Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 2003

Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Annual Report 2003

Board of the Foundation NLR

	Appointed by:
J. van Houwelingen, *Chairman*	Ministers of Transport, Public Works and Water Management, of Defence, of Economic Affairs and of Education, Culture and Science
Drs. A. de Ruiter	Minister of Transport, Public Works and Water Management for the Directorate-General of Civil Aviation
Ir. P.J. Keuning	Minister of Defence
Gen.-Maj. P.M.A. Vorderman	Minister of Defence for the Royal Netherlands Air Force
Drs. A.A.H. Teunissen	Minister of Economic Affairs
Drs. J.W.A. van Enst	Minister of Education, Culture and Science
Prof. B.A.C. Droste	Netherlands Agency for Aerospace Programmes (NIVR)
G.H. Kroese	Air Traffic Control The Netherlands (LVNL)
Ir. C.A.M. de Koning	Stork N.V.
Drs.ing. P.F. Hartman	KLM Royal Dutch Airlines
C.J.G. Dosker	Amsterdam Airport Schiphol
Ir. C. van Duyvendijk	Netherlands Organisation for Applied Scientific Research (TNO)
J.W.E. Storm van ‘s Gravesande	Board of the Foundation NLR
Ms.prof.dr.ir. M.P.C. Weijnen	Board of the Foundation NLR, upon nomination by the Works Council

Chairman of the Scientific Committee NLR/NIVR

Prof.dr.ir. P.J. Zandbergen

Board of Directors of NLR

Ir. F. Holwerda	General Director
Ir. F.J. Abbink	Technical Director
Drs. L.W. Esselman R.A.	Financial Director

General Secretary

E. Folkers

Composition as on 31 December 2003

Table of Contents

1 Preface

In the year 2003 NLR went through a demanding process of preparation for a reorganisation and rightsizing of its organisation.
Already in the fall of 2002 the NLR Board initiated an internal project to reassess the position and organisation of NLR in view of the different changes in its environment and the resulting need of a more flexible and customer focussed organisation.

In 2003 a detailed market analysis of NLR's products and capabilities was carried out and an evaluation of NLR's customer base and its competitiveness, national as well as international, was performed. Together with a benchmarking of its internal processes and newly set targets for overhead and productivity, this led to a blueprint of a "new" NLR with three divisions (Air Transport, Aerospace Vehicles and Aerospace Systems & Applications) and a substantially reduced workforce (approx. minus 20%). It is clear that the reduction of personnel and the restructuring of the organisation needed not only careful planning and full management attention but also Works Council involvement and – last but not least - the support of the Netherlands government. Preparation of the actual implementation took the whole year of 2003.

A major milestone for the Netherlands aerospace industry and their supporting research and technology institutions like NLR and the Delft University, was the selection of GLARE as the fuselage skin material for the Airbus A380. This new material ("Fibre metal laminate") developed in the Netherlands in an intensive co-operation between industry (Stork Aerospace), university (Delft University of Technology, faculty of Aerospace Engineering) and NLR illustrates the long and complicated process from idea (around 1975) to series production.

Netherlands Level 2-partnership in the Systems, Design and Development phase of the Lockheed Martin Joint Strike Fighter gives NLR important opportunities, i.e. direct contracts from the Level 1 partners in the program (LM Aero, Northrop Grumman, BAe) as well as contract research from participating industries, like Stork Aerospace, SP Aerospace and vehicle systems (structure and material testsupport), Dutch Space (embedded training) and Eldim (engine seal testing).

For NLR's main customer in military aircraft operations, the Royal Netherlands Air Force, the support and assistance was continued. A two-year contract for support in the F-16-successor project was granted to NLR and TNO. Moreover the RNLAF contracted NLR (together with TNO and ADSE) in the framework of the MoU signed between the Netherlands Minister of Defence and his French colleague to evaluate, specify and eventually design a so-called MALE-UAV (Medium Altitude Long Endurance Unmanned Aerial Vehicle).

In 2003 NLR continued its involvement in international technology development programs. Increasing demand for safety and environmental studies in the field of air transport as well as the research and contract work for harmonising air traffic control to reduce congestion and delays (Single European Sky) was mainly performed in fully integrated international partnerships.

During the summer of 2003 the Netherlands Ministry of Education and Science, in co-operation with the Ministry of Economic Affairs, started an evaluation of effectiveness of the national research and technology infrastructure. This project asked for a full internal audit of the large technological institutes, including NLR. This internal strenghts and weaknesses audit in all areas of NLR's business and research was a logical extension of the work done for the above-mentioned restructuring process of NLR's organisation. Also the NLR/NIVR Scientific Committee played an important role in this audit. It is expected that in 2004 the Netherlands government, on the basis of the analysis of the evaluation results, will draw its conclusions and if necessary take actions.

Although 2003 was a difficult year, I am confident that NLR, upon completion of the reorganisation process, will be in good shape and a strong position to face the new challenges. As part of an integrated European aerospace research and technology infrastructure, NLR will continue to support and serve its customers, national as well as international, in the best possible way.

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, technology development, testing services as well as consultancy to aerospace industries, civil and military aircraft operators, government agencies and international organisations. As a non-profit organisation, NLR conducts a basic research and technology development programme funded by the government to maintain its capabilities of providing technological support.

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

By its participation in international facilities and organisations, NLR is able to offer the national aerospace sector access to expertise and advanced joint test facilities and research capabilities. NLR co-operates on an equal base with the Deutsches Zentrum für Luft- und Raumfahrt (DLR) in the foundation German Dutch Wind Tunnels (Stichting Duits-Nederlandse Windtunnels – Stiftung Deutsch-Niederländische Windkanäle; DNW), which operates the Large Low-speed Facility in Flevoland and several other wind tunnels owned by NLR and DLR. Like DLR, the Ministry of Trade and Industry of the United Kingdom and the Office National d'Etudes et de Recherches Aérospatiales (ONERA) of France, NLR has an interest in the European Transonic Windtunnel (ETW) in Cologne, Germany. NLR is a member of the Association of European Research Establishments in Aeronautics (EREA), in which six aeronautical research establishments of member states of the European Union co-operate.

2.2 Activities in 2003

In 2003 NLR's turnover amounted to € 73.5 million. The revenues from contracts totalled € 53.8 million. The basic research and facilities development programme funded by the Dutch government totalled to € 19.5 million.
About 48 percent of NLR's activities were related to the operation and 52 percent to the development of aircraft and spacecraft; civil air transport amounted to approx. € 19 million (26 %), military aerospace support € 14 million (19 %), space € 5 million (7 %) and civil and military aircraft development € 35 million (48 %).
About 41 % of the contract research was carried out for international customers.

Services Provided under National Contracts

Activities under contract to customers from the Netherlands amounted to € 31.8 million. These contracts included aeronautics and space research and technology development for the Netherlands Agency for Aerospace Programmes (NIVR). In addition, a number of research programmes were executed under contract to the Royal Netherlands Air Force, the Royal Netherlands Navy, the Civil Aviation Authority Netherlands, Air Traffic Control the Netherlands (LVNL), Stork Aerospace and Dutch Space. NLR also carried out contract work to support the Netherlands Ministry of Defence, the Netherlands Ministry of Transport's Aviation Policy Department, DNW and several other customers such as SP aerospace and vehicle systems, Sulzer and Urenco Aerospace.

Services Provided to International Customers

NLR spent € 14.7 million on its basic aerospace research programme supported by the government, aimed at preserving NLR's capability to support the Netherlands aerospace sector in the future. Research aimed at the development and improvement of NLR's research facilities amounted to € 4.7 million (2002: € 4.9 million). A total of € 3.1 million was used for capital investments, of which investments in the ICT infrastructure, the housing of the Tower Research Simulator and in the DNW wind tunnels were the most important ones.

National and International Co-operation

A large part of NLR's basic research programme has been carried out as part of European research projects both in civil and in military programmes, such as the EU 5th Framework and EUCLID/ WEAO (European Co-operation for the Long Term in Defence/West European Armament Organisation) programmes. Another significant part has been carried out in co-operative programmes under the aegis of GARTEUR, the Group for Aeronautical Research and Technology in Europe, in which Germany, France, the United Kingdom, the Netherlands, Spain, Sweden and Italy take part.

Internationally, NLR was active in a number of Working Groups of the NATO Research and Technology Organisation (RTO).

In several projects NLR co-operated with research institutes, mainly the Netherlands Organisation for Applied Scientific Research (TNO), and universities of the Netherlands. NLR and the Delft University of Technology (TUD) jointly operate a Cessna Citation II, which is used as a research aircraft. In 2003 a 'Convenant' to further increase co-operation between the TUD and NLR was signed. Two members of NLR's staff were employed as part-time lecturers at the TUD. Another member was active as a part-time professor at the Cranfield Institute of Technology, UK.

Quality Assurance

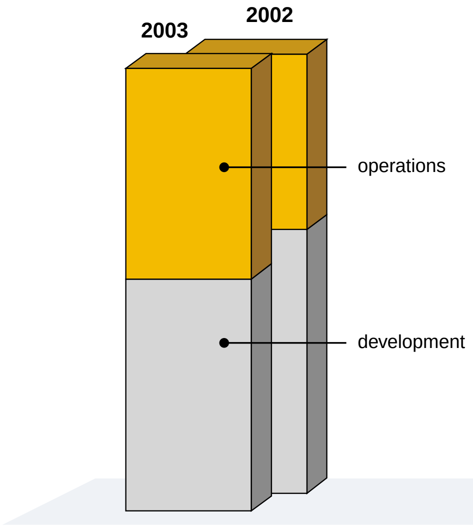
NLR holds ISO 9001:2000 / AQAP-110 quality assurance certificates for its whole organisation including all staff functions. In addition, NLR maintained accreditations for electromagnetic compatibility testing and for the calibration of forces, pressures and electronic quantities.

Outlook for the Coming Years

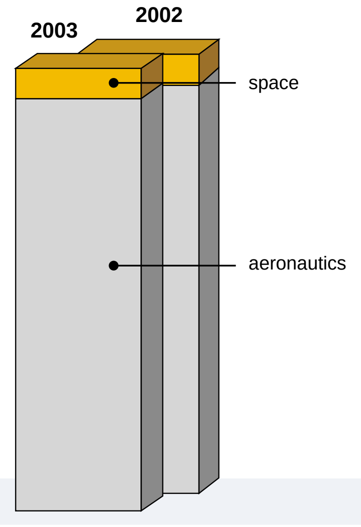
In the first quarter of 2003 NLR completed a full market analysis and a new business plan for the period 2003-2007. Total turnover for these years are foreseen as stable at approx. € 75 million. The market study revealed that NLR's activities in civil air transport will show a further growth in the coming years.

