacelle. Promising though active concepts in a laboratory environment may be, their application in aircraft is a long-term goal.

In the meantime, research on further optimization of liners and on new concepts of passive and/or adaptive liners is being carried out. The experiment on inlet liners described below is an example of such research, sometimes characterized as 'squeezing out the last decibel'. It is part of a research programme NLR has been carrying out in the field of aeroacoustics, funded mainly by the Netherlands Agency for Aerospace Programmes (NIVR). This programme has included the development and validation of models for predicting fan noise generation by the lifting-surface theory; duct acoustics and radiation; liner properties, using semi-empirical models; and liner attenuation. The research on liner attenuation has been co-sponsored by Northrop Grumman Corporation.

NLR has available an aeroacoustics laboratory with an anechoic wind tunnel and a facility for acoustic liner testing. A model turbofan used in fan noise generation and duct acoustics studies, known as the NLR fan noise model, is also available. This model can be extensively instrumented and placed in a wind tunnel for acoustic testing and validation of prediction models.

Until recently, it was mainly Fokker Aircraft that used the results of the aeroacoustic research by NLR. At present, NLR's aeroacoustic expertise and facilities form the basis of its participation in five European BRITE/EURAM projects on aircraft noise.

Background of the Liner Investigation

In the early nineties, Fokker, in co-operation with Rolls-Royce, Northrop Grumman Corporation and NLR, carried out a test programme (Reduced Exterior Noise – REN) for reducing the fly-over noise of the Fokker 100. A part of this programme dealt with the improvement of the acoustic treatment of the intake of the Rolls-Royce Tay 650 engine. It was decided to acquire acoustic information for liner design purposes by means of in-flight measurements. A special inlet for these measurements, provided by Northrop Grumman, was instrumented with 93 microphones and 9 accelerometers. The measurements enabled the properties of the prevailing acoustic field, the frequencies and spatial structure or modes, to be determined under various conditions.

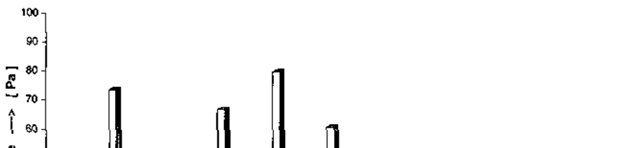


Fig. 1 – M-mode spectrum measured in the Rolls-Royce Tay 650 engine intake mounted on the Fokker 100, which is dominated by scattered modes at approach condition

From the measured modal spectra, it was found that the sound field propagating upstream in the inlet is strongly modulated by the non-cylindrical geometry, the non-axisymmetric flow velocity distribution, and the so-called intercostal strips in the lined area. These acoustically hard-walled strips, also called splices, form the connection between the liner segments. Usually the acoustic treatment of inlets consists of three partitions, connected by strips about 5 to 8 cm wide. The intense sound that originates from the fan is partly reflected by these strips, leading to a scattered modal spectrum and an adverse effect on the attenuation. The modulation of the sound field by the number of the strips (three) shows in the modal spectrum at the approach condition (see Fig. 1). Northrop Grumman manufactured a single-spliced inlet liner, which was flight tested on a Fokker 100 in 1992 and was found to give a significant noise reduction during approach and cut-back. It seemed that the use of a spliceless inlet liner, the manufacturing of which is patented by Northrop Grumman, would give additional benefit. The aim of the present study was to quantify the effects of the number and width of the splices on the acoustic attenuation of modes relevant for turbofan applications.

A similar experiment on modes of lower (less realistic) order was carried out at NLR several years ago, also in co-operation with Northrop Grumman.

Test Set-up

The test object, the NLR fan noise model, is a through-flow nacelle with one compressor stage: a rotor and a stator. The rotor is equipped with sixteen cylindrical rods instead of blades (aerofoils), since these create larger velocity disturbances. The stator consists of nine vanes, placed 15 mm downstream of the rods. The hub/tip ratio of the model is 0.6.

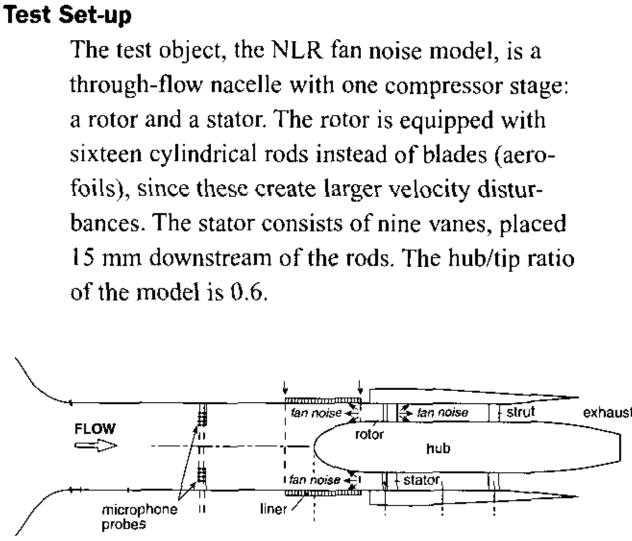


Fig. 2 – Schematic overview of the duct geometry

The fan noise is generated by the aerodynamic interaction between the rods and the stator. The wakes of the rotating rods impinge on the stator vanes located downstream, which experience a periodic variation of the flow angle. This interaction results in periodically varying pressure distributions on the surface of the stator vanes, causing them to radiate sound. This sound has tones with frequencies related to the shaft speed and number of rods (B): the harmonics of the Blade Passing Frequency, with frequencies $nB\Omega$, where $n = 1, 2, 3...$ and Ω is the angular frequency of the shaft. The spatial wave behaviour is related to both the 'blade' (B) and vane (V) numbers; the sound field of frequency $nB\Omega$ is composed of modes with m lobes, where $m = nB \pm kV$, $k = 0, 1, 2, 3...$ These sound waves are called Tyler and Sofrin (T+S) interaction modes, which can either propagate unattenuatedly (cut-on) or cannot propagate at all (cut-off) through a hard-walled duct.

Table 1 lists the parameters of the fan noise model. The model was coupled to the 400-mm diameter nozzle of the Small Anechoic Wind Tunnel by several duct sections of the Spinning Mode Synthesizer (SMS), designed for experimental duct acoustics studies. Duct flow Mach number in the hubless SMS is 0.15. The spliceless liner, which could be taped to simulate joints, was placed as closely as possible to the rotor (separation given by L/D ≈ 0.26). The detailed duct geometry is shown in Figure 2.

harmonic number	dimensionless frequency	T+S mode numbers of in-duct propagating sound waves (a minus sign indicates that the mode is counter rotating to the rotor)						
1	6.6	-2						
2	13.1	-13	-4	5				
3	19.7	-15	-6	3	12			
4	26.2	-26	-17	-8	1	10	19	
5	32.8	-28	-19	-10	-1	8	17	26

Table 1 – Expected frequencies and modes of the fan model equipped with 16 rods and 9 stator vanes, at a shaft speed of 6650 rpm

The sound field at the downstream (incident) and upstream side of the liner were measured using two radially and circumferentially traversing probes with a total of sixteen microphones. These probes cover a major part of the duct cross section (Fig. 3).

The signals of all microphones were amplified and led to the front-end of a 24-channel Fourier Analysis system based on a HP-9000 series 375 computer with LMS software. The front-end contains amplifiers, filters and analog-to-digital convertors. The signals were band-pass filtered using a high-bypass filter and an anti-aliasing filter. Data acquisition was done by the phase-locked time domain averaging technique, with the sampling process coupled to the rotation of the fan. The pulses for the external triggering and sampling processes were generated by an optical encoder system of the fan noise model. The microphone signals were on-line ensemble-averaged in the time domain. Afterwards, the time-domain-averaged data of the transducers were Fourier-transformed into the frequency domain. For each selected frequency the results were transformed into the wave number domain (circumferential, radial and axial wave numbers) and from these results the in-duct acoustic energy fluxes at the downstream and the upstream side of the liner were calculated, giving also the net damping attained by the liner. Wind tunnel parameters such as Mach numbers, temperatures, total and static pressures were both monitored and measured by the Fourier Analysis system. The experimental set-up in the Small Anechoic Wind Tunnel is depicted in Figure 4.

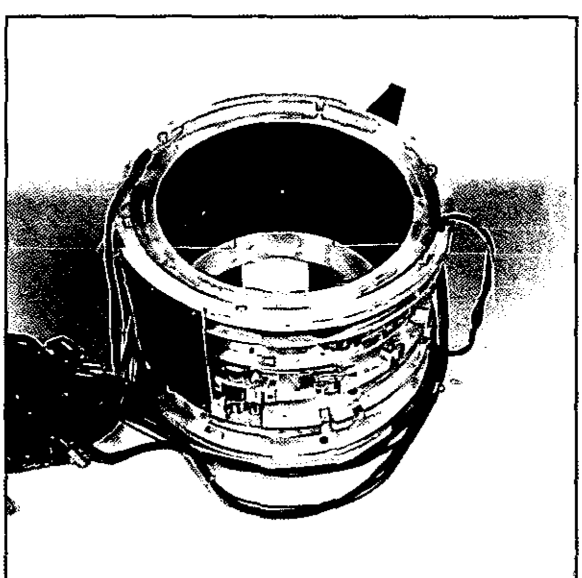


Fig. 3 – Circumferentially and radially traversing microphone probes to determine the acoustic field

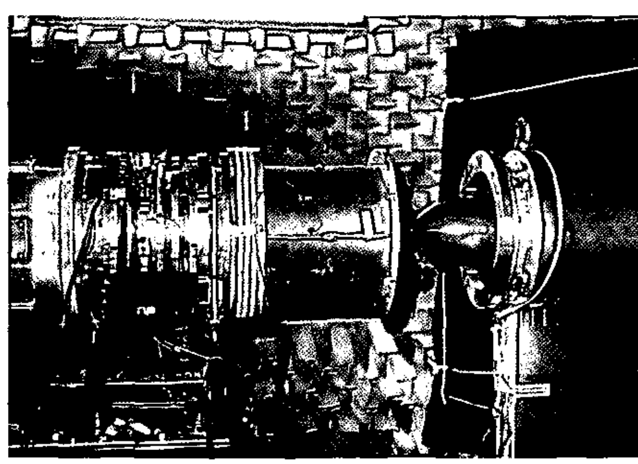


Fig. 4 – The experimental set-up in the Anechoic Wind Tunnel (left: microphone traverse system, middle: Northrop Grumman spliceless liner, right: NLR fan model)

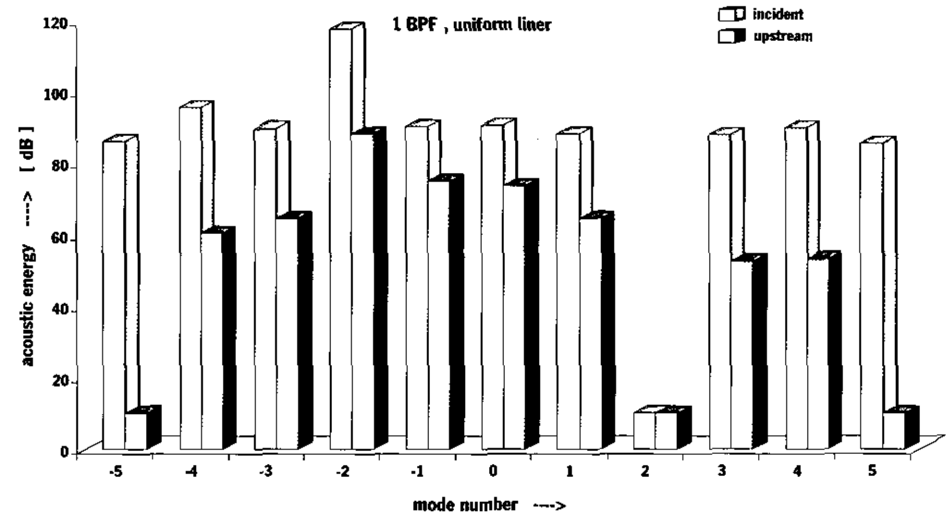
Test Programme

The test programme was defined in consultation with Northrop Grumman. Several liner configurations, with the number of splices ranging from 1 to 3 and with various widths of the splices, were studied. The area of covered liner varied between 1 and 12 per cent of the total liner area. Tests were carried out for two liner lengths (axial dimension): one duct diameter and a half duct diameter. The nominal shaft speed of the rotor was 6650 rpm.

Experimental Results

The acoustic field incident on the lined sections is dominated by the expected Tyler and Sofrin interaction modes. Their frequencies and mode numbers had the expected values listed in Table 1. In the case of a uniform liner, the incident modes are only attenuated: their amplitudes change but there is no creation of additional modes. The attenuation depends on frequency and mode number.

A typical result is shown in Figure 5, where the incident and transmitted acoustic energy fluxes per mode number are compared. The total damping at 1 BPF (Blade Passing Frequency) amounts to 30 decibel. At 3 BPF the damping is much lower: about 12 decibel.