In the military sector, development as well as support activities, a stable contract portfolio for the coming years can be maintained, as is the case for NLR's space activities. In case of successful acquisition of challenging new projects – such as the successor of the F-16 fighter aircraft (JSF), UAV studies for the RNLAF and the European satellite programme Galileo – this outlook might turn out to be conservative.

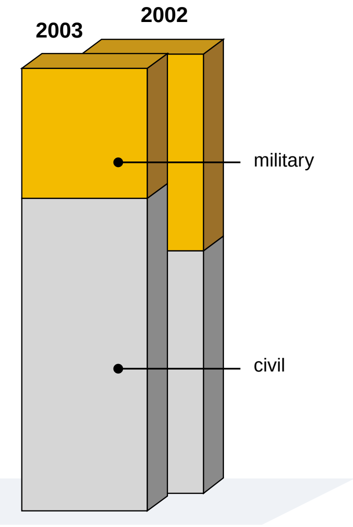
As in the past years, NLR's government funded research programmes will also in the coming years be attuned to the European research programmes such as the Framework programmes and the new programme 'Preparatory Action for Security and Defence' of the European Union. Increased co-operation and integration with activities of European partner institutes is ongoing, such as the integration of wind tunnel operations of DNW and ONERA, and the envisaged alliance on ATC/ATM activities between DLR and NLR. Establishing Networks of Excellence in the European aerospace research infrastructure as well as combined facility investments and operation are key elements of NLR's long term strategy.



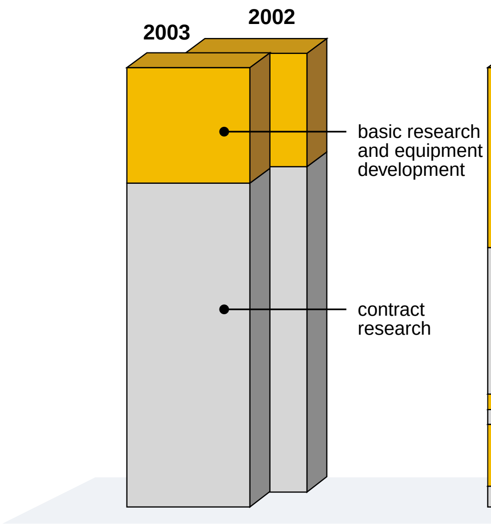
Division of the work into development and operations support



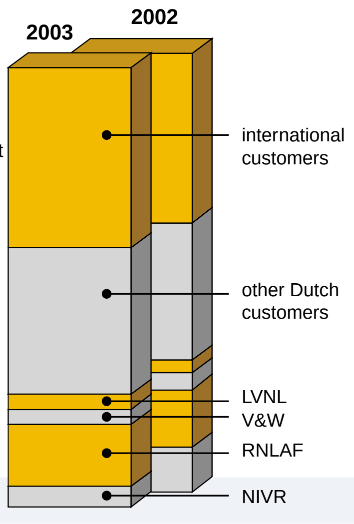
Division of the work into aeronautics and spaceflight support



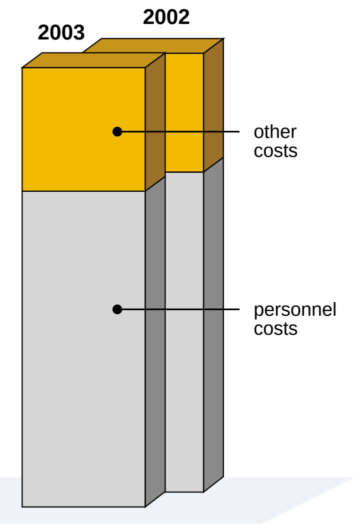
Division of the work into civil and military support



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

On 17 December 2003 drs. S. Veenstra (left), Head of IVW-DL, presented the JAR-145 certificate to ir. F.J. Abbink, Technical Director of NLR and Accountable Manager of the NLR Research Aircraft Maintenance organisation.

NLR operates two research aircraft, a Fairchild Metro II and a Cessna Citation II (50-50 shared ownership with Technical University Delft). NLR has its own facilities at Schiphol Airport to maintain and modify these aircraft.
Since 2000, NLR has started the project to certify the NLR Research Aircraft Maintenance organisation in conformance with the JAR-145 requirements. These European requirements are set up by the Joint Aviation Authorities, representing the civil aviation regulatory authorities of a number of European States, who have agreed to co-operate in developing and implementing common safety regulatory standards and procedures.
NLR is the first and only Aerospace Laboratory in Europe with full JAR-145 maintenance capabilities.

JAR-145 is a requirement to approve/accept maintenance organisations to maintain any aircraft used for commercial air transport. Originally published in 1991, there are some 3200 organisations approved throughout the world of which 1700 are in Europe, 1250 in North America and 250 in the rest of the world.
Although NLR does not perform commercial activities with its research aircraft, the importance was foreseen to comply with the high standard of JAR-145 and to set up a professional and full maintenance organisation. With compliance to JAR-145, NLR has also the ability to design and modify its research aircraft for flight test research purposes.

2.3 Organisation and Personnel

The Board of the Foundation NLR consists of members appointed by the Netherlands government, the Netherlands government, the industry and other organisations having an interest in aerospace research. The meetings of the Board are 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 following changes in the Board of the Foundation took place. The Ministry of Defence appointed Ir. P.J. Keuning as successor of Drs. E.A. van Hoek, Amsterdam Airport Schiphol appointed C.J.G. Dosker as successor of Ir. M.E. van Lier Lels, while Ir. C. van Duyvendijk succeeded Ir. E.I.L.D.G. Margherita as member, appointed by the Netherlands Organisation for Applied Scientific Research (TNO). Prof.dr.ir. Th. de Jong, appointed by Delft University of Technology, Faculty of Aerospace Engineering left the Board.

The laboratory was headed by a Board of Directors. At the end of 2003 the Board consisted of Ir. F. Holwerda, General Director, Ir. F.J. Abbink, Technical Director and Drs. L.W. Esselman R.A., Financial Director. E. Folkers was General Secretary.

Drs. A. de Graaff was Associate Director, charged with strategy affairs and co-ordination of European integration projects. The Board of Directors was further assisted by Ir. U. Posthuma de Boer, Head Marketing and Communication.

On 31 December 2003 the Heads of Divisions and Services were:

Dr. B. Oskam
Fluid Dynamics Division
Prof.drs. P.G.A.M. Jorna
Flight Division
Ir. H.A.J.M. Offerman
Air Transport Division
Ir. H.H. Ottens
Structures and Materials Division
Ir. B.J.P. van der Peet
Space Division
Ir. F.J. Heerema
Information and Communication Technology Division
Ir. M.A.G. Peters
Avionics Division
Ir. J. van Twisk
Engineering and Technical Services
W.C.P. van der Maas
General Services
Drs. L.W. Esselman R.A.
Administrative Services

The organisation of the laboratory on 31 December 2003 is shown on page 14.

A breakdown of the staff is given on page 15.

Organisation Diagram

31 December 2003

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

General Director
Ir. F. Holwerda — **D**

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

General Secretary
E. Folkers — **DA**

Associate Director	Drs. A. de Graaff	**DO**
Marketing and Communication	Ir. U. Posthuma de Boer	**DM**
Co-ordinators:		
- *Defence Projects*	Ir. W. Brouwer	CPD
- *Aircraft Development Projects*	Ing. P. Kluit	CPO
- *Spaceflight Projects*	Drs. J.C. Venema	CPR
- *Air Transport and Aircraft Operations Projects*	Ir. T.H.M. Hagenberg	CLV
- *Basic Research and Facilities Development*	Ir. F.J. Sonnenschein	CEW
Quality Management NLR	Ir. A.L.C. van Dorp	QM

Legal	Ms. M.Y. Spaargaren	**DJ**
Filing and Security	E. Folkers	**DB**
Personnel	Ms. Drs. M.J.A. Visée	**DP**
- *Co-ordinator Occupational Health and Safety, and Environmental*	Drs. H. van Bremen	AMC
Company Welfare Work	Ms. J.H. van Dijk-Bol	DW
	Ms. C. Diekema-Schipaanboord	DW

Fluid Dynamics
Dr. B. Oskam — **A**

- **Aerodynamic Engineering and Vibration Research** — Ing. J.A. van Egmond — **AE**
- **Computational Fluid Dynamics and Aeroelastics** — Ir. K.M.J. de Cock — **AT**
- **Aeroacoustics** — Dr. H.H. Brouwer — **AK**

Flight
Prof.drs. P.G.A.M. Jorna — **V**

- **Helicopters** — Ir. C. Hermans *a.i.* — **VH**
- **Training Development and Concept Validation** — Dr.ir. J.M. Hoekstra — **VT**
- **Flight Mechanics** — Ir. W.P. de Boer — **VM**
- **Operations Research** — Ir. G.J. Alders — **VO**
- **Human Factors** — Prof.drs. P.G.A.M. Jorna — **VE**

Air Transport
Ir. H.A.J.M. Offerman — **L**

- **Flight Testing and Safety** — Ing. M.A. Piers — **LV**
- **Airports** — Ir. A.D.J. Rutten — **LA**
- **Air Traffic Management** — Ir. J.C. Terlouw — **LL**
- **Transport and Environmental Studies** — Ms. Dr.ir. M.E.S. Vogels — **LT**

Structures and Materials
Ir. H.H. Ottens — **S**

- **Loads and Fatigue** — Ir. H.J. ten Hoeve — **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** — Ir. B. Moll *a.i.* — **RR**
- **Systems** — Dr.ir. H.F.A. Roefs — **RS**
- **Laboratories and Thermal Control** — Ir. M.P.A.M. Brouwer — **RL**

Information and Communication Technology
Ir. F.J. Heerema — **I**

- **Mathematical Models and Methods** — Dr. R.J.P. Groothuizen — **IW**
- **Software Applications** — Drs. G. Poppinga *a.i.* — **IA**
- **Data and Knowledge Systems** — Ir. J.C. Donker — **ID**
- **Information and Communication Services** — Ir. L.C.J. van Rijn *a.i.* — **IC**
- **Embedded Systems** — Drs. E. Kesseler — **IS**

Avionics
Ir. M.A.G. Peters — **E**

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

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

- **Technical Design** — Ir. J.H. Halm — **TO**
- **Technical Projects** — Ir. H.B. Vos — **TP**
- **Production Workshop** — Ing. W.A.M. Schrijver — **TW**
- **Service Workshop** — F. Hofman — **TS**

General Services
W.C.P. van der Maas — **G**

- **Electrical Engineering** — A.M.G. Reijntjens — **GE**
- **General Facilities** — Ms. J.L. Engelmoer-Leeuwen, R. Raterink — **GF**
- **Library and Information Services** — R. Lammers — **GB**
- **Document Processing** — Ing. D.J. Rozema — **GT**

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

- **Financial Administration** — N.C. van der Mey — **OA**
- **Financial Planning and Control** — M.W.H. Puijk — **OC**
- **Purchasing** — G.S. Wijdeveld — **OI**

Breakdown of the staff at the end of 2003

(Cat. I: university graduates, Cat. II: advanced technical college graduates, Cat. III: others; between brackets the numbers at the end of 2002)

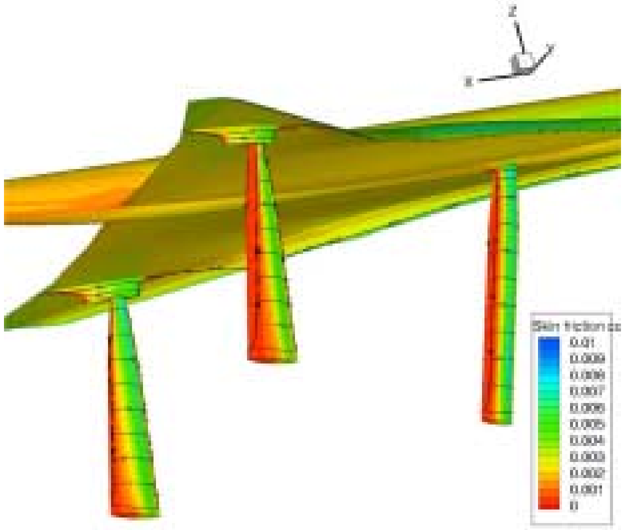
		Cat. I		Cat. II		Cat. III		Total	
Board of Directors		3	(3)	–	(–)	–	(–)	3	(3)
– Support Staff		15	(18)	7	(10)	8	(9)	30	(37)
		18	(21)	7	(10)	8	(9)	33	(37)
Fluid Dynamics Division	**A**	2	(4)	1	(1)	1	(1)	4	(6)
– Aerodynamic Engineering and Vibration Research	AE	10	(10)	1	(1)	–	(–)	11	(11)
– Aeroacoustics	AK	6	(6)	4	(5)	1	(1)	11	(12)
– Computational Fluid Dynamics and Aeroelastics	AT	16	(17)	–	(–)	–	(–)	16	(17)
		34	(37)	6	(7)	2	(2)	42	(46)
Flight Division	**V**	3	(3)	–	(–)	1	(1)	4	(4)
– Human Factors	VE	14	(17)	2	(3)	–	(–)	16	(20)
– Helicopters	VH	14	(17)	1	(1)	1	(1)	16	(19)
– Flight Mechanics	VM	9	(10)	–	(–)	1	(1)	10	(11)
– Operations Research	VO	18	(22)	5	(5)	1	(2)	24	(29)
– Training Development and Concept Validation	VT	10	(10)	10	(11)	–	(–)	20	(21)
		68	(79)	18	(20)	4	(5)	90	(104)
Air Transport Division	**L**	1	(2)	–	(1)	–	(–)	1	(3)
– Airports	LA	10	(10)	2	(4)	1	(1)	13	(15)
– Air Traffic Management	LL	26	(27)	3	(3)	–	(–)	29	(30)
– Transport and Environmental Studies	LT	6	(7)	6	(6)	1	(1)	13	(14)
– Flight Testing and Safety	LV	15	(14)	8	(8)	1	(1)	24	(23)
		58	(60)	19	(22)	3	(3)	80	(85)
Structures and Materials Division	**S**	1	(1)	3	(3)	1	(1)	5	(5)
– Loads and Fatigue	SB	19	(21)	3	(4)	1	(1)	23	(26)
– Structures Technology	SC	11	(16)	4	(5)	–	(–)	15	(20)
– Laboratory Facilities	SL	2	(2)	30	(33)	11	(13)	43	(48)
		33	(39)	40	(45)	13	(15)	86	(99)
Space Division	**R**	1	(1)	2	(2)	–	(–)	3	(3)
– Laboratories and Thermal Control	RL	6	(11)	5	(5)	–	(–)	11	(16)
– Remote Sensing	RR	7	(10)	3	(3)	–	(–)	10	(13)
– Systems	RS	11	(14)	–	(–)	–	(–)	11	(14)
		25	(36)	10	(10)	–	(–)	35	(46)
Information and Communication Technology Division	**I**	2	(2)	1	(1)	3	(3)	6	(6)
– Software Applications	IA	17	(16)	5	(6)	1	(1)	23	(23)
– Information and Communication Services	IC	13	(15)	19	(19)	6	(9)	38	(43)
– Data and Knowledge Systems	ID	16	(19)	9	(10)	–	(–)	25	(29)
– Embedded Systems	IS	9	(10)	7	(7)	–	(–)	16	(17)
– Mathematical Models and Methods	IW	15	(15)	–	(–)	–	(–)	15	(15)
		72	(77)	41	(43)	10	(13)	123	(133)
Avionics Division	**E**	3	(3)	1	(1)	1	(1)	5	(5)
– Avionics Systems	EA	11	(11)	7	(8)	–	(–)	18	(19)
– Electronics	EE	7	(7)	18	(19)	4	(4)	29	(30)
– Instrumentation	EI	8	(9)	16	(18)	3	(4)	27	(31)
		29	(30)	42	(46)	8	(9)	79	(85)
Engineering and Technical Services	**T**	3	(3)	–	(–)	1	(1)	4	(4)
– Technical Design	TO	1	(1)	10	(10)	1	(1)	12	(12)
– Technical Projects	TP	2	(2)	4	(5)	–	(–)	6	(7)
– Service Workshop	TS	–	(–)	2	(2)	3	(3)	5	(5)
– Production Workshop	TW	–	(–)	9	(10)	9	(11)	18	(21)
		6	(6)	25	(27)	14	(16)	45	(49)
General Services	**G**	1	(1)	–	(–)	–	(–)	1	(1)
– Library and Information Services	GB	–	(–)	4	(4)	3	(3)	7	(7)
– Electrical Engineering	GE	–	(–)	5	(5)	4	(5)	9	(10)
– General Facilities	GF	–	(–)	2	(3)	32	(33)	34	(36)
– Buildings	GG	–	(–)	1	(3)	2	(2)	3	(5)
– Document Processing	GT	–	(–)	6	(6)	24	(26)	30	(32)
		1	(1)	18	(21)	65	(69)	84	(91)
Administrative Services	**O**								
– Financial Administration	OA	1	(1)	17	(17)	6	(9)	24	(27)
– Financial Planning and Control	OC	1	(1)	1	(1)	–	(–)	2	(2)
– Purchasing	OI	2	(2)	4	(4)	1	(1)	7	(7)
		4	(4)	22	(22)	7	(10)	33	(36)
German-Dutch Wind Tunnels	WA/WN	14	(13)	40	(42)	16	(17)	70	(72)
Grand total		362	(403)	288	(315)	150	(168)	800	(886)

3.1 Fluid Dynamics

Research and development activities in fluid dynamics have been carried out in the areas of aerodynamic engineering and vibration research, aeroacoustics, computational fluid dynamics and computational aeroelasticity. Developments in applied aerodynamics and applied aeroacoustics were primarily related to aircraft operations near airports and to safety. Applied aeroacoustics work also supported aircraft and engine manufacturers. Other principal areas of investigation were applied aerodynamics and aeroelasticity of military vehicles and civil transport aircraft. In space applications, the work concentrated on computational aerodynamics related to base flows of space launchers. The volume of contract research and development activities in fluid dynamics was relatively large due to a high-volume contract covering low-speed testing of the Short Take Off / Vertical Landing (STOVL) version of the F-35 aircraft in the German-Dutch Wind Tunnels Large Low-speed Facility (DNW-LLF).

Computational Fluid Dynamics

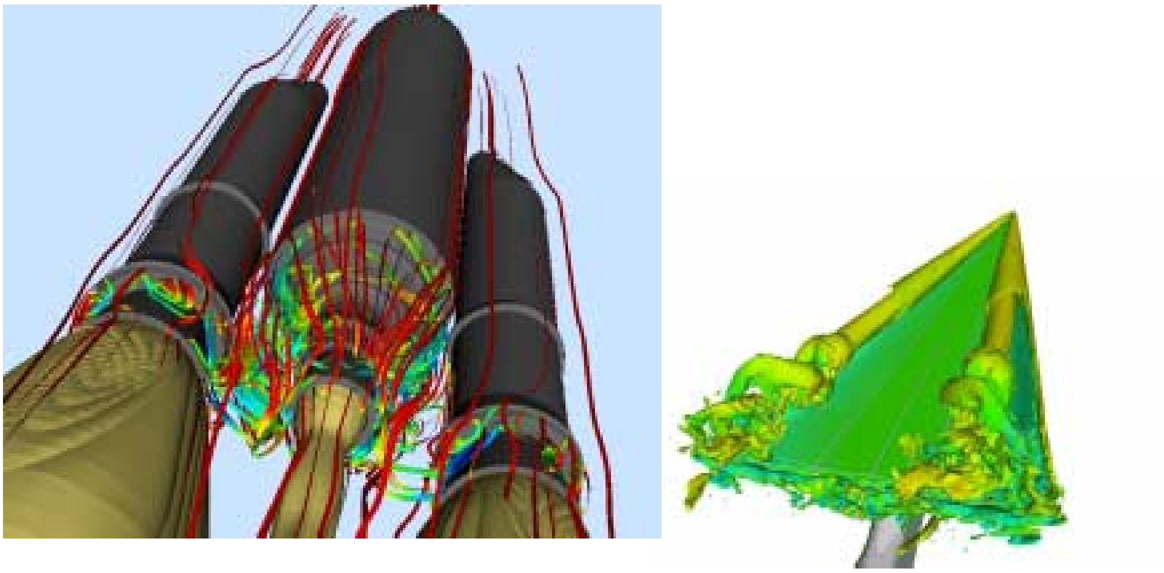
In 2003, NLR has finalised its activities in a European Union (EU) project (EPISTLE) on innovative leading-edge flap systems for a supersonic transport aircraft at low speed. The final stage of work consisted of analysing the



Visualisation of skin friction on a three-strut wind tunnel model support for a supersonic planform

experimental drag level of the configuration with double-hinge flap. This double-hinge flap has been defined by NLR earlier in the project, showing a major and continuous reduction of separated flow and consequently a significant reduction of drag at design lift. In the wind tunnel, the support struts are partially exposed to the air flow and contribute to the overall measured drag. The amount of drag on the struts has been quantified by computations, while the extent of areas

F-35B Joint Strike Fighter (STOVL variant); Photograph Lockheed Martin



Massively separated flow in the base region of a generic space launcher and on a delta wing exhibiting vortex breakdown, computed using the X-LES formulation

containing separated flow on the struts has been visualised as well. The results of the flow analysis on the struts were of major importance to confirm the significant reduction of drag at design lift.