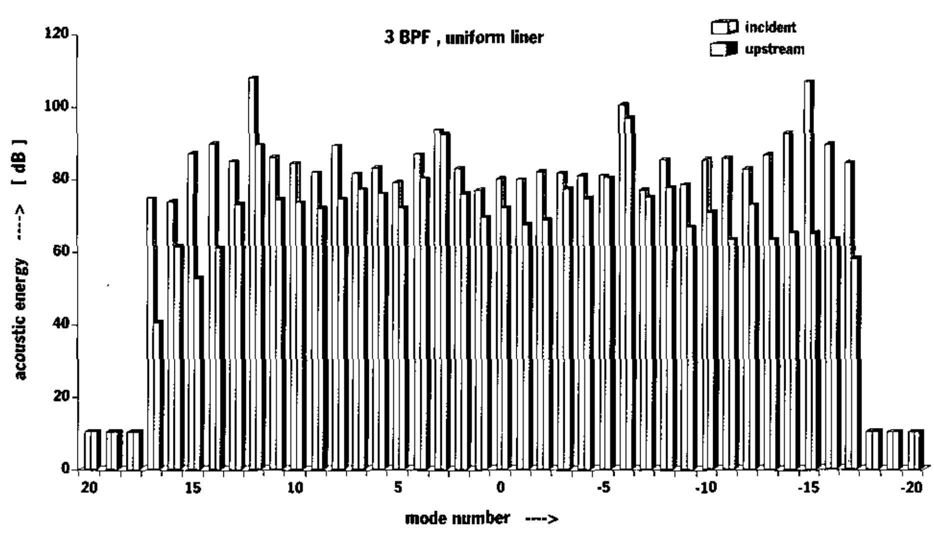


Fig. 5 – Comparison between the upstream acoustic energy fluxes in absence or presence of the uniform liner, 1 and 3 BPF

To illustrate the scattering of modes and the adverse effect on the attenuation, a result of the previous test on scattering of modes of low order is shown in Figure 6. The incident (downstream) acoustic field is dominated by a mode of order 3. The figure shows the comparison of the upstream in-duct acoustic energy fluxes per mode of a liner with three strips to those of the uniform liner. The attenuation by the liner is decreased, in this case by 4 decibel. Furthermore, acoustic energy is transmitted by additional modes, which are due to the interaction with the splices, causing scattering of the modes and an additional loss of liner performance. The mode numbers of the newly created modes differ by a multiple of three from the incident mode (mode number 3) and are absent in the case of a uniform liner. Qualitatively the same physical features have been found in the latest experiment on modes of higher order.

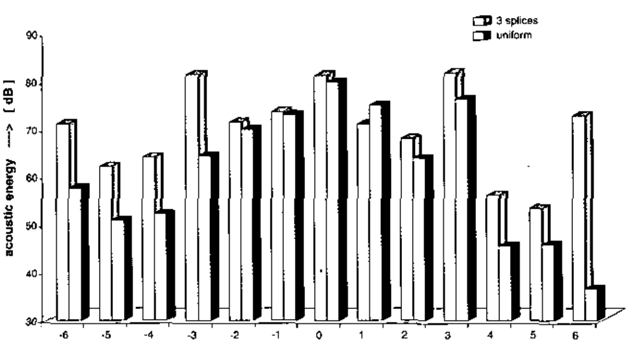


Fig. 6 – Scattered m-mode spectrum of a liner with three splices with an incident mode with mode number 3 at 2330 Hz

Concluding Remarks

Noise measurements during fly-over of the Fokker 100, in which the standard intake liner with three splices was replaced by a single-spliced liner of Northrop Grumman, showed significant noise reduction at approach and cut-back conditions. These results, obtained from a co-operation of Fokker, Northrop Grumman, and NLR, were published in the early nineties. In the present experimental investigation, the adverse effects of splices were studied further. It was confirmed that the reduction of liner performance can be ascribed to both the reduced effective liner area and the scattering of interaction modes to modes which are less attenuated.

The increased knowledge on the effect of splices has led to industrial applications. In the design of the intake of the Pratt and Whitney PW4000 engine powering the Boeing 777, special care was taken to minimize the adverse effects of liner splices on attenuation. Secondly, Dutch airlines recently modified the intakes of the CFM-56 turbofans mounted on their Boeing 737s by reducing the non-uniform (or spliced) liner area, obtaining an additional fly-over noise reduction of about 2 decibels.

The noise exposure experienced by communities neighbouring airports urges further reduction of aircraft noise. Considering the fan noise reductions which may result from the installation of spliceless intake liners, it makes sense to explore the benefits of this measure in more detail, although it entails higher manufacturing costs. The overall effects of installing spliceless lined intakes will depend on engine and aircraft type and on operating conditions.

2 Robust Flight Control: The GARTEUR Design Challenge

Under NLR's chairmanship, twenty-three European aircraft manufacturers, research establishments and universities have collaborated in a project aimed at improving the efficiency of the design process of flight control laws. The project has focused on treating parameter variations and uncertainty in aircraft models more systematically than before, by applying modern robust control techniques. An industrial evaluation of thirteen techniques as applied in twenty-one designs has shown that modern control methods should be considered to complement the techniques that are currently used by the aeronautical industry.

Introduction

An increasing number of aircraft fly by wire, with digital flight control systems allowing pilots to control aircraft states, rather than controlling engines and control surfaces directly. These flight control systems give new opportunities to increase the overall level of safety through their flexibility enabling complex algorithms, referred to as control laws, to be implemented. Furthermore, fly-by-wire can contribute to improved dynamical behaviour. For example, certain military aircraft could not be flown without a stability augmentation system.

In the past, the control stick was typically connected with rods or cables to the control surfaces. Since then, increased economical, performance and safety demands have forced aircraft manufacturers to extend flight control systems to high levels of complexity. Performance benefits achieved by using advanced flight control systems, however, run the risk of being undone by high development costs.

In the development process of flight control systems, control laws designers assume a central position. Schematically, their work consists of the following sequence of activities. The first step is to derive a nonlinear dynamic model of the aircraft to be controlled. Getting familiar with the dynamical behaviour by means of trimming, stability and control analysis, nonlinear simulations (for stable aircraft) and understanding the influences of the modelling assumptions is most important at this stage. Linearization and linear simulation of the model are also performed. The next step is to define the controller architecture and to make an initial design which includes gain scheduling to cover the aircraft flight envelope. The control law is then implemented in the nonlinear model, for off-line and piloted simulation. This sequence may be repeated to optimize the design.

In the current industrial development process, high non-recurring costs are involved, because a time-consuming trial-and-error approach is used to achieve a satisfactory result. This trial-and-error approach should guarantee that the closed-loop system is robust against the large number of parameter variations and model uncertainties that influence the design.
Especially when control laws have to be redesigned in a late stage of the aircraft development process, this approach becomes expensive, because extensive tests must be performed to validate the controlled system for each iteration. Each update also affects the work carried out in related disciplines such as system loads and structural dynamics analysis, which may cause substantial additional costs.

In order to investigate the possibility of achieving a mature design of the control laws in an early phase of the development programme, GARTEUR, the Group for Aeronautical Research and Technology in Europe, established the Flight Mechanics Action Group (FM) AG-08, 'Robust Flight Control in a Computational Aircraft Control Engineering Environment' in October 1994. The Action Group was chaired by NLR, with ONERA *(Office National d'Études et de Recherches Aérospatiales)* providing the vice-chairman. Its objective was to contribute to improving the efficiency of the industrial flight control laws design process for civil and military aircraft, by demonstrating the application of modern control techniques. These robust control methods take into account model uncertainties and parameter variations explicitly.

GARTEUR Action Group (FM) AG-08

Twenty-three organizations from seven European countries participated in the Action Group carrying out basic, pre-competitive research.

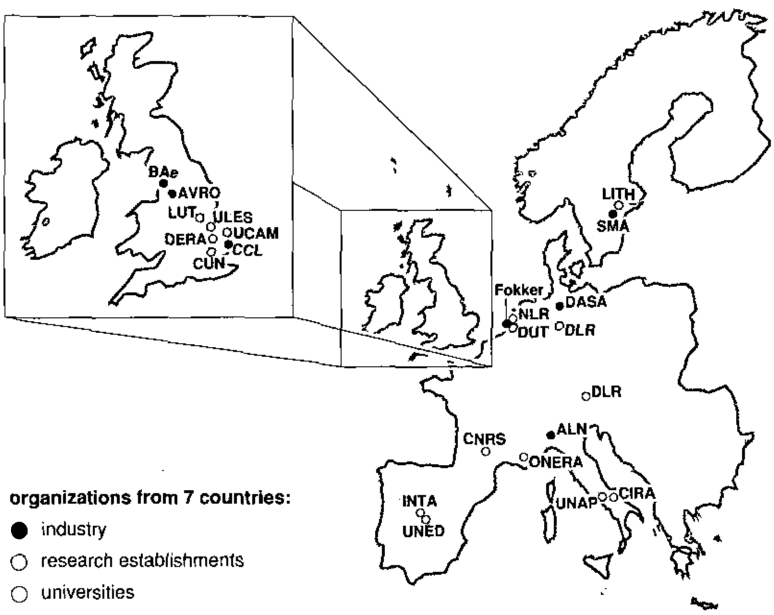


Fig. 1 – Organizations participating in GARTEUR Action Group (FM) AG-08

Seven research establishments, eight industries and eight universities participated:

Aeronautical Research Establishments

- Centro Italiano Ricerche Aerospaziali (CIRA) of Italy
- Deutsches Zentrum für Luft- und Raumfahrt (DLR) of Germany
- Defence Evaluation and Research Agency (DERA) of the United Kingdom
- Instituto Nacional de Técnica Aeroespacial (INTA) of Spain
- Laboratoire d'Automatique et d'Analyse des Systèmes of France
- National Aerospace Laboratory NLR of the Netherlands
- Office National d'Études et de Recherches Aérospatiales (ONERA) of France

Industry

- Alenia Aeronautica of Italy
- Avro International Aerospace of the United Kingdom
- British Aerospace, Dynamics of the United Kingdom
- British Aerospace Military Aircraft of the United Kingdom
- Cambridge Control of the United Kingdom
- Daimler-Benz Aerospace Airbus of Germany
- Fokker Aircraft Company of the Netherlands
- Saab Military Aircraft of Sweden

Research Organizations: Universities

- Cranfield University of the United Kingdom
- Delft University of Technology of the Netherlands
- Linköping University of Sweden
- Loughborough University of the United Kingdom
- University of Cambridge of the United Kingdom
- University of Leicester of the United Kingdom
- Università di Napoli 'Fedirico II' of Italy
- Universidad Nacional de Educación a Distancia of Spain

The Robust Flight Control Design Challenge

At the outset it was recognized that a thorough demonstration of modern design techniques, applied to genuine flight control problems, was required in order to get the desired feedback from industry. The state-of-the-art with respect to modern robust control should be demonstrated in a way relevant to the aircraft industry. At the same time it was the intention to clarify what is needed for a design method to be accepted by an industrial design office. To achieve this, control engineers from industry were asked to give inputs for two benchmark problems, which were subsequently developed by people from research establishments and universities. The first benchmark problem, RCAM (Research Civil Aircraft Model), is based on the automatic landing of a large, modern cargo aircraft.

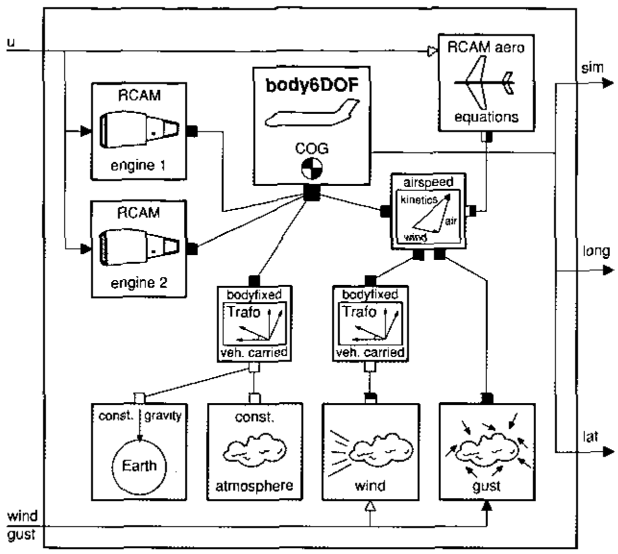


Fig. 2 – Dynamic objects of the Research Civil Aircraft Model (RCAM). Connection arrows between objects characterize physical interactions (source: DLR)

The second benchmark problem, HIRM (High Incidence Research Model), considers the control of a military aircraft across a wide design envelope.

Both benchmarks are based on six-degrees-of-freedom mathematical aircraft dynamics models, defined in Matlab/Simulink software. They include aerodynamic, engine, atmosphere and gravity models. In addition, actuator and sensor characteristics are taken into account, together with models for wind, atmospheric turbulence and windshear. An extensive set of design requirements is given, which can be tested with software for frequency and time domain evaluations. To make the benchmarks realistic, parameter variations are specified and some hardware implementation issues are considered.

It was decided to limit the scope of the demonstration of the techniques to design and computer simulations. Twenty-one teams have participated.

They have applied the following techniques:

- Lyapunov Methods
- Space Parameter Methods
- H_∞ Mixed Sensitivity
- H_∞ Loop-Shaping
- Linear Quadratic Optimal Control
- Predictive Control
- μ-Synthesis
- Multi-Objective Parameter Synthesis
- Fuzzy Logic Control
- Eigenstructure Assignment
- Non-linear Dynamic Inversion
- Robust Inverse Dynamics Estimation
- Classical Control

The designs have been evaluated by a large group of control engineers primarily from the European aeronautical industry under the supervision of British Aerospace for the HIRM designs and of Daimler-Benz Aerospace Airbus for the RCAM designs.