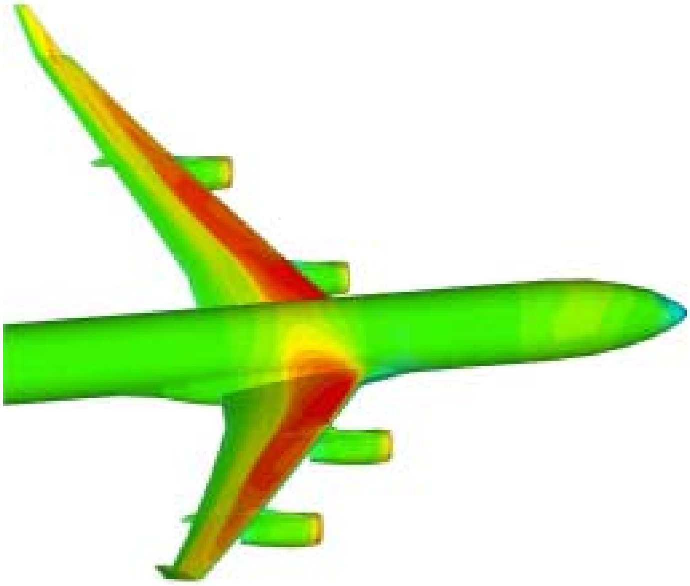
Modelling of Massively Separated Flows

An important application of Computational Fluid Dynamics (CFD) is enabling the computation of refined unsteady aerodynamic loads. For airframe configurations and flow conditions involving flow unsteadiness, improved flow physics modelling is required. The base region of a generic space launcher is an example of such a configuration with unsteady flow under operational conditions. In 2003, NLR continued its research to improve the fidelity of CFD predictions of dynamic external loads on structural components. A composite turbulence modelling formulation, based on the Reynolds-Averaged Navier-Stokes equations and a Large Eddy Simulation, has been studied. This new composite turbulence modelling formulation is called “extra Large Eddy Simulation” (X-LES). Compared to dynamic external loads computations based on Reynolds-Averaged Navier-Stokes equations, the new composite X-LES formulation shows potential for a significant improvement of the modelled flow physics in massively separated areas.

Simulation of massively separated turbulent flows is also required to accurately model the sources of noise in many aeroacoustical applications. For stability characteristics of military aircraft influenced by non-linear flow instabilities, this new X-LES physical modelling is equally relevant. For instance, accurate simulation of roll instabilities due to vortex breakdown requires adequate turbulence modelling for unsteady flows. The simulation technology to model viscous unsteady phenomena in vortex-dominated flows has been relying to a considerable extent on the achievements of the international project called “Joint Programme 12.15” within the THALES framework. This project has been concluded in 2003 with unsteady viscous flow simulations for a geometrically refined F-16 configuration, and with international code-to-code and code-to-experiment comparison of delta wing simulations for one degree of freedom in roll and in response to various aileron inputs. Furthermore, as a contribution to the RTO AVT-082 group, vortex breakdown on the ONERA 70 degree delta wing has been simulated using unsteady CFD modelling. First results indicate that future application of the X-LES modelling will allow more fidelity of the predicted spectrum of the flow unsteadiness in case of vortex breakdown.

Computational Aeroelasticity

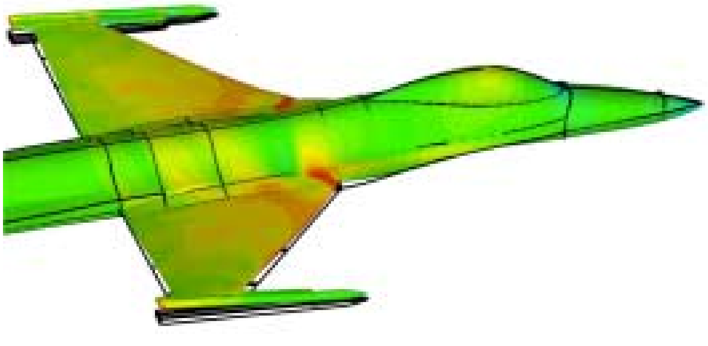
In 2003, NLR has worked on an aeroelastic analysis of wings including winglets in an EU project (AWIATOR). The analysis was performed prior to the flight tests of an A340, aimed at getting an impression of the deformation differences between different winglet types and the resulting wing loads. The work focuses on the impact of replacing the standard winglet by a larger one. It is expected that a larger winglet will have beneficial influences on the overall aircraft performance, but wing deformations due to larger winglets mounted on the wing tips might reduce or annihilate the potential benefits. Optimal design of wing tip devices is studied, based on viscous flow simulations coupled with an aeroelastic model of the wing including the different tip devices (EU project M-DAW).



Wing loads analysis for an A340 configuration with winglets

Life-Cycle Assessment of Military Aircraft

NLR continued its support to the certification and qualification of RNLAF F-16 configurations. With respect to assessing changes in the aeroelastic behaviour due to aircraft ageing, research has been focussed on the possibilities to use data recorded in-flight with the F-16 FACE system. More specifically, this ongoing research is aimed at creating means to facilitate datamining of the FACE database in order to assess the usefulness of its content with respect to mapping changes in aeroelastic behaviour due to aircraft ageing.



Static deformation analysis for an F-16 configuration with heavy wing-tip stores

NLR also continued its research on outer wing loads in the framework of life-cycle assessment. Additional analysis has been performed to quantify the deformations and stresses in the F-16 outer wing at extreme limit load conditions. For a manoeuvre at limit load conditions, it has been shown that Navier-Stokes flow analysis is necessary to obtain realistic loads and deformations. The severe flow separations on the wing at the extreme conditions analysed necessitates the use of a time-accurate approach and full non-linear physics modelling to obtain the wing loads in an efficient way. The loss of lift due to flow separations has been compensated by increasing the incidence. Resulting loads and deformations are input to the structural analysis.

New research has been started on creating a methodology for the quantitative life prediction of military aircraft airframes. This research is characterised by a strong interaction between different disciplines, i.e. aerodynamics, flight mechanics, structures and maintenance. Such a strong interaction is required for translating aircraft usage into external load, internal load, fatigue life and subsequently into maintenance aspects such as inspection intervals.

Aeroacoustics

Air Vehicle Operations-related Acoustics

One of the important activities of NLR is to develop noise computation procedures for aircraft operations. These are applied to predict noise levels to support the government of the Netherlands, as well as private enterprises such as airports and aircraft operators. For this reason, NLR started to develop an acoustic model for complete aircraft. Using this new aeroacoustic aircraft model, it will be feasible to study effects of noise directivity, atmospheric conditions, and flight procedures on the noise footprint of the aircraft. This model is based on theoretical models for individual aircraft noise sources and on experimental data from advanced measurement procedures using arrays of microphones. The data from the theoretical models and from the experiments are combined into a noise source distribution on a hemisphere below the aircraft. This noise source distribution is then coupled to routines for atmospheric propagation of sound.

Airframe Noise

Under contract with the Netherlands Agency for Aerospace Programmes (NIVR), research has been carried out on the characterisation of noise sources on landing gears. Acoustic array measurements from DNW-LLF wind tunnel tests on a full-scale landing gear were analysed in order to validate a new method which produces absolute noise levels from the array data. The acoustic source plots clearly show the position of dominant noise source regions, and on which locations noise reductions are obtained after application of special devices. The new method was successfully validated and enabled the quantification of both *local* noise reductions and the effect on the *overall* landing gear noise.
In a next step, the new quantification method was extended to *moving* noise sources, and was applied to array measurements on landing aircraft at Amsterdam Airport Schiphol. In this way, the contribution of the landing gear to the total aircraft noise was determined for several aircraft types.

To support airframe noise models, an experimental study was performed into gear wake / flap interaction noise (EU project SILENCE(R)). Although flight measurements indicate that this mechanism may be important, it has never been investigated in detail. Acoustic wind tunnel tests were carried out on a 1:13 scaled 2D wing section, including a generic main landing gear. Several measurement techniques were applied to determine the acoustic and aerodynamic characteristics of the flow. The test results clearly indicate the presence of interaction

Close-up of 2D wing model with landing gear (looking upstream)

Main landing gear with noise-reducing streamline fairings tested in-flight in EU project SILENCE(R)

noise radiated from the flap leading-edge behind the landing gear. The gear rather than the cavity is found to be the most important contributor to the turbulent wake impinging on the flap. It turns out that interaction noise can be reduced by placing the gear more upstream or by lining the flap leading edge.

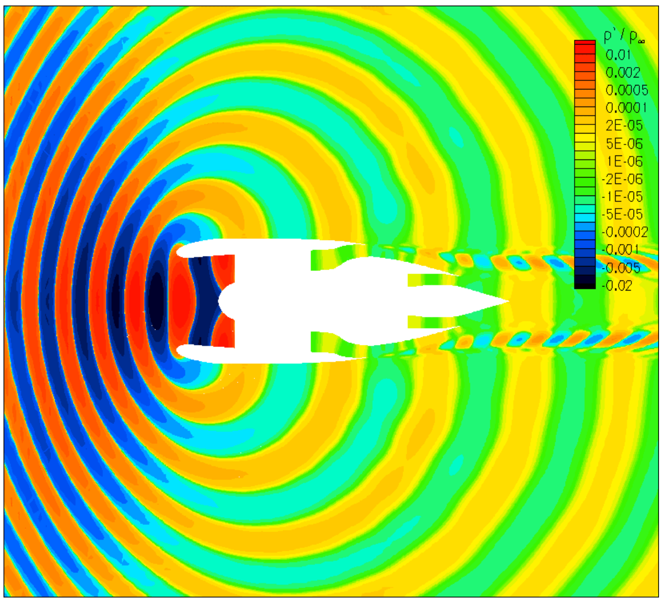
In an EU research project (AWIATOR), several devices are developed to improve the efficiency of aircraft wings. To investigate the aerodynamic and acoustic properties of these wing devices, wind tunnel tests were performed on an Airbus A340 model in the DNW 8m x 6m closed test section. For the purpose of these tests, additional to the existing acoustic wall array, two new arrays of larger size were built to enable detection of the noise radiation in three directions. It was shown that some devices have a *local* effect on the noise radiation. However, narrowband acoustic spectra, obtained by integrating all sources on the wing, showed a negligible effect on the *total* wing noise.

Noise Propagation

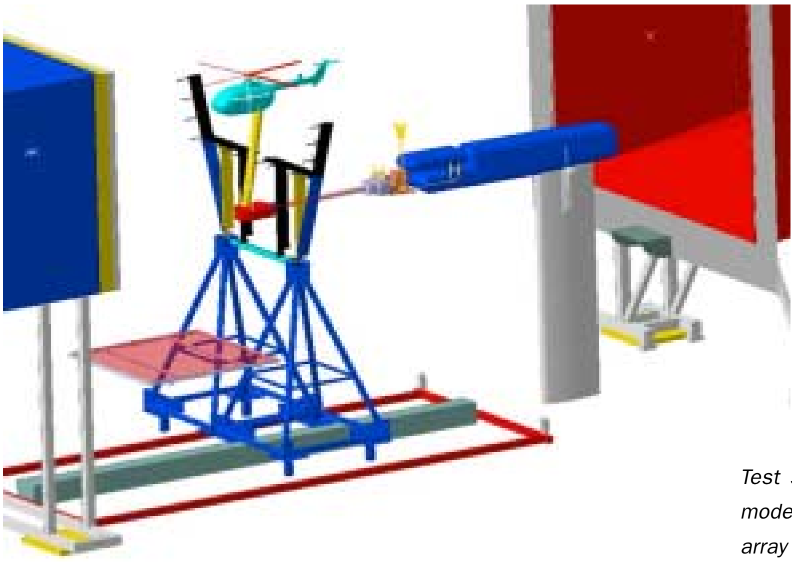
To better support industry and government, NLR's CFD system ENFLOW was extended with computational aeroacoustic modelling capabilities. It concerns an algorithm for the computation of near-field noise propagation based on the linearised Euler equations. A high-order, optimised numerical scheme is implemented that yields highly accurate results for aeroacoustic problems. The newly developed algorithm within the ENFLOW CFD system has been demonstrated for an acoustic wave propagating into the non-uniform flow around an engine.

Helicopter Noise

Acoustic wind tunnel tests were performed in the DNW-LLF on a helicopter model with main and tail rotor (EU project HeliNOVI). Besides an in-flow microphone rake, a traversable out-of-flow acoustic array (4m x 4m) was used to enable noise source localisation for different observer locations. The results indicated dominant noise source locations, which vary as a function of operation mode and observer location. By comparing measurements with main rotor only, tail rotor only and both, interaction effects could be investigated.



Noise radiation from an aircraft engine inlet



Test set-up for acoustic measurements on a helicopter model in the DNW-LLF wind tunnel (the out-of-flow acoustic array is shown in red)

Vibration Research

Vibration Tests at Civil and Military Aircraft

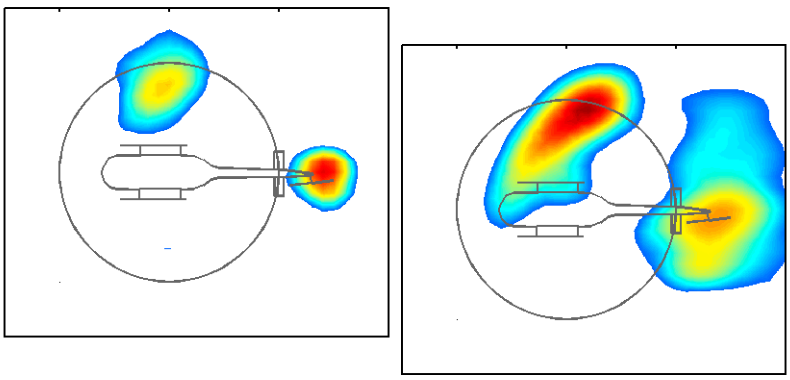
In order to avoid unacceptable vibration levels in civil and military aircraft due to modifications of the structure, vibration measurements have been performed by NLR for selected aircraft. For NLR's civil laboratory aircraft, the Swearingen Metro II and the Cessna Citation, measurements were performed in the cabin to register vibration levels at positions where new (vibration sensitive) equipment is to be installed. Equipment to be mounted outside the aircraft is instrumented with accelerometers to monitor vibrations during flight for which permission is needed from the Inspectorate General of Transport, Public Works and Water management (IVW-DL).

For the Chinook helicopters of the Royal Netherlands Airforce and the Lynx helicopters of the Royal Netherlands Navy, the structural modifications concerned "Missile Warning" systems, and "Forward Looking InfraRed (FLIR)" systems. To avoid unacceptable vibration levels, the natural frequencies of such systems should not interfere with the rotational orders (blade-passing frequencies) of the rotors during flight. For that reason vibration measurements on the ground are always performed as a (limited) ground vibration test to get insight in the vibration characteristics like natural frequencies, mode shapes and damping factors.

Non-aerospace Research

Testing Wind Turbine Models

A large wind turbine model will be tested in the DNW-LLF, to generate a database of wind turbine aerodynamic data, both from the turbine blades and from the turbine wake (EU project MEXICO). To minimise wall



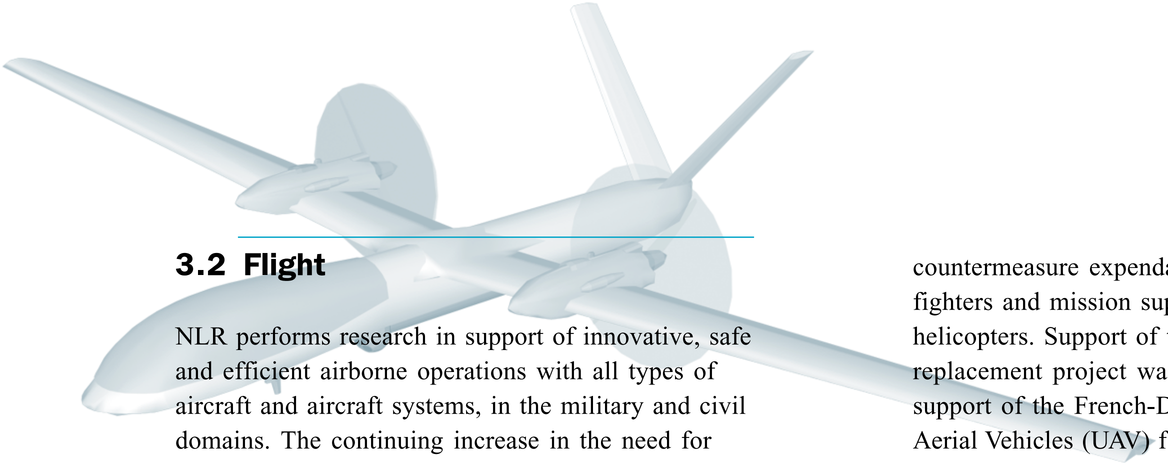
Noise sources on the helicopter model with main and tail rotor during level flight, as experienced by an observer below the model (left) and by a more upstream observer (right)

Structural modifications of the Citation (laser reflector of the Flight Inspection System) and the Chinook (missile warning system) that require vibration testing

interference effects on the required large model, it was decided to do the tests in an open jet. In preparation of this experiment, some preliminary tests were made for a small-scale wind turbine model in the small DNW Pilot Low-speed Wind Tunnel. The test set-up is a 1:10 scale representation of the tests to be run in the DNW-LLF. The objectives of these tests are to get a better understanding of the flow around the wind turbine in the open jet wind tunnel and to estimate wall interference effects that are to be expected for the large-scale experiment in the DNW-LLF. A further objective of the experiment was to evaluate the stability of the open jet of the wind tunnel when the turbine is operating at large yaw angles.

In co-operation with the National Renewable Energy Laboratory in the USA, aeroacoustic wind tunnel tests were performed with six airfoils that are candidates to be used on small wind turbines. The acoustic measurements were executed in the NLR Small Anechoic Wind Tunnel, for a range of wind speeds and angles of attack with and without boundary layer tripping. Besides the airfoil self-noise measurements in a clean tunnel flow, the models were also tested with a turbulence grid in the nozzle, to investigate airfoil noise associated with in-flow turbulence.

Structural modifications of the Chinook (missile warning system) that require vibration testing



3.2 Flight

NLR performs research in support of innovative, safe and efficient airborne operations with all types of aircraft and aircraft systems, in the military and civil domains. The continuing increase in the need for civil air transport will necessitate the use of advanced aircraft systems for navigation and separation of aircraft, in order to allow more aircraft to operate in the same airspace. Both civil and military aircraft operate in or near hostile environments.
Self-protection systems and knowledge of weapon system effectiveness against different aircraft are crucial for safe and sustainable (peace keeping) operations in various areas of the world.
Innovative aircraft systems that address the challenges of Air Traffic Management and future operations are modelled, simulated and tested in realistic flight simulators under the expected operational circumstances in order to assess and predict their operational utility and cost effectiveness. Potential risks, such as human performance issues, failure states, handling qualities problems and imperfect or even flawed operating procedures are identified.

Problems in society are not solved by technology alone. Any new technology has to be accepted and implemented, its users have to be trained, and operating procedures have to be adapted. In response to these requirements, NLR has gained experience with a new department, Training Development and Concept Validation, that focuses on both the validation of potential technologies and the implementation requirements associated with training and retraining of staff or with new selection requirements. By the use of objective experiments and data gathering techniques, the department will provide independent information for national and international government policy development and industrial decision making.