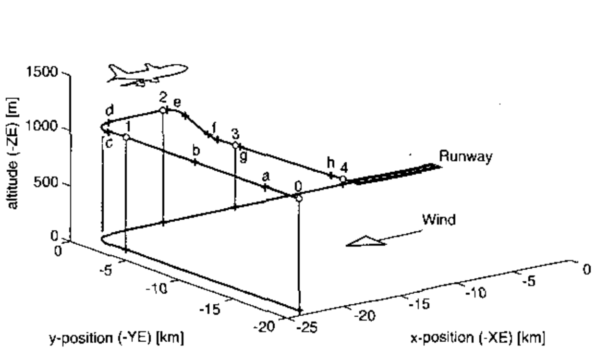


Fig. 3 – The landing approach for RCAM

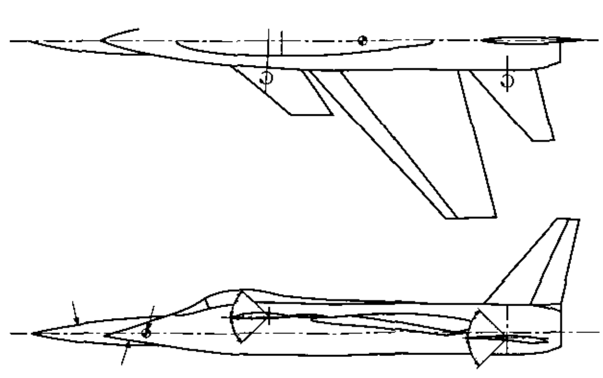


Fig. 4 – High Incidence Research Model (HIRM) configuration (source: DERA)

An Industrial View on the Design Challenge

The major European aircraft manufacturers, Aérospatiale, Alenia, British Aerospace, DASA, Fokker Aircraft and SAAB, have contributed to the Design Challenge, because it provided a cost-effective means of evaluating various design techniques in a short period of time.
Their motivation is driven by economical requirements. The use of new methods would be justified if:

- a satisfactory design would be impossible to achieve with the existing approach;
- the new method would provide a quicker and/or more cost-effective means to achieve a similar design;
- a lower level of skill would be sufficient due to inherent possibilities for automation;
- system simplifications could be achieved.

New methods are introduced into the industrial development process conservatively, because of the investments in trained people, software tools, etc. New methods will only be adopted if the benefits are quantified and the associated risks are acceptable.

Typical industrial considerations for the application of design techniques are the following. Flight control systems are designed to be capable of providing good aircraft handling qualities over a wide range of operating conditions. At any stage of the design process, a competent engineer other than the original designer may inherit design responsibility and must be able to take over the design without undue difficulty. From a wider perspective, visibility of the functionality of the design is important, as a range of specialists and managers need to work with the control laws. It is essential to keep in mind that the controller algorithms need to be executed in real time in the aircraft's flight control computer. Finally, the availability of appropriate software tools, the investments for the training of designers, and a straightforward flight clearance process are of interest.
In summary, four issues are important to the industry:

- the effort to learn, to implement and to apply the method;
- the applicability of the design method to flight control laws design;
- the complexity of the resulting controller, its implementation and certification issues;
- the robustness and performance of the controller.

Evaluation

The issues important to the industry have been elaborated in an evaluation questionnaire that was used by a group of experienced flight control professionals to assess the design reports. One questionnaire was used for both HIRM and RCAM.

The HIRM challenge poses a relatively straightforward task, compared with current industrial design problems, particularly for aircraft with high levels of inherent instability. To simplify the task, air compressibility effects did not have to be considered. A wider flight envelope should be considered in a follow-on project, because this will enforce gain scheduling to show the true complexity of some of the controllers proposed. Furthermore, it is recommended to include the effects of the aircraft centre of gravity moving fore and aft, since this would have provided a good robustness test with a simple physical interpretation. Notwithstanding these comments, it is considered that given the limited time available to the design teams, the problem as defined was suitable for its purpose.

The RCAM benchmark is based on a simplified model of a civil transport aircraft that has well-behaved natural dynamics. The design mission, an automatic ILS (Instrument Landing System) approach without flare, represents a small but relevant sequence of a typical transport aircraft mission. Some commonly used measurements, which are available from the inertial reference systems, are not offered and were in some cases estimated by the design teams. For future projects it is recommended to add more demanding missions, to allow the potential of powerful methods to be better demonstrated. Nevertheless, the RCAM design task is much more realistic than typical academic problems and can become the benchmark problem for demonstrating new flight control design methods to civil aircraft manufacturers.

The Design Challenge has been a unique chance to benchmark new design techniques. The large number of design entries, thirteen for RCAM and eight for HIRM, reflects the high interest of universities and research establishments in flight control problems. Arguably there are many design techniques chasing relatively few real-life flight control applications. The techniques, however, have potential value for a wide range of engineering applications, and flight control provides a relevant, interesting and challenging platform for their development.

To achieve a satisfactory design, a suitable choice of the controller architecture, based on flight physics and mission demands, is more relevant than the synthesis method applied. The Design Challenge has reconfirmed that to establish a suitable architecture, the designer needs to have, as an absolute minimum, a good understanding of flight mechanics and flight control. Most design teams have used traditional flight control architectures, based on de-coupling the controllers for longitudinal and lateral motion, and hierarchical structures with an inner loop for stabilization/attitude control and an outer loop for guidance. As a result, in most cases only the low-level structure was influenced by the synthesis method.

Based on the Design Challenge, the expected benefits of using advanced design techniques rather than a classical design approach are associated with establishing a logical framework for managing the linear design, which explicitly includes both design specifications and modelling uncertainties. Another advantage is improved efficiency by the use of optimization algorithms.

Alternative measures of robustness were proposed. These should be beneficial over classical measures, provided they can be calibrated in terms of physical characteristics.

Disadvantages observed were associated with lacking visibility and high complexity, particularly if the controllers were of excessively high order and presented in state-space format. These aspects could be addressed by improved presentation and documentation of the controllers to provide total visibility and by further developments in model reduction techniques to reduce complexity.

In terms of specific developments of the methods, it is considered that the following areas should be addressed:

- controller visualization techniques;
- controller order reduction techniques;
- means of measuring design method benefits;
- development and calibration of robustness measures;
- non-linear analysis development (e.g. to cover rate limiting effects);
- design automation.

To complement the methods development work, industry needs to prepare further challenging and realistic benchmark problems, preferably based on existing aircraft, to enable the flight control researcher to address genuine industrial applications. There should be more discussions between research design teams and industry, to ensure that design requirements and constraints are fully understood and included in design studies.

Concluding Remarks

GARTEUR Action Group (FM) AG-08 has demonstrated what can be achieved if a project of mutual interest can be identified and resources aligned to achieve common objectives. Many new contacts were established; the project essentially created a network of flight control researchers across Europe. The activities were concluded in April 1997, when the Action Group presented its results at a two-day GARTEUR Specialists Workshop, attended by 120 delegates from the European flight control community.

The Action Group has spent much time on documenting its work. In total 36 technical publications have been written, most of which can be obtained via the Internet (http://www.nlr.nl/public/hosted-sites/garteur/rfc.html). The most significant output is a monograph which captures the majority of the technical work (Robust Flight Control: A Design Challenge; Springer Verlag LNCIS 224).

The project has revealed a wide gap between the industrial application of flight control and the majority of the studies being undertaken by the research community, which is relatively large. To some extent, the Design Challenge has proven that modern techniques can be used to design controllers for realistic problems. Additionally, it has confirmed that the requirements for industrial application of new techniques are quite severe. From an industrial point of view, desirable features of any new technique can be assumed to be: transparency, simplicity, quality, accuracy, fidelity, reliability, implementability, predictability and generality. Even though the applied methods have much potential in the field of improved robustness, better performance, decoupled control and simplification of the design process, some of them do not yet have the maturity required for industrialization. However, projects such as this one will help to narrow the gap by allowing a two-way exchange of information.

Improvements of the two benchmarks are within reach. For HIRM, for example, it would be interesting to allow a variation in the location of the centre of gravity to introduce relaxed aircraft stability. Design specifications for both benchmarks can be further improved and it may be advisable to propose controller architectures for a next Design Challenge, which would simplify the comparison of design methods. Extensions of the flight envelopes for RCAM and HIRM would make gain scheduling necessary in most cases. It would be interesting to see how advanced techniques cope with this additional complexity.

In Europe, aeronautical research and technology development projects are likely to be carried out more and more on a multinational scale. Such projects may benefited from two aspects of the present study. Firstly, twenty-three organizations worked together, in parallel but as a team, enabling results to be obtained in only two and a half years. Secondly, the close collaboration between many people from industry and the scientific community seems to have accelerated the process of bringing theory to practice.

3 Fuselage Panel Test Facility

A fuselage panel test facility has been designed and built at NLR Noordoostpolder. The facility is capable of performing static and fatigue tests on fuselage panels sufficiently large (3 m * 1.4 m) to contain significant structural details such as frame-skin connections.
The high testing frequency, 10,000 flights per 24 hours, limits the test duration.

The accuracy of the load introduction and the resulting panel stress distribution were evaluated in a panel test. Strain gauge readings taken during static tests showed a uniform strain distribution over the panel.

The panel test was used to evaluate a fuselage panel of glass fibre/aluminium alloy laminate (GLARE) made by Fokker, with a potential weight reduction of 37%. The panel, representative of the crown section of the Fokker 100 fuselage just in front of the wing, appeared applicable.

Introduction

Fuselage skins of most aircraft are subjected to biaxial loads, owing to pressurization of the fuselage during cruise at high altitudes. In evaluating damage tolerance properties of candidate fuselage skin materials it is therefore essential that these materials are tested under biaxial loading conditions.

Several years ago NLR developed a cruciform specimen that enabled biaxial fatigue and residual strength tests to be performed on flat coupons. Tests with this type of specimen are ideally suited as an early step in material evaluation programmes or for studying the behaviour of structural details in fuselages such as riveted joints.

The behaviour of cracks in curved structures, however, may differ significantly from that in flat structures. Thus, in fuselage design studies and development programmes there will always be a necessity to test components more realistically. For this purpose one generally uses a so-called barrel test set up. This is a full-size cylindrical pressure vessel consisting of several interconnected fuselage panels.

A barrel test set-up, however, has some features which make it less flexible and therefore less attractive for studies not directly related to a particular aircraft design:

- the radius of curvature is fixed;
- a large number of panels has to be tested simultaneously;
- the test frequency is rather low.

In addition, barrel tests are very expensive to carry out due to the high development costs of the set up and long testing times.

In view of the disadvantages of a barrel test set up, it seemed logical to develop a facility for testing fuselage skin sections that has a high degree of flexibility and can be run at a relatively high testing speed and low costs. Tests in such a facility could fill the gap between tests at the coupon level and full-size barrel tests. Such a facility could also be used to study the effects of design modifications following a barrel test.

NLR has therefore designed and built a fuselage panel test facility. The first panel test performed in the facility was also used to verify the stress and strain distribution in the panel. The design and the features of the test facility and the results of the first panel test are described below.

BRITE/EURAM Involvement

The development of the testing methodology and the initial design activities of the testing frame were done under contract to the European Commission in the BRITE/EURAM programme 2040: 'Fibre Reinforced Metal Laminates and Carbon Fibre Reinforced Plastic (CFRP) Fuselage concepts'. The final design and the manufacturing of the test facility were done under NLR's programme for facilities development.

The main reason for incorporating the development phase of the test methodology into the BRITE/EURAM programme was that the introduction of new materials such as GLARE and CFRPs and the introduction of new fuselage concepts were expected to require a large amount of testing.

Design Objectives

With the new facility it should be possible to carry out:

- tests on fuselage panels of aircraft types with widely different fuselage diameters, and with various stiffener and frame pitches;
- flight simulation fatigue tests simulating cyclic loads due to variations in cabin pressure and axial loads due to gusts and manoeuvres;
- residual strength tests on panels with relatively large, two-bay, fatigue cracks;
- fatigue tests at a relatively high test frequency.

In order to reduce the costs associated with a test on a particular panel, the number and complexity of the so-called panel-specific parts were kept to a minimum. In the design of the facility much attention was paid to the inspectability of the panels during the tests.

To specify the design requirements, three typical fuselage panels were considered: panels for the Fokker 50, Fokker 100 and Airbus A300 aircraft. The design loads for the test facility were derived from the fatigue and static design loads of the fuselage crown sections of these aircraft.

Test Panel Requirements

A typical fuselage panel that can be tested in the new test facility is shown schematically in Figure 1. The panel has a cylindrical shape and basically consists of a skin, stiffeners (longerons), frame sections and frame-stiffener connections. Obviously, the panels may contain several other structural details, such as:

- longitudinal or transverse joints;
- different frame-skin connections;
- window holes;
- crack stoppers.

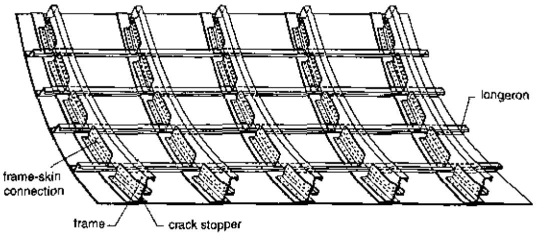


Fig. 1 – Typical fuselage panel

Maximum Panel Dimensions

The maximum length of panels to be tested was determined by the requirement that the facility should enable residual strength tests to be carried out on panels with a two-bay crack (a crack with a length of two frame pitches). In this case one bay at each end of the panel is required for redistribution of the stresses, such that the clamping conditions at the edges of the panel have no significant effect on the stress distribution in the area around the crack. If the axial loads are to be introduced through bolt holes in the skin, some additional length will be required for a gradual run-out of the stiffeners and for local reinforcements of the skin at the curved edges. To allow for a frame pitch of about 0.5 m, the facility can accommodate panels with lengths up to at least 3 m.

The facility is primarily meant to perform tests on upper fuselage panels. It should, however, also allow so-called fuselage side wall panels, panels which include a window bay, to be tested. It was anticipated that a typical side wall panel would consist of a window bay that includes the window frame and four stringers, two above and two below the window. To allow for a stringer pitch of 0.15 m, the facility can accommodate panels with a width of up to at least 1.3 m.

The panel dimensions specified above are not rigid limitations. Larger panels can be tested after slight modifications to the facility.

Fig. 2 – The fuselage panel test facility

The Fuselage Panel Test Facility

Figure 2 shows the facility. An assembly drawing of the test fixture is given in Figure 3. During the final stage of the design, the test facility was fine-tuned for tests on Fokker 100 upper fuselage panels.

The major components of the test facility are the main frame and the pressure chamber. One of the innovative features is the way of introducing the hoop loads.

Main Frame

The main frame is a very stiff steel structure, high stiffness being required to ensure uniform stress distributions in the test panels. The frame consists of heavy bottom and top beams and two vertical main columns, as shown in Figure 3. In addition, there are two auxiliary vertical columns. A pyramidal steel frame, which houses the hydraulic actuator, is mounted on the top beam and the auxiliary vertical columns. The total mass of the main frame is about 28,000 kg. The height of the test facility is about 7.2 m and the width is about 4.5 m.

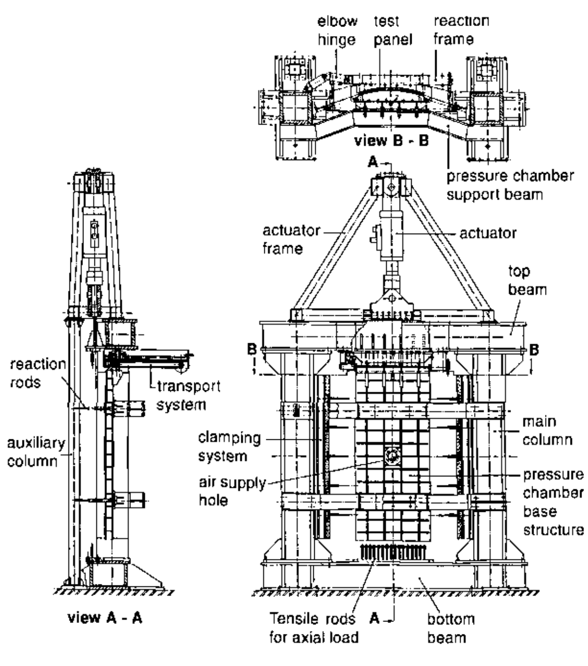


Fig. 3 – Assembly drawing of the test fixture

Load Introduction Concepts

Tangential Load Introduction

Pressurisation of a fuselage results in the development of tangential stresses (or hoop stresses) in its skin. The fuselage frames will prevent free expansion of the skin and attract some load. The stress level in the frames will largely depend on the stiffness of the frame-skin connection. To obtain a proper (and adjustable) ratio of the stresses in the skin and frames of the panels to be tested, the loads into skin and frames are introduced by two separate loading mechanisms. The load introduction concepts applied for the skin and frames are shown schematically in Figure 4.

The skin of the test panels is connected to the main frame through the following elements (see Figure 4):

- composite sheets;
- steel joining pieces;
- steel, tangential plates;
- adjustable clamping arrangement.

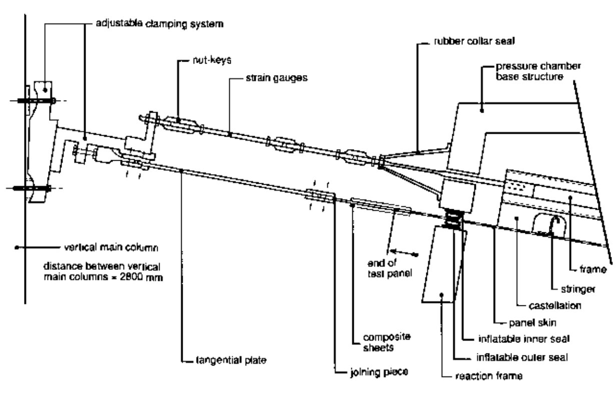


Fig. 4 – Schematic of the tangential load introduction system, showing the connection of the panel skin and the panel frames to the main frame of the test rig

For the introduction of the tangential loads, specially prepared composite sheets are bonded to the edges of the panel. These composite sheets consist of single-ply unidirectional woven glass fibre bonded to the panel edge and bonded to a steel joining piece (see Fig. 4). The steel tangential plates are connected to the adjustable clamping arrangement bolted to the main frame.

One advantage of using unidirectional fibre weaves is that the loads are introduced evenly over the length of the panel. Therefore hardly any distance is required for stress redistribution. In addition, the use of unidirectional fibres does not result in local stiffening of the panel edges in the axial direction.

The panel frames are loaded separately by means of tensile rods. At one end the rods are connected to the tangential clamping device and at the other end to the locally reinforced panel frame. The length of the rods is adjustable with nut-keys. A load cell is incorporated in the load introduction mechanism of each panel frame. Using the nut-keys and the output of the load cell, the load in each panel frame can be adjusted to the desired level, to match a specified ratio of skin and frame loads.

Axial Load Introduction

In an aircraft fuselage, axial skin stresses originate from cabin pressurisation and from fuselage bending due to gusts or manoeuvres. In the present test facility, all axial loads are introduced into the fuselage panel by a single hydraulic actuator. For the Fokker 100 upper fuselage GLARE panels it was decided to introduce the axial loads directly into the skin through a series of 16 adjustable tensile rods with self-adjustable sleeve bearings at the rod ends, as shown in Figure 5. The curved panel ends are locally reinforced to account for the reduction in cross-sectional area and the stress concentrations associated with the bolt holes. To simplify the sealing of the pressure chamber at the top and bottom of the panel, the end sections of the panel are not stiffened. This has made it possible to seal directly on the skin of the panel.

At one side the axial tensile rods are connected to rod mounting plates. The bottom rod mounting plate is directly bolted to the bottom beam of the main structure (see Fig. 5), and the top rod mounting plate is bolted to a trapezoidal plate that distributes the axial load equally over all tensile rods. This load distribution plate is connected to the lug of the actuator using clamping plates.

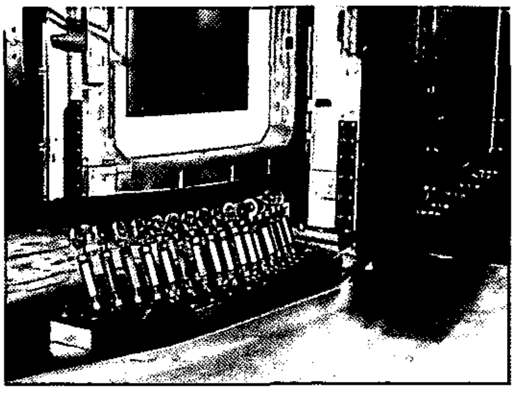


Fig. 5 – Axial load introduction system (bottom edge of the panel)

Each tensile rod is equipped with strain gauges. At the start of the test, the length of each tensile rod can be adjusted with nut-keys such that a uniform stress distribution is achieved over the panel width when the panel is loaded. The axial loads are measured with a load cell mounted between the upper load distribution plate and the hydraulic cylinder.

The connection of the tensile rods to the panel is outside the pressure chamber, and the panel is sealed directly on the skin. This keeps the sealing of the pressure chamber simple.

Pressure Chamber

The main parts of the pressure chamber are the base structure, the so-called reaction frame and the seals. A transport system is incorporated in the test fixture. With this transport system the complete base structure can easily be shifted aside during the test, which significantly improves the inspectability of the test panel at the pressurised side.

During tests, the chamber is pressurised with air supplied by a large power unit. Air was preferred to water since it is the more realistic choice. In addition, the use of air allows for a vertical position of the testing rig without causing a pressure gradient over the length of the panel (as would occur if water was used).

During tests, the pressure chamber is filled with foam blocks for about 85%. The remaining volume of the chamber was about 0.5 m^3 in the Fokker 100 panel test.

Base Structure

The base structure of the pressure chamber is formed by a stiffened steel base plate and two heavy steel support beams which are bolted to the vertical columns of the main structure. The base plate has a large central hole for air supply.

At the front, the base plate has wooden blocks around the edges which form the side walls of the pressure chamber (see Fig. 5). The wooden blocks are bolted to the base plate using a sealant between the blocks and the base plate. The curvature of the blocks at the top and bottom sides obviously corresponds to the curvature of the test panel. At the front, the pressure chamber is closed by the panel. The inflatable inner seal is mounted on the wooden blocks.

Reaction Frame

In order to accomplish an air-tight seal between the base structure and the panel surface, the inner tube seal is inflated such that its surface is pressed against the panel skin. However, the use of a single seal at one side of the panel would result in radial forces along the panel edges, which obviously is not a very realistic loading situation. A second seal is therefore applied, at the outside of the panel just opposite the inner seal. When both seals are pressurised the forces exerted by the inner seal are more or less counterbalanced by the forces exerted by the outer seal, such that there is almost no net radial force acting on the panel edges during tests.

The outer seal is mounted on the so-called reaction frame, which consists of an open rectangular steel frame with wooden blocks bolted to it. The outer seal is bonded to the wooden blocks in the same way as the inner seal is bonded to the wooden blocks of the base structure.

Seals

The gap between the wooden blocks of the base structure and the surface of the test panel is sealed air tight with an inflatable, silicone fabric reinforced tube seal, which is bonded to the wooden blocks as schematically shown in Figure 4. The use of inflatable seals has the advantage that it allows for relatively large variations in the size of the gap during the test without significant air leakage. In order to keep the radial loads resulting from the seals as low as possible, the pressures in the inner and outer seals are controlled.

Tests on a GLARE Fuselage Panel

Objectives

Under the BRITE/EURAM IMT 2040 project 'Fibre reinforced metal laminates and CFRP fuselage concepts', Fokker built two panels representative of the crown section of the Fokker 100 fuselage just in front of the wing, using the glass fibre/aluminium alloy laminate type GLARE A as skin material. One of these panels has been tested in the NLR fuselage panel test facility. It had a GLARE A (thickness 0.85 mm) skin and GLARE N (thickness 1.4 mm) stringers. In the frame-skin attachments the frames were connected to the stringers by means of cleats, instead of to the skin by means of castellations as was normally done.

A comparison of a complete GLARE A top section with GLARE N stringers and rigid stringer-frame attachments to the Fokker 100 design shows a weight reduction of 37%.

The test panel, 1210 mm wide and 3030 mm long, contained five aluminium frames, seven stringers and a longitudinal riveted lap joint in the centre. Three types of frames were used: a Z-shaped frame, a thin C-shaped frame and standard C-shaped frames.

The objectives of the test were threefold:

- Verification of the applicability of GLARE A as a fuselage skin material for loading conditions which are representative of the crown section of the Fokker 100 fuselage;
- Generation of test evidence on the static strength and fatigue behaviour of rigid stringer-frame attachments in the GLARE fuselage;
- Determination of the deterioration of the static strength of the GLARE skin (lap joint, skin-stringer) after two times the design life (two times 90,000 flights).

Panel Loads

For the test panel, the static load cases and fatigue spectrum were derived from those representative for the Fokker 100 aircraft (take-off weight 98,000 lbs). The fatigue spectrum consists of 36 repeating test blocks of 5000 flights. The axial loads consist of loads due to cabin pressurization and bending loads due to taxiing and gusts. Each flight has five segments: ground, initial climb (flaps out), climb/ descent, cruise and approach (flaps out). The circumferential load sequence is less complicated. During the ground segments the cabin pressure (Dp) is zero, during the cruise segment 7.45 psi (0.514 bar).

For the static tests the panel is subjected to one Limit Load case, the relief valve setting (Dp = 7.75 psi) plus the maximum limit bending moment. The Limit Load test is followed by two Ultimate Load tests. The first Ultimate Load case is twice the cabin pressure. The second Ultimate Load case is 1.5 times the cabin pressure plus 1.5 times the bending moment. For the failure strength test the applied loads are: the relief valve setting (Dp = 7.75 psi) and an increase in the axial load until failure of the panel.