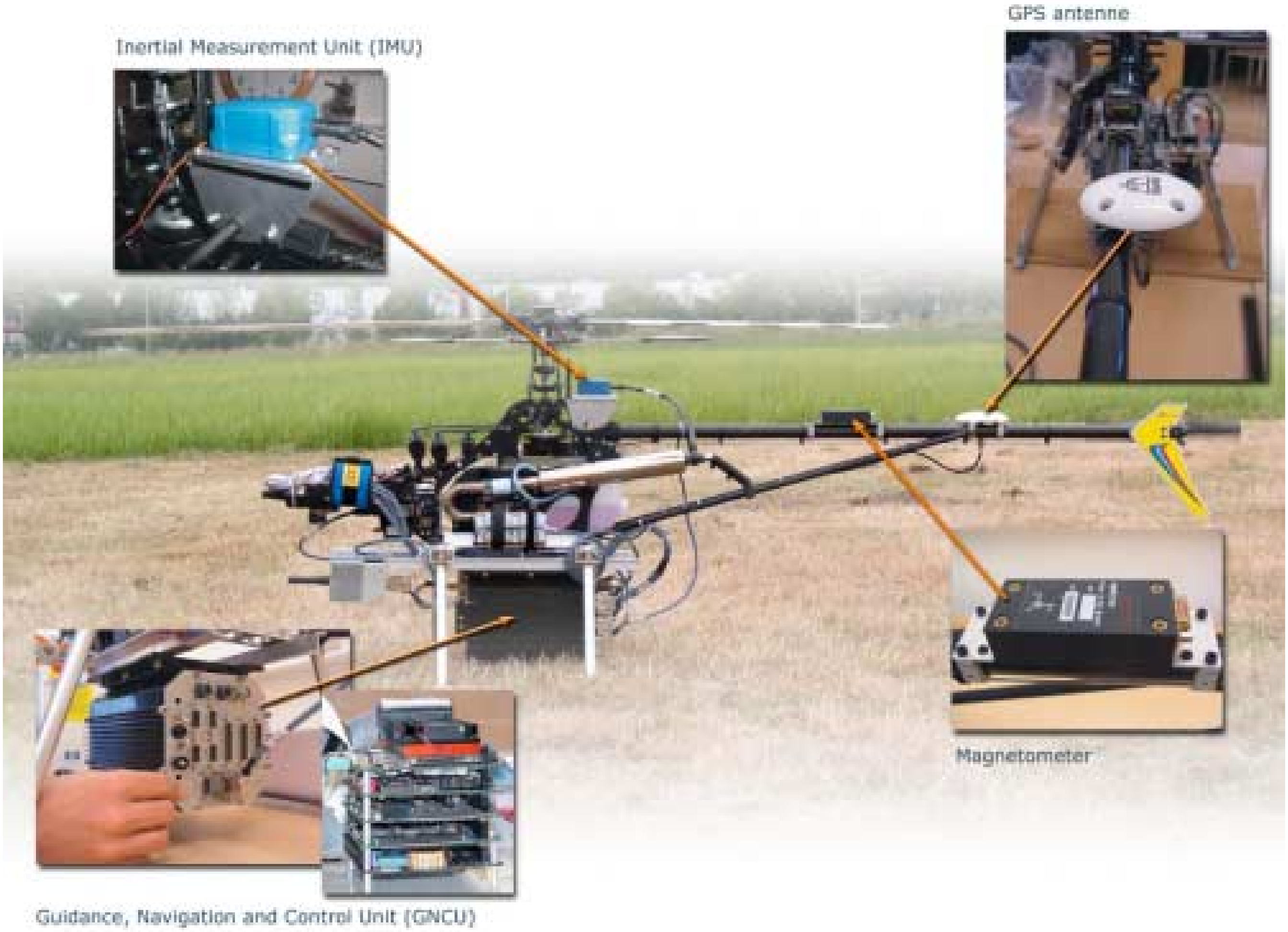
Some examples of specific activities and projects are mentioned below.

Procurement and Assessment
In the area of aircraft procurement and assessment, work focused on the evaluation of new equipment in fighters and helicopters, such as aircraft self-protection suites, countermeasure expendables, recce systems for fighters and mission support systems for helicopters. Support of the RNLAF F-16 replacement project was continued and support of the French-Dutch MALE Unmanned Aerial Vehicles (UAV) feasibility study was started. Assessment work included the experimental evaluation of voice as a system control input and of the feasibility of embedded training concepts, both in fighter aircraft. Work on the application of UAVs was continued intensively in collaboration with Dutch industry.

Research into Autonomous Unmanned Aerial Vehicles
In 2003, the milestone of 100 years of manned and powered flight was celebrated. In the past two decades, however, the activities on design, production and operation of UAVs increased exponentially. UAVs started as a remotely piloted vehicle, for which control commands from the operator on the ground are sent to the aircraft via a datalink. In recent years, there is an increasing demand for more autonomous UAVs that can fly pre-programmed missions with a minimum of interaction with a human operator. Increased autonomy increases the system's safety (in case of loss of datalink), reduces operator workload and can provide the capability to perform missions where continuous input from an operator is undesirable (covert operations) or impossible. Therefore, the Flight Division is executing research into UAV autonomy in two projects.

In the ARA-UAV project, NLR, Delft University of Technology (TUD) and FlyCam B.V. have equipped a small, unmanned helicopter with a newly developed guidance, navigation and control system on which advanced control techniques, including autonomy, can be tested in the coming years. The NLR and TUD activities in the project are funded by the NIVR.

In February 2003, the Group for Aeronautical Research and Technology in Europe (GARTEUR) has initiated the Flight Mechanics Action Group 14 on Autonomy in UAVs. The objective of this group is to explore



Nova Cuattro test helicopter showing some parts of the Guidance Navigation and Control Unit development kit (Courtesy of FlyCam B.V.)

the potential benefits of decision-making and route-planning techniques, which enable groups of UAVs to perform a mission completely autonomously and in collaboration with each other. The group of UAVs should be able to make adjustments to a global mission plan, based on events that occur and new information that becomes available during the mission. For this purpose, a baseline challenge has been formulated for a Suppression of Enemy Air Defence (SEAD) mission. In this group, NLR and TUD have teamed up. A literature survey has been conducted in 2003, whereas in 2004 a promising method will be implemented and tested on the baseline challenge.

Civil Applications for Unmanned Aerial Vehicles

Although UAVs are currently used almost exclusively for military applications, also civil and commercial applications are envisaged for the future. Therefore a thematic network UAVNET, funded by the European Union, was set up to investigate civil and commercial applications for UAVs. Under the umbrella of this network, workshops are organised to network with international partners, explore the possible applications and identify the problems that need to be solved. NLR takes part in this network by attending workshops and giving presentations.

Systems and Operational Concept Design

In the area of aircraft systems and operational concept design, various studies and experiments were performed. These studies are compatible with ACARE, the Advisory Council for Aeronautical Research in Europe, that drafted the strategic research agendas needed to ascertain environmentally friendly and safe air travel in 2020 and beyond.

Mediterranean Free Flight

Under sponsorship of the European Commission, the Mediterranean Free Flight (MFF) Programme is investigating the application of the Free Flight or ASAS (Airborne Separation Assurance System) concept, the Mediterranean area being the proving ground. MFF is led by ENAV (Italy) and involves a number of European partners, including NLR.

To facilitate the transition towards Free Flight, a number of Free Flight supporting applications enabling Free Flight have been defined in MFF and are being investigated. One of these applications is ASAS Spacing. ASAS Spacing involves the delegation to the pilot of certain sequencing (follow, merge behind) and passing (pass behind, pass below) tasks in relation to a specified target aircraft. The pilot takes responsibility for identifying the target aircraft and establishing separation based on instructions from the ground. Whilst relieving the controller of a number of routine tasks, he remains responsible for ensuring standard separation.

Early 2003, the so-called “Air Weeks” simulations were conducted in the scope of the MFF programme. The “Air Weeks” simulations aimed at evaluating the effects that ASAS Spacing applications would have on the flight crew, especially in terms of workload and pilot acceptance. In addition, the effects that ASAS manoeuvres would have on flight efficiency and safety were under consideration.

The “Air Weeks” experiment involved three cockpit simulators, each connected to an Air Traffic Control simulator, physically located at the ENAV Experimental Centre in Rome. Apart from the Eurocontrol Multi-Cockpit Simulator (MCS) and the ENAV Advanced Cockpit Simulator (ACS), the NLR Research Flight Simulator (RFS) was also connected to the Air Traffic Control simulator in Rome with simulated Automatic Dependent Surveillance – Broadcast (ADS-B) data and via a dedicated telephone line for Radio Telecommunication.

Overview of the simulation set-up

The "Air Weeks" experiment provided very important findings in the context of MFF and the airborne evaluation of ASAS applications. The experiments pointed out that ASAS Spacing operations are acceptable from a pilot point of view, in both en-route and arrival flight phases, although considered more applicable in the Terminal Manoeuvring Area (TMA) than en-route.

Furthermore, the 'Air Weeks' experiments proved the technical feasibility of running connected real-time simulations as four different simulation platforms were used.

DLR Advanced Technologies Testing Aircraft System (ATTAS)

X-31 Vectoring Extremely Short Takeoff and Landing Control and Tailless Operation Research (VECTOR) aircraft (Photographs courtesy of DLR)

Aircraft Pilot Coupling

The introduction of fly-by-wire flight control systems in modern aircraft made it possible to optimise the aerodynamics and structure of aircraft for higher performance and efficiency. As a result aircraft could be built with characteristics that would otherwise be impossible to realise. However, the result of this optimisation process often puts a very high demand on the performance of the flight control system, and may increase the risk of adverse interactions between the human pilot and the aircraft dynamics. These phenomena are called PIO (pilot-induced oscillations, pilot-in-the-loop oscillations, pilot-involved oscillations) or APC (aircraft-pilot coupling). It is the responsibility of the aircraft designer, and especially the aircraft flight control system designer, to make sure that the aircraft is sufficiently free from PIO tendencies before it can enter service. A number of incidents in the rather short history of fly-by-wire aircraft development has shown that tools, methods and procedures used so far had their limitations, and that there is still a need to develop them further. Examples of aircraft projects that have encountered PIO problems in flight which could have been avoided include: YF-16, YF-17, JAS 39, YF-22, Boeing 777, and YC-17.