Testing and Results

During a fatigue test, up to 180,000 flights, both visual and eddy current inspections were performed, but no cracks or damage were found. The testing frequency was about 10,000 flights per 24 hours. The fatigue test, including the inspections, was performed within five weeks.

The fatigue test was followed by a Limit Load test and two Ultimate Load tests to demonstrate the residual strength. The panel did not fail during the Limit Load test or during the Ultimate Load tests. During all tests, strain gauge readings were taken to verify the strain or stress distribution in the panel. In Figures 6 and 7 the tangential and the axial strain distributions in the panel are given for different load steps up to Limit Load. The dip in the tangential strain distribution is caused by the longitudinal lap joint in the panel at that location. A smooth axial strain distribution is observed. Clearly visible is the small contribution of the cabin pressure to the axial strain levels. The influence of the bending moment on these axial strain levels is much larger.

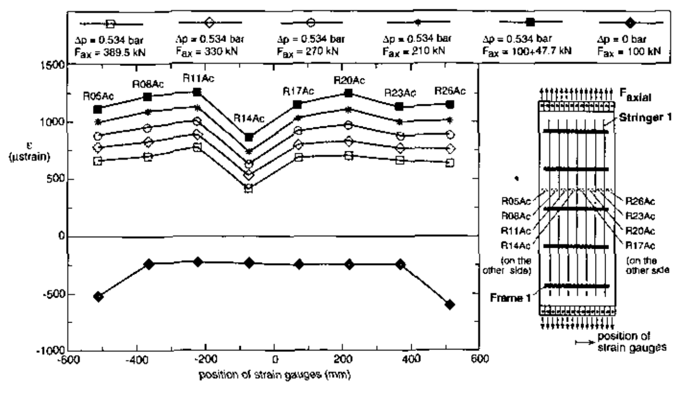


Fig. 6 – Tangential strains during the Limit Load test

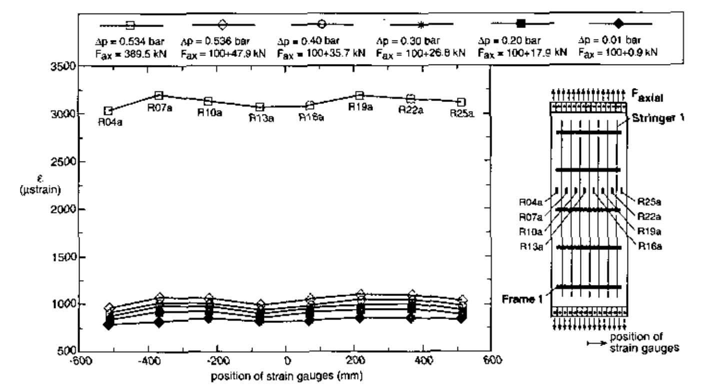


Fig. 7 – Axial strains during the Limit Load test

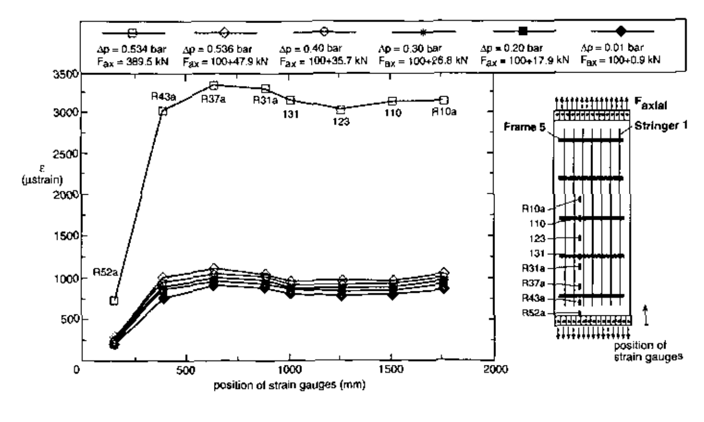


Fig. 8 – Axial strains during the Limit Load test

Figure 8 gives the axial strain levels from station zero (bottom of the panel in the test facility) until the fourth frame. Clearly visible is the pillowing of the skin in the second bay and the lower axial stress in the third and fourth bay, caused by the stringers couplings and difference in stiffness of the frames (the second is a Z-shaped frame, the third is a thin C-shaped frame and the others are standard C-shaped frames).

Finally, a failure test was done, where the cabin pressure was kept constant at Dp and the axial load was increased. Failure occurred at an axial load of 770 kN, 15% higher than the theoretically expected axial failure load of 656 kN.

Figures 9 and 10 show the panel after failure. The skin failed between the third and fourth frame at the cross-section of the last rivets of the stringer couplings. The second and sixth stringer delaminated and cracked at the rivets of the cleats of the fourth frame.

The conclusion after the fatigue and static tests is that, in the crown section of the Fokker 100, GLARE A as fuselage skin material and GLARE N as stringer material are applicable. The rigid stringer frame attachments (cleats) had enough fatigue and static strength.

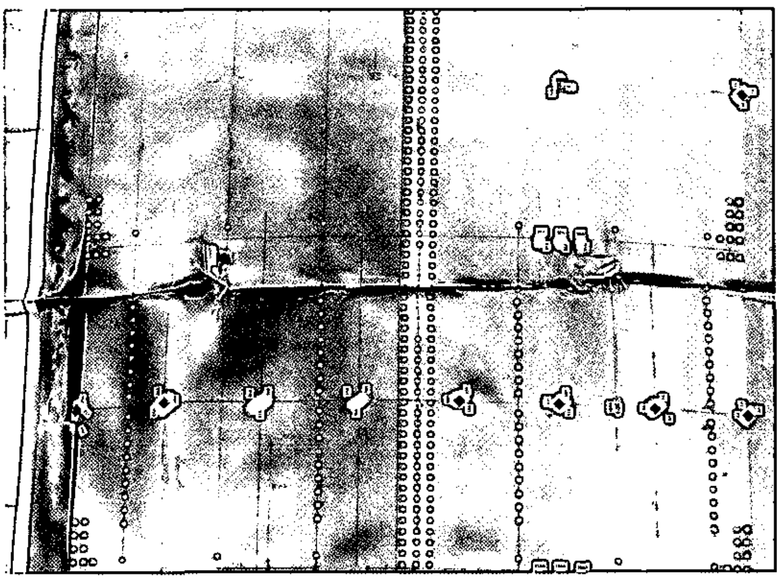


Fig. 9 – Detail of the outside failure area

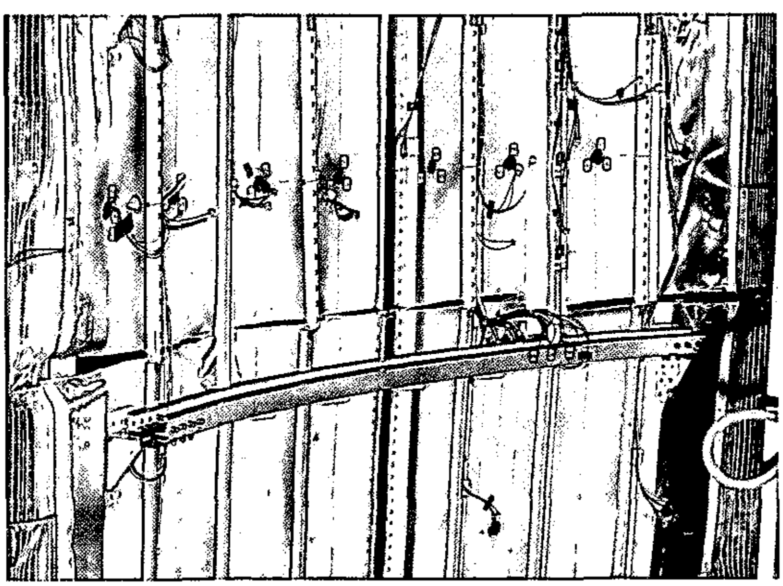


Fig. 10 – Detail of the inside failure area

4 Test and Verification Equipment for Spacecraft Attitude and Orbit Control Systems

New-generation Test and Verification Equipment (TVE) has been developed for use in the integration and testing of Attitude and Orbit Control Systems (AOCS) of spacecraft. This TVE is a successor to an earlier test station used in several satellite projects. The first TVE was built for the European Space Agency (ESA) as a prototype demonstrating the new standard test station featuring re-usable hardware and software for various satellite projects. Based on this TVE, test equipment has been developed for Matra Marconi Space of the UK for the AOCS subsystem level testing of the scientific satellites X-ray Multi-Mirror mission (XMM) and International Gamma-Ray Astrophysics Laboratory (Integral). The system level testing of the XMM takes place at DASA Dornier, in Germany, and that of the Integral at Alenia Spazio, in Italy.

XMM and Integral Satellites

The scientific satellites X-ray Multi-Mirror mission (XMM) and International Gamma-Ray Astrophysics Laboratory (Integral) belong to ESA's Horizon 2000 long-term programme.

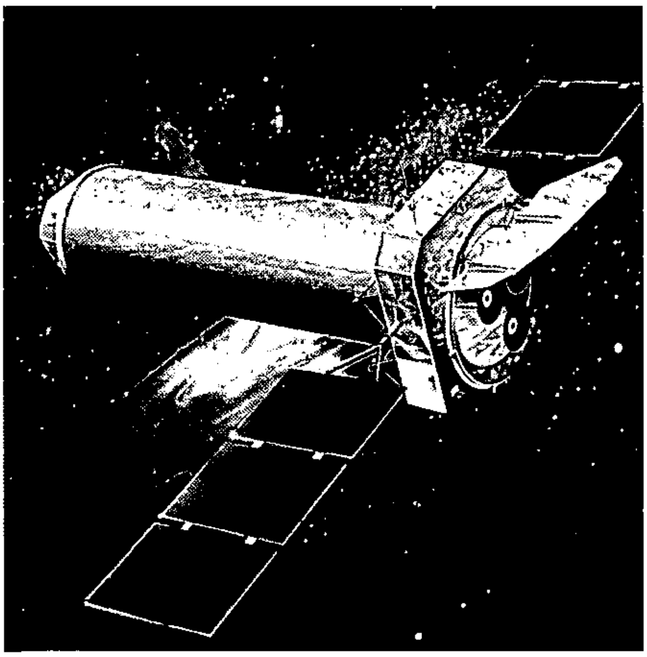


Fig. 1 – Artist's view of X-Ray Multi-Mirror Observatory

XMM is an observatory dedicated to the soft X-rays portion of the electromagnetic spectrum. The X-ray telescope consists of three large mirror modules and associated focal plane instruments, held together by the telescope central tube with a length of 6.8 m. An artist's view of XMM is shown in Figure 1. XMM will be placed in a highly eccentric orbit which allows long observations of X-ray sources to be made. These observations are aimed at investigating the structure and heating mechanism of stellar coronae, the mass exchange in binary systems (double stars) and hot plasma in galaxies. XMM, with a resolution of 20 arcsec, will be able to observe the density and temperature distribution of hot gas in galaxies that are bright extended X-ray sources.
XMM has also the capability to look with a low exposure extremely deep in the universe, enabling objects to be studied that were created when the universe was very young.

Integral is dedicated to fine spectroscopy and fine imaging of celestial gamma-ray sources in the energy range 15 keV to 10 MeV, with concurrent source monitoring in the X-ray and optical energy ranges. Gamma-ray astronomy explores the most energetic phenomena that occur in nature. It addresses fundamental problems found in astrophysics and phenomena such as nova and supernova explosions, interstellar medium, neutron stars, black holes and gamma-ray bursts. Gamma rays allow us to look deeper into these objects, which often radiate much of the power at gamma-ray energies.

The XMM and Integral satellites use almost identical service modules. These modules contain the attitude and orbit control, the onboard data handling, the power supply with solar panels, the radio frequency system and the associated structure with thermal control.

For testing the Attitude and Orbit Control subsystems of these and similar modules, new Test and Verification Equipment (TVE) has been developed. This TVE is used in subsystem-level testing and system-level testing in the satellite assembly, integration and test phases for both the XMM and Integral satellites.

Generic Design

The Test and Verification Equipment (TVE) has been developed under contract to ESA's European Space Technology and Research Centre (ESTEC), in close co-operation with Fokker Space and Adelsy of Switzerland. The design of the TVE is generic. It employs a special Front End to interface with on-board data buses of spacecraft. It has been extended with stimuli and monitoring equipment for the XMM and Integral satellites. The TVE uses VME standard technology, and is controlled by TVE test software and user-defined simulation software running on a workstation.

The test software is built around the simulation support tool PROSIM (Programme and Real time Operations Simulation), developed primarily for the NLR Research Flight Simulator. This test software provides the user with the tools necessary to operate the AOCS under test through the TVE Front End. The equipment under test, in particular the embedded AOCS on-board control software, has to be offered an environment closely resembling the in-orbit environment. Therefore, the test software enables project-dependent models of all relevant parts of the spacecraft (dynamics, unit behaviour) and the orbital conditions to be included. The test software contains an extensive set of commands and interfaces to the TVE Front End.

The XMM project, which was started during the final pase of the TVE development, is the first application of the TVE to real AOCS integration and testing. The Integral project followed, with the same TVE baseline for AOCS testing.

Test Concept and Test Configuration

In the integration and test phase, spacecraft AOCS subsystems are gradually built up as their components become available. Verification of attitude control modes and real-time performance is done in the early part of the integration phase, using a combination of real and simulated units. The test equipment allows partially or fully integrated AOCS subsystems to be tested realistically, supporting the required incremental test approach.