In 1999, the Group for Aeronautical Research and Technology in Europe (GARTEUR) established an Action Group on Aircraft Pilot Coupling to address the need for the development of a design guideline on APC/PIO analysis and experimental evaluation techniques. A follow-up of this research has been established to further mature the most promising methods for PIO prediction with analytical as well as experimental techniques and to further develop the envisaged PIO handbook and analysis tools. For this purpose, the extension to actual flight test is sought to validate the experimental methods in-flight and to provide a database for comparison with offline and simulator analysis. Both commercial (DLR/ATTAS) as well as military aircraft will be considered (X-31). Additionally, as part of a collaboration programme between NLR and the Russian Central Aerohydrodynamic Institute TsAGI, methods will be developed to correlate simulator as well as real in-flight test measurements with predicted in-flight test results. The aim is to update the current PIO analysis tools with the capability for simulator-to-in-flight prediction. This enables to get early insight into possible PIO susceptibility problems during the FCS design phase before any real flight test is conducted. NLR will be mainly involved in conducting simulator experiments in conjunction with flight tests using DLR's ATTAS. So far, results of the research have been applied and validated in the Eurofighter development programme.

Affordable Digital Flight Control System for Small Commercial Aircraft (ADFCS-II)

Fly-by-wire (FBW) technology provides advantages in the field of flight safety, aircraft handling and direct operating costs. Extension of these benefits to small or medium size commercial aircraft is very desirable but will only be achieved if the cost of the technology can be reduced. FBW technology is state-of-the-art in modern medium to large civil transport aircraft. In small commercial aircraft (business jet/regional), the flight control systems are mechanically signalled and most of them are also hydraulically powered. Currently, several aircraft manufacturers are considering to adopt FBW technology for new generation small and medium commercial aircraft. These developments are potentially very significant in the highly competitive small-medium aircraft market.

The EU project Affordable Digital Flight Control System for Small Commercial Aircraft -Phase II- (ADFCS-II) investigates the feasibility of introducing FBW technology to the small and medium commercial aircraft market (30,000-60,000 lb. max. takeoff weight) utilising new technologies in the area of fault tolerant control, flight control architectures and handling qualities. The second phase of the project (2001-2004) has been primarily focussed on further maturing the most promising technologies taking into account the cost drivers identified during the first phase of the project (1998-2000). This includes consolidation of the benefits resulting from the introduction of new fault tolerant control techniques, actuator technology, handling qualities and FBW control methods. As part of the ADFCS-II programme, a consolidated flying qualities requirements design guideline for small to medium commercial aircraft has been developed to address the benefits of FBW technology. This includes a set of recommended flying qualities criteria and best practices for carefree manoeuvring, FBW control methods and control law design under normal, degraded and emergency mode. In 2003, an extensive simulator campaign has been conducted utilising NLR's Research Flight Simulator (RFS) to gain hands-on experience in an operational environment and finalise the FBW design guideline using pilot ratings. Apart from handling qualities criteria evaluation, novel FBW control methods like FBW flight path control have been investigated in order to reduce the pilot's workload while providing accurate flight path control. A FBW architecture based on electro-hydraulic actuator technologies has been evaluated to further improve FBW system affordability by reducing the required amount of hydraulic systems while maintaining adequate control redundancy in case of system failure modes. The conducted simulator campaign was a collaborative effort between NLR and partners from the United Kingdom (BAE Systems), Israel (Israel Aircraft Industry/ Technion), Italy (Alenia/University of Naples), Greece (University of Patras) and Poland (University of Warsaw).

Flight Operations

Pilot Model Development for ICAO-OCP Balked Landing Study

To determine the dimensions of the Obstacle Free Zone (OFZ) regarding new larger aeroplanes, such as the A-380, studies are conducted by ICAO-Obstacle Clearence Panel on the balked landing manoeuvre. Since the FAA has emphasized the importance of manual (flight director guided) approaches, automatic

ADFCS-II Simulator Campagne

approaches and also manual approaches, will be included in the Monte Carlo simulations. Within this scope, ICAO has undertaken a co-operated effort for the development of two mathematical pilot models. One model is developed by QinetiQ and the other by NLR, in consultation with AMSConsult BV. The NLR work is carried out under contract with IVW-DL.

As a first step, it was decided to start with the development of a pilot model for a Boeing 747-400. NLR completed a provisional mathematical pilot model for this type of aircraft. In November 2003 the NLR model was implemented and extensively tested in Boeing's highly non-linear simulation environment in Seattle. This resulted in a successful demonstration of the NLR pilot model for a group of Boeing and FAA delegates. Results of this mathematical pilot model were compared with flight simulator tests carried out in the Boeing 747-400 cab simulator.

Instrumentation Systems for On-board Wake Vortex Detection, Warning and Avoidance

In the European Union project I-WAKE it is investigated how on-board systems can detect wake vortex hazards. A concept for a future Human Machine Interface (HMI) was prototyped which displays the relevant information on potential wake vortex encounters. Its objective is to provide the pilot with situational awareness and cues for avoidance manoeuvres. Also, a concept was defined for a Detection, Warning and Avoidance (DWA) system. The DWA decides, based on sensor input and the current flight path, whether wake vortices from other traffic are a potential threat to the aircraft and whether information should be sent to the HMI. In this project it is assumed that the future DWA concept acquires its inputs from a Lidar sensor system, and from a model-based estimation of the vortex location and strength.

Besides the aforementioned study on a future wake vortex warning system, part of the project focuses on flight testing a current Lidar system, with the objective of detecting wake vortices in real-life conditions. In the summer of 2004, NLR's Cessna Citation will be equipped with a lidar system and will fly behind an Airbus 340-600. For this purpose, a flight test plan has been generated for aircraft installation and flight test execution.

Support for the Military

In the military field, support for the industry aiming at participation in the System Design and Development (SDD) Phase of the Joint Strike Fighter (JSF) was continued as well as the actual participation in the final development of naval helicopters (NH90). This NH90 programme gained great success by receiving orders for significant numbers of helicopters. Military self-protection has become more important than ever, so the research and consultancy into issues associated with missile and laser threats, self-protection systems and flying techniques was continued.

In the NIVR project FalconEar, NLR teamed with Philips Speech Processing to develop a fighter cockpit voice control application, as a candidate for inclusion in the JSF. The voice control application was implemented and evaluated on the National Simulation Facility (NSF), NLR's F-16 Mid-Life Update flight simulator. Functions were developed to demonstrate voice applications across the various domains of a fighter cockpit employment. They included emergency checklist control, interactive data retrieval procedures, and speaker-independent recognition in parts of the syntax, to facilitate name recognition to retrieve navigational aid and radio data. Simulator trials were used to conduct both system performance and human factors analysis of the voice control application. Analysis of pilot errors showed a strong training effect, with the average error rate decreasing from 27% to 13% over the course of training. Overall, pilots felt that commands were consistent, concise, natural, and easy to comprehend. Further, pilot ratings indicated that voice control did not negatively affect aircraft system awareness, overall situation awareness or task saturation.

Cougar hover in wind and low speed capabilities during land-based flight trials

Dedicated helicopter-ship qualification programmes are being executed by NLR for both the Royal Netherlands Navy (RNLN) and the Royal Netherlands Air Force (RNLAF) to determine the operating limitations that allow maximum availability of the helicopter within the constraints of safety for ship-borne operations.
Subject platforms are the RNLN Lynx onboard the Air Defence and Command Frigate LCF (Luchtverdedigings- en Commando Fregat) and RNLAF Cougar for operations onboard the Landing Platform Dock "Hr. Ms. Rotterdam". The RNLN project is at the stage of assessing the LCF full-scale airwake environment above the flight deck and the ship dynamic characteristics. The RNLAF project currently addresses Cougar hover in wind and low speed capabilities during land-based flight trials. Future developments are expected in the field of increased application of simulation, due to the risks and cost involved in flight testing and the difficulty to easily control test conditions. NLR is currently exploring the ability to support future helicopter/ship flight test activities by predicting helicopter/ship operational envelopes in the course of the NTP project ROSDYS.

NLR continued to support both the RNLAF and RNLN in the area of helicopter (system) procurement, work focusing on airworthiness certification of helicopter integrated self-protection suites, communication equipment, cockpit management systems and on the NH90 helicopter.

For several years NLR participates in a series of EU partially funded projects, dealing with the development of critical technologies for a European tilt rotor aircraft (Enhanced Rotorcraft Innovative Concept Achievement – ERICA). ERICA aims to develop a more innovative second-generation tilt-rotor architecture which has as its key characteristic the minimum rotor diameter, still compatible with hover performance, and in the tilting of the outboard portion of the wing, located in the slipstream of the rotors. NLR is involved in the EU projects ACT-TILT (development of the power-thrust management system), TILTAERO (wind tunnel testing in the DNW-LLF for rotor – wing interaction and acoustics), ADYN (whirl flutter predictions and wind tunnel testing in the DNW-LLF), RHILP (handling qualities) and TRISYD (architecture for a Health and Usage Monitor System).

The KLPD (Korps Landelijke Politie Diensten) has contracted NLR to review the certification approach of its MD900 Explorer helicopter. The MD900, specially configured for KLPD, is currently under development at MD Helicopters Inc.

NLR uses the commercial FlightLab software as the main engineering environment for helicopter and tilt-rotor dynamics model development and (real-time) simulation. The FlightLab object code is integrated into NLR's simulation software environment, which drives the various simulation hardware devices. The NLR in-house thermodynamic real-time gas turbine program TERTS is used for the simulation of the helicopter engines.
At present under contract of the RNLAF, flight mechanics models of the AH-64D Apache, the

ERICA (courtesy AgustaWestland)

CH-47D Chinook and Cougar helicopter are under development. A wide range of mathematical (sub)models with various levels of sophistication is available within FlightLab environment. The model library can also be extended with user-defined components. The modular design and the graphical user interface enable users to rapidly modify or expand model definitions, such as for sling load applications. The helicopter flight dynamics model comprises rotor, fuselage, tail surfaces and/or wing, interactional aerodynamics, landing gear, control system and engine modules. The rotor models used for real-time simulation are based on the blade element model approach.