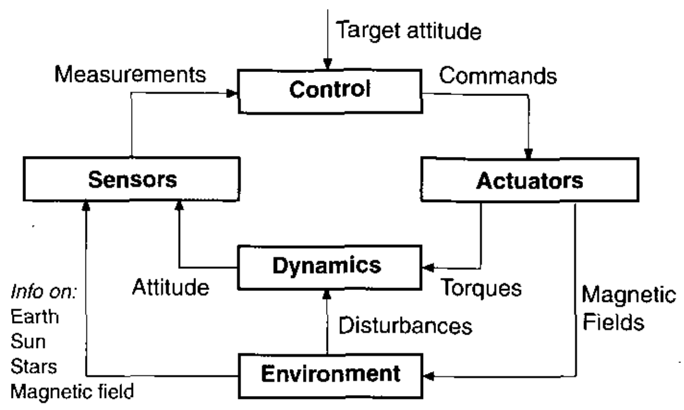


Fig. 2 – Generic attitude control system

Figure 2 gives a schematic overview of a generic AOCS for spacecraft. The diagram also reflects the cyclic nature of such systems.
A complete AOCS system, including dynamics and environment, can be considered as a loop which is actively closed by the Attitude Control Computer (ACC). Therefore the minimal closed loop test configuration contains an ACC interacting with at least one real or simulated sensor and one real or simulated actuator via the Modular Attitude Control Subsystem (MACS) bus and adequate simulation models for satellite dynamics and space environment.
In realistic test configurations, the ACC, the sensors and the actuators are real units, as in the AOCS test configuration shown in Figure 3. In this case the simulation software provides the computation of stimuli for the sensor unit and the processing of monitor data from the actuator unit. The stimulated sensor will deliver sensor measurements to the ACC via the MACS bus. In the ACC the received data will be fed into the attitude control laws, which results in commanding of the actuator unit. The response of the actuator unit is measured with a monitoring device of the Front End and routed back to the corresponding simulation software model. In this way the loop is closed.

If the loop is cut somewhere, because of missing elements or connections, the configuration is referred to as 'open loop test configuration'. A closed loop test configuration with simulated ACC functions is a 'pseudo-closed loop test configuration'.

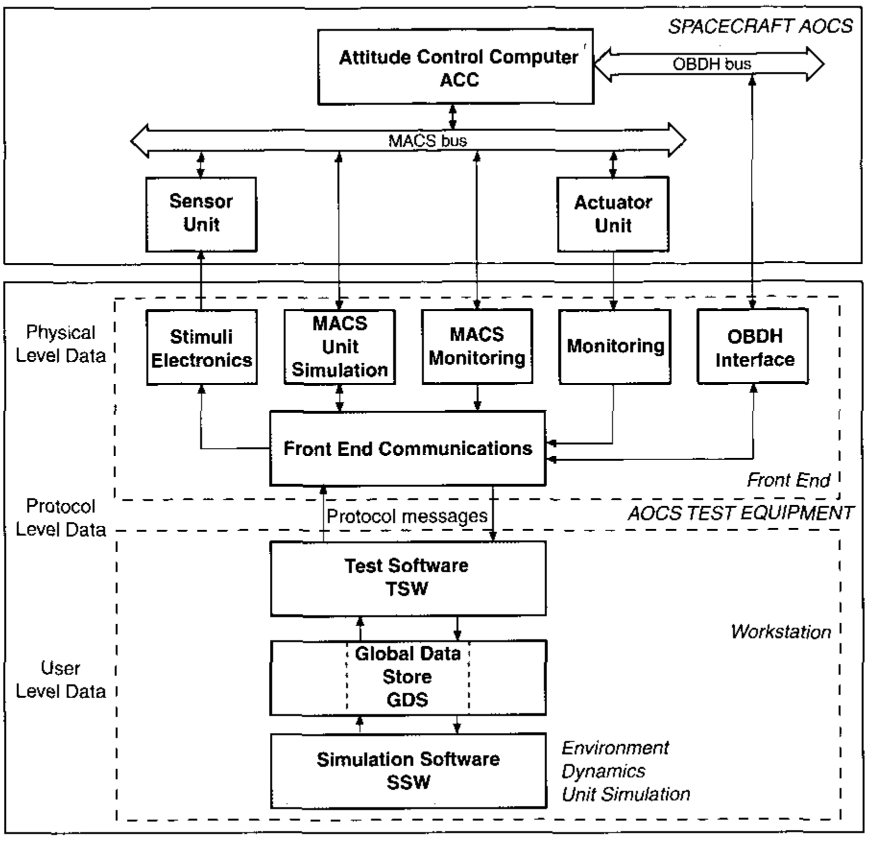


Fig. 3 – AOCS closed loop test configuration

During a test, all MACS bus events can be 'read' with the MACS monitoring function of the Front End, the MACS spy function. The MACS interface is programmable to reflect any combination of real and simulated units. If the real sensor and/or actuator unit are not yet available, they can be electrically simulated with the MACS simulator function of the Front End.

TVE Front End

The TVE has been extended for the XMM and Integral satellites. It consists of a modular VME system and two workstations.

The modular VME system of the Front End includes various units:

- Interfaces to the Onboard Data Handling bus, including the Remote Terminal Unit simulator;
- Interface to the MACS bus with the capability of AOCS unit simulation;
- Stimuli and Monitoring electronics to interface with the electronics of real (physical) AOCS units (about 140 channels are available, including bi-level current/voltage stimuli and high resolution current stimuli sources);
- Power Distribution Unit simulator, to supply power to units on the AOCS test bench;
- Connections for optical testing of the Sun Acquisition Sensor and Star Tracker.

One of the workstations hosts the test software (TSW) and user-defined simulation software, and one is used for enhancing the graphical user interface.

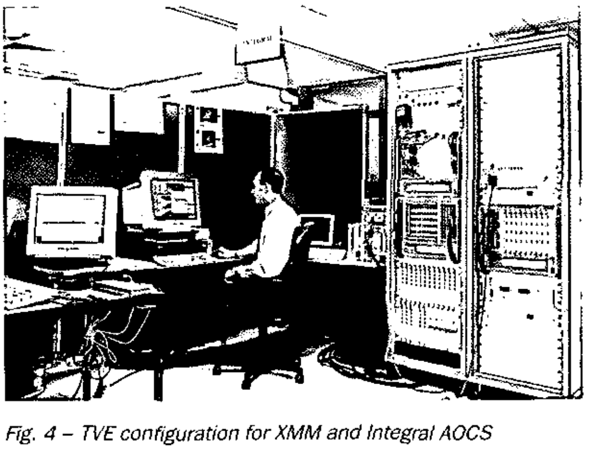


Fig. 4 – TVE configuration for XMM and Integral AOCS integration and testing with Stimuli equipment, Remote Terminal Unit simulator and Power Distribution Unit simulator

Figure 4 shows the TVE configuration for XMM and Integral AOCS integration testing.

Test Software and Simulation Software

The test software (TSW) is based on the general purpose simulation support tool PROSIM (Programme and Real time Operations SIMulation), developed by NLR as a system-independent simulation program for advanced flight systems. The characteristics of the simulated systems are implemented using simulation models that describe the specific behaviours of the systems. Within the AOCS TSW, the simulation functionality is performed by dedicated simulation software (SSW), simulating the space environment and the dynamics of the spacecraft under test. Furthermore, the SSW simulates the sensor heads and actuator units of the AOCS units that are actually present, and simulates the behaviour of lacking units.

The TSW consists of a real-time part that takes care of the activities related to the closed loop simulation and test script execution, and a non-real-time part that takes care of among other things data archiving and user interfacing. The real-time part has been designed to run on a single- or multi-processor workstation (the host computer). Real-time processes are controlled by a dedicated scheduler that can be synchronised with the operating system clock or with periodically sampled output from AOCS actuators. Figure 5 schematically shows the real-time simulator in operational state.
The user interfaces are loosely coupled to the real-time processes via TCP/IP connections and can be executed on the real-time workstation and/or remote workstations.

The real-time processes communicate mainly via a static Global Data Store (GDS) and a dedicated dynamic message buffer pool. The open structure of these interfaces, combined with the precise scheduling of the processes involved, provides reliable direct access to all important data for test scripts, the graphical user interface and archiving processes.

Test Scripts

An important function of the TSW is the automated execution of real-time AOCS tests. These tests are in general controlled via scripts written in Mission Definition Language (MDL). These MDL scripts can be used as Automatic Test Procedures since they can be initiated by certain conditions in the GDS. MDL scripts can also be initiated by other Automatic Test Procedures, or via the Graphical User Interface by the test conductor. Note that all MDL scripts are executed synchronously with the SSW. MDL commands can also be executed interactively in a dedicated manual commanding window.

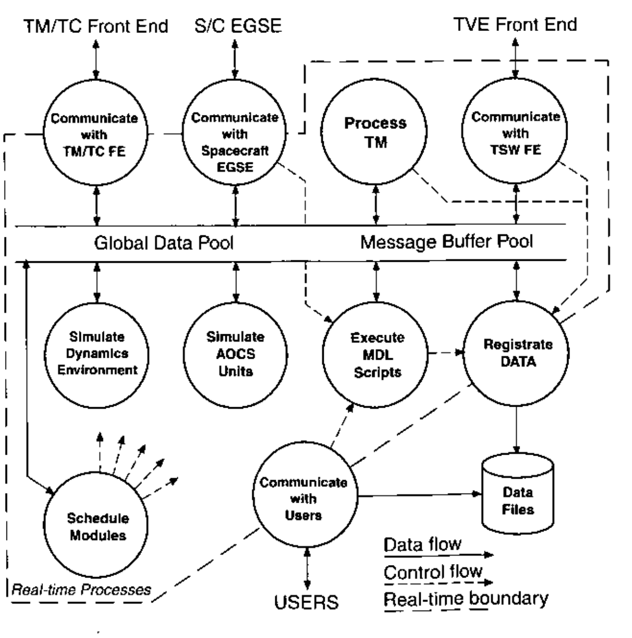


Fig. 5 – Real-time simulator, in operational state

The Graphical User Interface has also facilities for defining test setup and test control, monitoring of MACS bus traffic, monitoring and modification of GDS variables, telecommanding and display of telemetry, and editing MDL scripts.

During test runs all kinds of data can be registered. The TSW provides postprocessing facilities to inspect these registered data afterwards. Postprocessing provides a variety of plotting functions for GDS variables and certain parameters of protocol messages.

Graphical User Interface

The graphical user interface is capable of displaying on one screen the MACS spy window, a GDS monitor window and a Plot monitor window at the same time. The MACS spy displays a chronological list of newly captured and selected MACS bus transactions. The actual data of attitude angles and angular rates are given in the GDS Monitor window. The Plot window shows the spacecraft attitude angles during the execution of a test.

TVE Projects

XMM Project

Within the XMM project two almost identical test systems were developed and built. One system, called AOCS EGSE (Electrical Ground Support Equipment), is used by Matra Marconi Space (MMS) of Bristol, UK, for testing the AOCS on the subsystem level. The second system, called SCOE (Special Check Out Equipment), is used by Dornier Satellitensysteme of Friedrichshafen, Germany, for testing the AOCS on the system level.

The development and integration of the AOCS test systems for the XMM has been performed in parallel with the XMM design, production and testing, according to an incremental approach. The AOCS EGSE system was delivered in November 1996, before all software functionalities were completed. This first delivery allowed MMS to start Electrical Model (EM) integration, which was continued in 1997.

In 1997, the remaining software functionalities were developed in close co-operation between MMS and NLR. These functionalities were integrated in the subsystem test configuration by NLR.

In April 1997, the AOCS SCOE system was delivered to Dornier Satellitensysteme. It was then successfully integrated in the system level test setup.

On-site support has been provided for both systems, and some practical enhancements have been implemented.

The AOCS Test Equipment for the XMM has successfully been applied during subsystem and system tests. Both systems became ready for the final acceptance, planned for the beginning of 1998. At a Workshop at ESTEC in September 1997, Matra Marconi Space reported that the AOCS EGSE had successfully been applied to the XMM EM test campaign with good correlation between simulated performance and test results.

Integral Project

In November 1996 the development of a third AOCS EGSE system was started. This system will be used by MMS for Integral EM integration testing and in a later stage by Alenia Spazio for Integral AOCS system level testing.

The production of the test equipment, including the VME master crate, Remote Terminal Unit, Stimuli and Monitoring electronics and Power Distribution Unit simulator, has been completed in 1997. The test software has been upgraded to comply with the Telemetry and Telecommand definition of the Integral satellite.

Test procedures have been written to support the test system integration and end-to-end acceptance tests. In the autumn of 1997 a shadow test system for AOCS software-in-the-loop testing was delivered to MMS for early support in training of Integral test procedures. The delivery of the AOCS EGSE for the Integral project was planned for early 1998.

Appendices

Appendices

1 Publications

In 1997, NLR produced a total of 675 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

TP 93407 U

Optimal thresholding in wavelet image compression

Presented at the International Society for Optical Engineering (SPIE) Conference, San Diego, USA, 11–16 July 1993.

Zeppenfeldt, F.O.; Borger, J.B.; Koppes, A.

TP 93501 U

Het gebruik van case tools bij de ontwikkeling van on-board ruimtevaart-programmatuur

Gepubliceerd in 'Informatica'.

Dekker, G.J.; Hameetman, G.J.

TP 94241 U

On transforming accelerometer data to angular rate

Vreeburg, J.P.B.

TP 95101 U

Nash equilibria in risk-sensitive dynamic games

Presented at the 1995 American Control Conference, Seattle, USA, 21–23 June 1995.

Klompstra, M.B.

TP 95547 U

Applying formal methods in the DO-178B certification process: An introduction

Vries, L.M.G. de

TP 95574 U

Gas turbine engine simulation at NLR

Presented at the CEAS (Confederation of European Aerospace Societies) Symposium on Simulation Technologies 'Making it Real', Delft, The Netherlands, 30 October – 1 November 1995

Visser, W.P.J.

TP 95666 U

Human factors issues with airborne datalink: towards increased crew acceptance for both en-route and terminal flight operations

Gent, R. van

TP 96033 U

The National Simulation Facility NSF: The application of the real-time simulation support tool PROSIM

Presented at the CEAS Symposium on Simulation Technology 'Making it Real', Delft, The Netherlands, 30 October – 1 November 1995.

Brouwer, W.; Dam, A.A. ten; Schrap, P.

TP 96082 U

Four-stream atmospheric correction model

Verhoef, W.

TP 96133 U

Damage tolerance analyses of bolt / nut assemblies

Koning, A.U. de; Henriksen, T.K.

TP 96193 U

Experiences with Ultra-high-bypass simulators from calibration and isolated engine testing

Presented at the Workshop on Aspects of Airframe Engine Integration for Transport Aircraft, Braunschweig, Germany, 6–7 March 1996.

Hegen, G.H.; Kiock, R.

TP 96220 U

A survey of the NARSIM C/S middleware

Michiels, R.

TP 96251 U

Parallel machine scheduling by column generation

Presented at the 5th International workshop on project management and scheduling, Poznan, Poland, 11–13 April 1996.

Akker, J.M. van den; Hoogeveen, J.A.; Velde, S.L. van de

TP 96279 U

Analysis of measured in-flight tail loads

Presented at the 20th ICAS Congress, Sorrento, Napoli, Italy, 9–13 September 1996

Gelder, P.A. van

TP 96283 U (1)

Adaptive generation of structured grids - Part 1: Introduction and state-of-the-art

Presented at the 27th Computational Fluid Dynamics VKI lecture series, Von Karman Institute, Rhode-Saint-Genèse, Belgium, 25–29 March 1996.

Hagmeijer, R.; Kok, J.C.

TP 96283 U (2)

Adaptive generation of structured grids - Part 2: Weighted least squares formulation

Presented at the 27th Computational Fluid Dynamics VKI lecture series, Von Karman Institute, Rhode-Saint-Genèse, Belgium, 25–29 March 1996.

Hagmeijer, R.; Kok, J.C.

TP 96284 U

Flow field survey in trailing vortex system behind a civil aircraft model at high lift

Presented at the 78th AGARD Fluid Dynamics Panel Meeting and Symposium on 'The Characterisation and Modification of Wakes from Lifting Vehicles in Fluids', Trondheim, Norway, 20–23 May 1996.

Bruin, A.C. de; Hegen, G.H.; Rohne, P.B.; Spalart, Ph. R.

TP 96286 U

ENFLOW, a full-functionality system of CFD codes for industrial Euler/Navier-Stokes flow computations

Presented at the 2nd International Symposium on Aeronautical Science and Technology (ISASTI'96),
Jakarta, Indonesia, 24–27 June 1996.

Boerstoel, J.W.; Kassies, A.; Kok, J.C.; Spekreijse, S.P.

TP 96288 U

Adaptive 3D single-block grids for the computation of viscous flows around wings

Presented at the 5th International Conference on Numerical Grid Generation in Computational Fluid Dynamics and Related Fields, Starkville, Mississippi, USA, 1–5 April 1996.

Hagmeijer, R.

TP 96297 U

Adaptive grid generation by using the Laplace-Beltrami operator on a monitor surface

Presented at the 5th International Conference on Numerical Grid Generation in Computational Field Simulations, Mississippi State University, USA, 1–5 April 1996.

Spekreijse, S.P.; Hagmeijer, R.; Boerstoel, J.W.

TP 96312 U

Propeller-wing interference effects at low speed conditions

Presented at the DLR Workshop on 'Aspects of Engine-Airframe Integration for Transport Aircraft', Braunschweig, 6–7 March 1996.

Custers, L.G.M.

TP 96320 U

Design and testing of a low self-noise aerodynamic microphone forebody

Presented at the 2nd AIAA/CEAS Aeronautics Conference, State College, PA, 6–8 May 1996.

Dassen, T.; Holthusen, H.; Beukema, M.

TP 96323 U

A robust multi-block Navier-Stokes flow solver for industrial applications

Presented at the third ECCOMAS Computational Fluid Dynamics Conference, Paris, France, 9–13 September 1996.

Kok, J.C.; Boerstoel, J.W.; Kassies, A.; Spekreijse, S.P.

TP 96338 U (1)

Multiblock grid generation part 1: Elliptic grid generation methods for structured grids
(Adaptation of 'Elliptic Grid Generation Based on Laplace Equations and Algebraic Transformations', Journal of Computational Physics 118, 38–61, 1995).
Presented at the 27th Computational Fluid Dynamics VKI lecture series, Von Karman Institute, Rhode-Saint-Genèse, Belgium, 25–29 March 1996.
Spekreijse, S.P. and Boerstoel, J.W.

TP 96338 U (2)

Multiblock grid generation part 2: multiblock aspects
Presented at the 27th Computational Fluid Dynamics VKI lecture series, Von Karman Institute, Rhode-Saint-Genèse, Belgium, 25–29 March 1996.
Spekreijse, S.P. and Boerstoel, J.W.

TP 96341 U

Damage propagation in composite structural elements - Analysis and experiments on structures
Presented at the 8th International Conference on Composite Structures, Paisley, Scotland, 11–14 September 1995.
Wiggenraad, J.F.M.

TP 96344 U

A symmetrical boundary element formulation for sound transmission through cabin walls
Presented at the 12th GAMM-Seminar on Boundary Elements 'Implementation and Analysis of Advanced Algorithms', Kiel, Germany, 19–21 January 1996.
Schippers, H.; Grooteman, F.P.

TP 96350 U

Results of a wind tunnel study on the reduction of airfoil self-noise by the application of serrated blade trailing edges
Presented at the 1996 European Union Wind Energy Conference and Exhibition, Gothenburg, 20–24 May 1996.
Dassen, T.; Parchen, R.; Bruggeman, J.; Hagg, F.

TP 96352 U

Simulator evaluation on control and display issues for a future regional aircraft
Presented at the AIAA Atmospheric Flight Mechanics Conference, San Diego, 29–31 July 1996.
Verspay, J.; Muynck, R. de; Nibbelke, R.; Bosch, J.J. van den; Gelder, C.A.G. van

TP 96355 U

4D ATM cockpit: Set-up and initial evaluation
Presented at the 20th ICAS Congress, Sorrento, Napoli, Italy, 9–13 September 1996.
Hoogeboom, P.J.; Huisman, H.

TP 96380 U

High efficiency low pressure drop two-phase condenser for space
Presented at the 26th International Conference on Environmental Systems, Session 'Thermal Control Technology - Two Phase Technology', Monterey, CA, USA, 18–11 July 1996.
Delil, A.A.M.; Heemskerk, J.F.; Mastenbroek, O.; Supper, W. (ESA)

TP 96411 U

Developing the EATMS architecture: Think big - start small
Presented at the 'EATMS Architecture Workshop' organized by Eurocontrol, 11–13 June 1996
Dieleman, P.; Kesseler, E.

TP 96424 U

NICE: Do-it-yourself flow solutions for engineers and scientists
Presented at the International EUROSIM Conference 'HPCN challenges in telecomp and telecom', Delft, 10–12 June 1996.
Ven, H. van der

TP 96431 U

An explicit multi time stepping algorithm for aerodynamic flows
Presented at the International Congress on Computational and Applied Mathematics, Leuven, Belgium, 21–26 July 1996.
Ven, H. van der, Niemann-Tuitman, B.E.; Veldman, A.E.P.

TP 96443 U

Development and operations in the Dutch utilisation centre

Presented at the 4th International Symposium on Space Mission Operations and Ground Data Systems (SpaceOps96), Track 2 - Ground Segment Engineering and Architecture, Munich, Germany, 16–20 September 1996.

Pronk, Z.; Brouwer, M.P.A.M.; Visser, F.B.; Haas, J. de

TP 96446 U

A real-time visualization system for computational fluid dynamics

Published in: NEC Research & Development, Vol. 37, No. 1, pp. 114–123, January 1996.

Rijn, L.C.J. van; Schultheiss, B.C.

TP 96463 U

NLR's CACE working environment ISMuS

Presented at the IEEE International Symposium on Computer-Aided Control System Design, Dearbon, Michigan, USA, 15–18 September 1996.

Couwenberg, M.J.H.; Cazemier, R.J.

TP 96464 U

Early benchmark results on the NEC SX-4

Presented at Parallel CFD '96, Capri, Italy, 20–23 May 1996.

Potma, K.; Hameetman, G.J.; Loeve, W.; Poppinga, G.

TP 96479 U

A system theoretical framework to study unilaterally constrained mechanical systems

Presented at the session on Hybrid Mechanical Systems at the European Control Conference ECC'97, Brussels, Belgium, 1–4 July 1997.

Dam, A.A. ten, Willems, J.C.

TP 96485 U

Looking for the last drag count – Model vibrations vs. drag accuracy

Presented at the International Symposium on Strain-Gage Balances, NASA Langley Research Center, 22–25 October 1996.

Fuykschot, P.H.

TP 96487 U

Fully automatic Navier-Stokes algorithm for 2D high-lift flows

Presented at the 15th International Conference on Numerical Methods in Fluid Dynamics, Monterey, California, USA, 24–28 June 1996.

Cock, K.M.J. de

TP 96502 U

ARCADE, an automation & Robotics demonstrator project

Presented at the Annual Congress 1996 of the 'Deutsche Gesellschaft für Luft- und Raumfahrt' (DGLR), Dresden, Germany, 24–27 September 1996

Schoonmade, M.

TP 96504 U

A symmetrical boundary element formulation for sound transmission through fuselage walls - theory, implementation and test cases

Presented at ISMA21, International Conference on Noise and Vibration Engineering, Leuven, Belgium, 18–20 September 1996.

Grooteman, F.P.; Schippers, H.; Boer, A. de

TP 96507 U

A symmetrical boundary element formulation for sound transmission through fuselage walls - Application

Presented at ISMA21, International Conference on Noise and Vibration Engineering, Leuven, Belgium, 18–20 September 1996.

Grooteman, F.P.; H.; Boer, A. de

TP 96512 U

Variation in load factor experience: A re-analysis of Fokker F-27 and F-28 operational acceleration data

Jonge, J.B. de; Hol, P.A.

TP 96513 U

Materiaalkeuze voor vliegende gasturbines

Presented at the Themadag 'Non-Ferro Metalen en Mobiliteit: Materiaalkeuze en Duurzamer Functionaliteit', Autotron, Rosmalen, 15 October 1996

Kolkman, H.J.

TP 96518 U

A concept for a low-cost dedicated infrastructure for the monitoring of tropical forests

Presented at the IAA Symposium on Small Satellites for Earth Observation, Berlin, Germany, 4–8 November 1996.

Looyen, W.J.; Algra, T.; Brouwer, M.G.A. de

TP 96520 U

Video for flight test

Presented at the 8th European Symposium of the Society of Flight Test Engineers at Blackpool, England, 10 June 1996.

Brugman, J.

TP 96523 U

Influence of blade rotation on the sectional aerodynamics of rotating blades

Presented at the Twenty-second European Rotorcraft Forum, Brighton, United Kingdom, 17–19 September 1996.

Bosschers, J.; Montgomerie, B.; Brand, A.J.; Rooij, R.P.J.O.M.

TP 96530 U

Full scale glare fuselage panel tests

Presented at the FAA-NASA Symposium on Continued Airworthiness of Aircraft Structures, Atlanta, GA, USA, 28–30 August 1996.

Vercammen, R.W.A.; Ottens, H.H.

TP 96550 U

Strain gauge balance development at NLR

Presented at the International Symposium on Strain-Gauge Balances, NASA Langley Research Center, 22–25 October 1996.

Vos, H.B.

TP 96555 U

General design aspects of low speed wind tunnels

Presented at the Fall 1996 AGARD-FDP Symposium on 'The Aerodynamics of Wind Tunnel Circuits and Their Components', Moscow, Russia, 30 September – 3 October 1996.

Jaarsma, F.

TP 96563 U

The RNLAF approach to certification of the avionics control and management system of the CH-47D Chinook

Presented at the 22nd European Rotorcraft Forum, Brighton, UK, 17–19 September

Gebhard, A.; Cappelle, G.J. van de

TP 96564 U

Dynamics and control of a spacecraft with a moving, pulsating ball in a spherical cavity

Vreeburg, J.P.B.

TP 96570 U

ARTEMIS network user interface

Presented at the 47th International Astronautical Congress, Beijng, China, 7–11 October 1996

Dorp, A.L.C. van; Wijk, K.M. van; Spaa, J.

TP 96573 U

Development procedures of the on-board attitude control software for the SAX satellite

Presented at the 27th BIAS '96 Conference, Milan, Italy, 26–28 November, 1996.

Dekker, G.J.

TP 96575 U

Experiences with advanced CFD algorithms on NEC SX-4

Presented at the 2nd International Meeting on Vector and Parallel Processing, Porto, Portugal, 25–27 September 1996.

Ven, H. van der, Vegt, J.J.W. van der

TP 96588 U

A data acquisition system for the RNLAF MLU F-16 – Requirements and proposal

Presented at the AGARD FVP Symposium on 'Advances in Flight Testing', Lisbon, Portugal, 23–26 September 1996.

Koolstra, H.; Hollestelle, P.M.N.; Klijn, J.M.

TP 96589 U

Experiments with remote visual access and on-line space services

Presented at the First Symposium on the Utilisation of the International Space Station, ESOC, Darmstadt, 30 September – 2 October 1996.

Kuijpers, E.A.

TP 96591 U

Experiences in aeroelastic simulation practices

Presented at EUROMECH Colloquium 349, Göttingen, Germany, 16–18 September 1996

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

TP 96592 U

Some results of piloted simulator investigations on windshear detection systems and icon display concepts

Presented at the 20th ICAS Congress, Sorrento, Napoli, Italy, 9–13 September 1996.

Rouwhorst, W.F.J.A.; Haverdings, H.

TP 96625 U

Simulation at a cell switch network for the control of a switch matrix in a high-speed avionics network

Presented at the AGARD MSP 6th Symposium on 'Advanced Architectures for Aerospace Mission Systems', Istanbul, Turkey, 14–17 October 1996.

Aupers, D.A.; Heerink, G.J.; Wellink, S.

TP 96642 U

An emerging strategy of general aviation noise reduction

Submitted to InterNoise 96

Peterse, A.H.

TP 96649 U

A plane wave synthesis facility for sound transmission measurements on panels

Presented at the NAG Symposium on Sound Intensity Techniques, 17 September 1996.

Wal, H.M.M. van der; Demmenie; E.A.F.A.

TP 96655 U

Application of genetic algorithms in the aerospace domain

Presented at EUFIT'96, The Fourth European Congress on Intelligent Techniques and Soft Computing, Aachen, Germany, 2 September 1996

Hesselink, H.H.; Kuiper, H.; Akker, J.M. van den

TP 96656 U

Mission Planning Systems: Cubic multipliers

Presented at the MSP 6th Symposium on Advanced Architectures for Aerospace Mission Systems, Istanbul, Turkey, 14–17 October 1996.

Moel, R.P. de; Heerema, F.J.

TP 96668 U

Space automation and robotics activities past, present and future: next steps and robotics laboratory

Presented at the 4th ESA Workshop on Advanced Space Technologies for Robot Applications 'ASTRA 96', Noordwijk, The Netherlands, 6–7 November 1996.

Kuijpers, E.A.; Schoonmade, M.

TP 96719 U

Fatigue and fracture in an aircraft engine pylon

Presented at the International Conference 'Engineering Against Fatigue', Sheffield, Engeland, March 1997.

Wanhill, R.J.H.; Oldersma, A.

TP 96735 U

Elliptic generation systems

To appear in Handbook of Grid Generation, eds. J.F. Thompson, N.P. Weatherill and B.K. Soni, CRC Press Inc.

Spekreijse, S.P.

TP 96748 U

Airfoil design and optimization methods – Recent progress at NLR

Presented at the ECCOMAS 96 Conference on Computational Fluid Dynamics, Paris, France, 9–13 September 1996.

Soemarwoto, B.I.; Labrujere, T.E.

TP 96789 U

Overview and discussion of electronic exchange standards for technical information

Presented as invited paper at the CALS Europe'96 Conference 'SGML, HTML, the paperless office... what about the forests and the trees', Paris, 29–31 May.

Kuiper, H.; Donker, J.C.

TP 97006 U

Impact damage and failure mechanisms in structure relevant composite specimens

Presented at the Eleventh International Conference on Composite Materials (ICCM-11), Gold Coast, Australia, 14–18 July 1997.

Wiggenraad, J.F.M.; Ubels, L.C.

TP 97015 U

Gust load conditions for fatigue tests based on a continuous gust concept

Presented at the 38th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, Kissimmee, Florida, 7–10 April 1997.

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

TP 97018 U

A generic architecture for crew assistant systems

Published in 'Advanced Architectures for Aerospace Mission Systems', AGARD Conference Proceedings of the Symposium by the Mission Systems Panel, Istanbul, Turkey, 14–17 October 1996

Urlings, P.J.M.; Zuidgeest, R.G.

TP 97036 U

Derivation of lateral and vertical gust statistics from in-flight measurements

Presented at the 38th AIAA/ASME/ ASCE/ASC Structures, Structural Dynamics and Materials Conference, Kissimmee, Florida, 7–10 April 1997.

Gelder, P.A. van

TP 97068 U

Design fabrication and testing of a composite bracket for aerospace application

Presented at the Ninth International Conference on Composite Structures, 8–10 September 1997.

Thuis, H.G.S.D.; Biemans, C.

TP 97082 U

Comparison of measured and predicted noise of the Brite-Euram SNAAP advanced propellers

Published as AIAA Paper 97-1709 in the Proceedings of the 3rd AIAA/ CEAS Aeroacoustics Conference, American Institute of Aeronautics and Astronautics, Atlanta, Georgia, USA, 12–14 May 1997.

Schulten, J.B.H.M.

TP 97086 U

A ground vibration test on the GARTEUR testbed SM AG-19

Presented at the 15th International Modal Conference, Chuo University, Tokyo, Japan, 1–4 September 1997.

Persoon, A.J.; Balmès, E. (ONERA)

TP 97113 U

Creating capabilities for effective and controllable scientific and engineering computations – Benefits to the end users of integrated HPCN environments

Presented at HPCN Europe, and RCI European Member Management Symposium IX, Brussels, 16–18 April 1996 and NLR Noordoostpolder, 5–7 June 1996.

Loeve, W.

TP 97155 U

Failure detection, isolation and recovery system concept for the European robotic arm

Presented at the International Conference on Safety and Reliability ESREL'97, Lisbon, Portugal, 17–20 June 1997.

Bos, J.F.T.; Oort, M.J.A.

TP 97183 U

Collision risk related to the usage of parallel runways for landing

Presented at the International Aviation Safety Conference 1997, Rotterdam, The Netherlands, 27–29 August 1997.

Speijker, L.J.P.; Couwenberg, M.J.H.; Kleingeld, H.W.

TP 97482 U

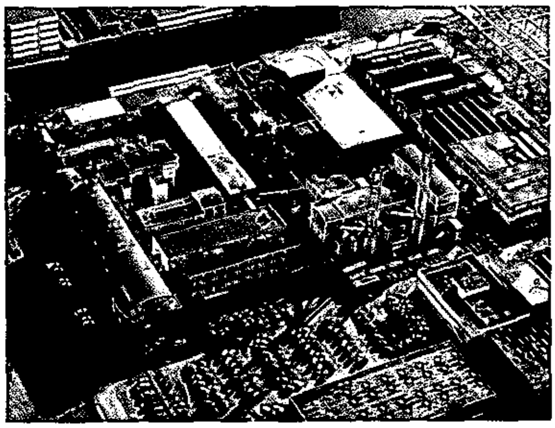
Adaptation of structured grids based on weighted least squares formulations

Hagmeijer, R.

2 Abbreviations

AECMA	Association Européenne des Constructeurs de Matériel Aérospatial (The European Association of Aerospace Industries)
AEREA	Association of European Research Establishments in Aeronautics
AGARD	Advisory Group for Aerospace Research and Development (NATO)
AIAA	American Institute of Aeronautics and Astronautics
APERT	Aerospace Programme for Education, Research and Technology
ARALL	ARamide Aluminium Laminate
ATC	Air Traffic Control
BCRS	Beleidscommissie Remote Sensing (Netherlands Remote Sensing Board)
BMBF	Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (Federal Ministry for Education, Science, Research and Technology)
BMVg	Bundesministerium für Verteidigung (Federal Ministry for Defence)
BRITE	Basic Research in Industrial Technologies for Europe
CAE	Computer-Aided Engineering
CAESAR	CCD Airborne Experimental Scanner for Applications in Remote Sensing
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 Raumfart
DNW	*Duits-Nederlandse Windtunnel (German-Dutch Wind Tunnel)*
EFIS	Electronic Flight Instrument System
EMI	Electro-Magnetic Interference
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESOC	European Space Operations Centre
ESPRIT	European Strategic Programme for Research and Development in Information Technology
ESTEC	European Space Research and Technology Centre
ETW	European Transonic Wind Tunnel
EU	European Union
EUCLID	European Co-operation for the Long term In Defence
EURAM	European Research on Advanced Materials
Eurocontrol	European Organization for the Safety of Air Navigation
EZ	Ministerie van Economische Zaken (Ministry of Economic Affairs)
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FEL	Fysisch Elektronisch Laboratorium (TNO) (Physics-Electronics Laboratory)
FFA	Flygtekniska Försöksanstalten (Aeronautical Research Institute of Sweden)
FSS	Fokker Space & Systems
GARTEUR	Group for Aeronautical Research and Technology in Europe
GPS	Global Positioning System
HSA	Hollandse Signaalapparaten B.V.
HST	Hoge-Snelheids Tunnel (High Speed Wind Tunnel)
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IEPG	Independent European Programme Group
ILST	Indonesische Lage-Snelheids Tunnel (Indonesian Low Speed Tunnel)

INTA	Instituto Nacional de Técnica Aeroespacial (Aerospace Research Institute of Spain)
IPTN	Nusantara Aircraft Industries (Bandung)
ISARD	Integrated Support for Aeronautical Research and Development
ITB	Institut Teknologi Bandung (Indonesië) (Technological Institute of Bandung, Indonesia)
JAR	*Joint Airworthiness Regulations*
KLM	Koninklijke Luchtvaart Maatschappij N.V. (KLM Royal Dutch Airlines)
KLu	Koninklijke luchtmacht (Royal Netherlands Air Force)
KM	Koninklijke marine (Royal Netherlands Navy)
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
KNVvL	Koninklijke Nederlandse Vereniging voor Luchtvaart (Royal Netherlands Aeronautical Association)
LAGG	Aero-Gas Dynamics and Vibration Laboratory
LST	*Lage-Snelheids Tunnel (Low Speed Wind Tunnel)*
LVB	Luchtverkeersbeveiligingsorganisatie (ATC The Netherlands)
MLS	Microwave Landing System
MRVS	Meet-, Registratie- en Verwerkingssysteem (Measurement, Recording and Data Processing System)
NAG	Netherlands Aerospace Group
NASA	National Aeronautics and Space Administration (USA)
NATO	North Atlantic Treaty Organization
NIVR	*Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programs)*
NKO	Nederlandse Kalibratie Organisatie (Netherlands Calibration Organization)
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory NLR)
NPOC	National Point of Contact
NSM	Niet-Stationaire Meetmethode (Non-Stationary Measurement Method)
NSF	Nationale Simulatie Faciliteit (National Simulation Facility)
ONERA	Office National d'Etudes et de Recherches Aérospatiales (Aerospace Research Institute of France)
PHARUS	*Phased Array Universal Synthetic Aperture Radar*
RLD	Rijksluchtvaartdienst (Netherlands Department of Civil Aviation)
RLNAF	Royal Netherlands Air Force
RTCA	Radio Technical Commission for Aeronautics
RTO	Research and Technology Organization (NATO)
SICAS	SSR Improvement and Collision Avoidance System
SPOT	Système Probatoire Observation Terrestre
SSR	*Secondary Surveillance Radar*
SST	Supersone Snelheids Tunnel (Supersonic Wind Tunnel)
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)
TPD	Technisch Physische Dienst TNO-TU
TPS	Turbine-Powered Simulation
TTA	Technological/Technical Assistance
V&W	*Ministerie van Verkeer en Waterstaat (Ministry of Transport and Public Works)*
VKI	Von Kármán Institute of Fluid Dynamics
WEAG	Western European Armament Group
WL	Waterloopkundig Laboratorium (Delft Hydraulics)



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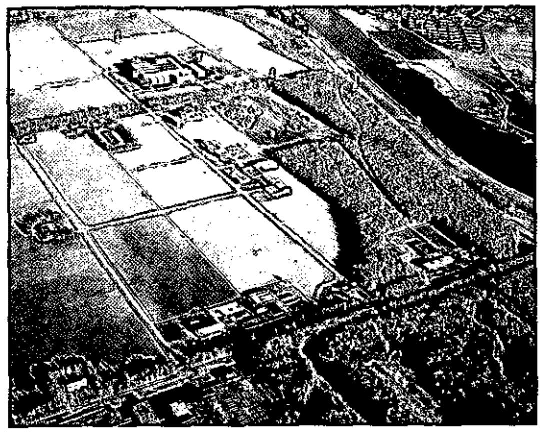

NLR Noordoostpolder

photography: KLM Luchtfotografie

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