Gas turbines

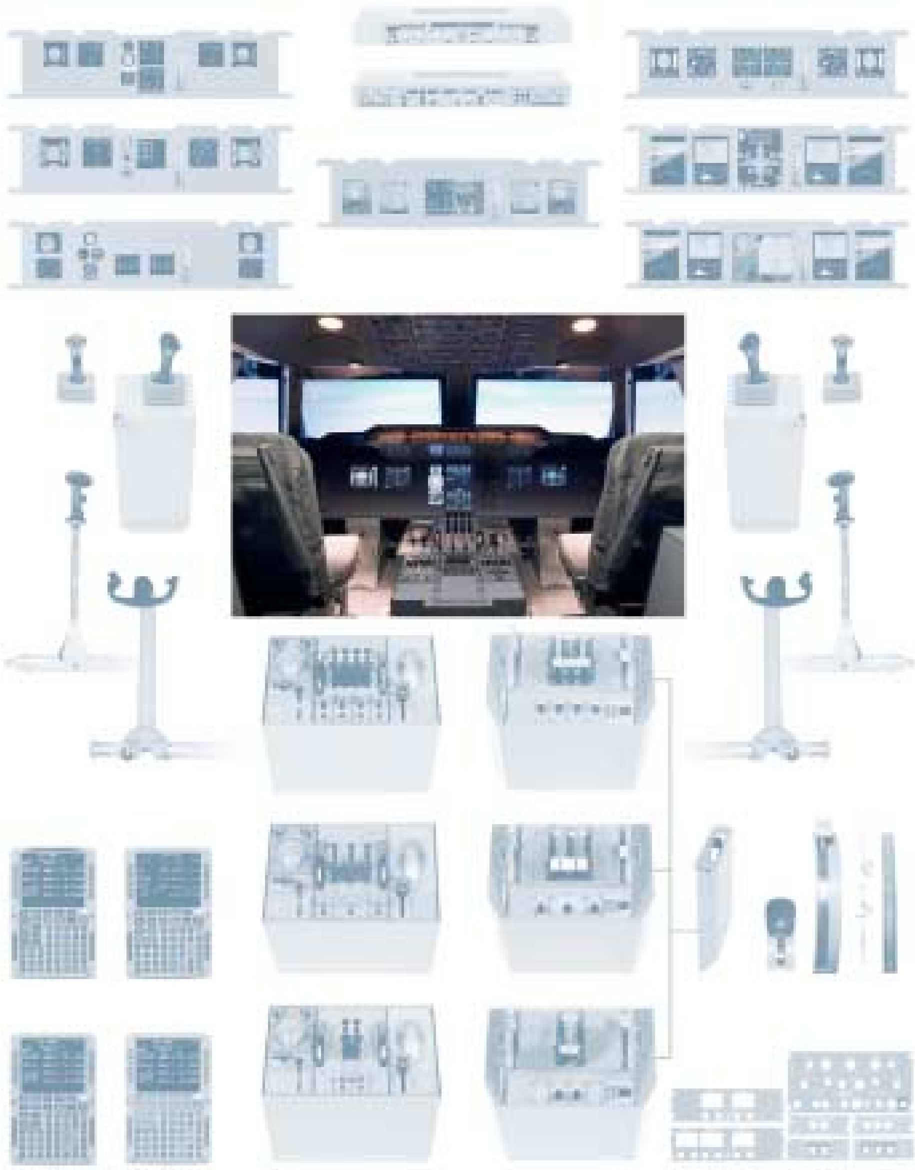
The Gas turbine Simulation Program (GSP) has gained increasing international interest following development of version 10 and the informative web-site at www.gspteam.com. Gas turbine models have been developed for Original Equipment Manufacturers such as Samsung Techwin (STW) and Alstom, while professional licenses have been sold to a.o. KARI and BAE Systems. In 2003 GSP won the contract as Defence Science and Technology Laboratory (DSTL's) primary gas turbine system simulation tool over several British and other international competitors. A contract with DSTL has started for developing and deploying GSP at several DSTL research facilities. Samsung STW has chosen GSP as simulation tool for their new engine development programs. NLR and STW have successfully embedded GSP in STW's own simulation environment using the GSP Application Programmer's Interface (API).

A generic engine condition monitoring functionality has been developed inside GSP in a NIVR funded BRP project. The GSP adaptive modelling component can turn any GSP model into an engine gas path diagnostics tool. A case study with KLM's CF6 engine test bed results has successfully demonstrated GSP's ability to identify engine problems and component deterioration, potentially saving high costs associated with identifying engine faults purely by disassembly of the engine.

For the EU project (AERO2K) the mission model E-Mission has been developed. E-Mission allows calculation of engine thrust and emissions through entire aircraft flight profiles, built from separate segments.
E-Mission provides a direct link to GSP through the GSP API, where for each calculation step the GSP model can be called with power setting or thrust demand.
For the helicopter department, a real-time thermodynamic TERTS engine model has been developed for the European tiltrotor ERICA, to be used within the Flightlab simulation software. Development of TERTS models for the RNLAF helicopters is in progress.
The TUD has been supported in the GERST project on analysis of effects of engine design and operations on emissions around airport.
For the lecturing on gas turbines a new English language gas turbine theory textbook has been written, while the gas turbine off-design (GSP) analysis workshop course is fully conducted by NLR.

NH90 Naval Frigate Helicopter (NFH) Three Crewmember Concept Qualification

NATO Helicopter Industries (NHI) is in the process of the qualification of NH90 NFH's capability to carry out missions with a crew of three: Pilot, Tactical Co-ordinator, and Sensor Operator. Since the year 2000, NLR supports Agusta in this area.
The three-crewmember qualification consists of the validation of the NFH crew workload and of all system requirements that have a relationship with the number of crewmembers and with Human-Machine Interface requirements. Industry and the customer together with NLR agreed on the approach and the experimental verifications necessary for the qualification. NLR's expertise concerning the assessment of human behaviour and simulator instrumentation was used to determine the set-up of the flight simulation trials at the Agusta premises in a fixed base tactical simulator. Crews from several nations participated. During the trials NLR had the responsibility for the operational process, Agusta for the operation of the tactical simulator and the training material. NLR analysed the data of eight crews and together



The versatility of NLR's new Flight Simulator GRACE

with industry and customers drew conclusions about the workload of the crewmembers and the feasibility of the three-crewmember concept. In the next stage of the qualification flight tests in a prototype NFH are planned. These test results should serve as complementary means of compliance and will be performed to validate the findings of the simulator tests.

Flight Simulation

GRACE

NLR completed the development of a new flight simulator cab: Generic Research Aircraft Cockpit Environment (GRACE), a versatile transport airliner cockpit. Since the delivery of the new cockpit in December 2002, NLR integrated the new cockpit with the simulation hardware and software. After a few weeks a completely new infrastructure arose next to the existing Research Flight Simulator (RFS). A visual projection system was added, interface software was adapted, equipment calibrated, drive laws for the new controls and panels were developed. Furthermore a new control desk was set up and miscellaneous equipment such as air conditioning and audio systems were developed and/or integrated. In the afternoon of 2 April 2003 the new GRACE cockpit made her maiden flight, an approach to Amsterdam Airport Schiphol.

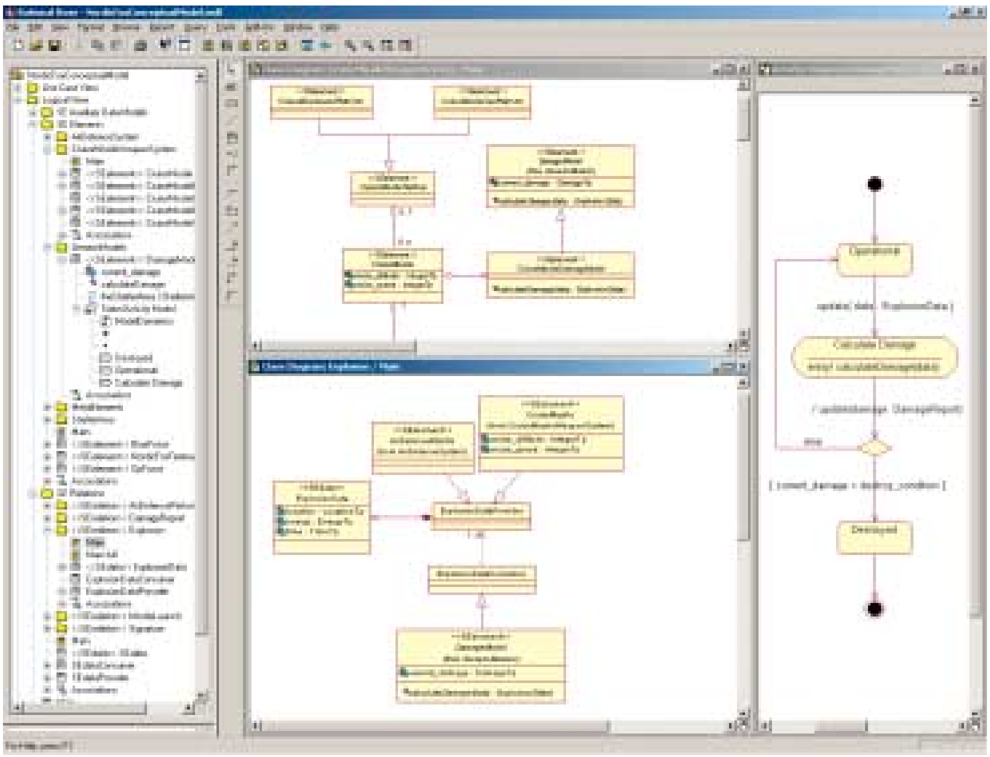
Pilots were enthusiastic about the level of realism achieved by this simulator. GRACE features a unique system of adaptable hardware and software. Standard column/wheel controls, as well as side-sticks or centre-sticks may be installed. Also the sticks are servo-controlled to enable research on active-sticks and haptonomic controls.

Using large displays and masks, a modular, exchangeable pedestal and in-house developed software, a range of different aircraft can be simulated. The cockpit can be equipped to simulate an Airbus340/330/320 just as well as a Boeing 747-400 or a business jet. The combination of a generic cockpit with this level of type specific realism makes GRACE a unique research flight simulator.

EUCLID Research and Technology Project (RTP) 11.13

The EUCLID RTP 11.13 project addresses the issue of 'Realising the potential of networked simulation in Europe'. Setting up complex military exercises that involve networks of many different types of simulations will play a crucial role in future military strategy. The aim of RTP 11.13 is to overcome the obstacles that prevent these Synthetic Environments (SEs) being exploited in Europe. This will be realised by developing processes and integrated prototype tool-sets that will reduce the cost and time-scale of creating and utilising SEs for training, mission rehearsal and simulation based acquisition.

NLR has led various work elements, with the main focus in the areas of conceptual modelling, requirement specification, and evaluation. Besides processes and methodology, three prototype tools have been co-developed by NLR to demonstrate the SE development concepts: the Synthetic Environment Specification Tool-set (SEST) consisting of the Conceptual Modelling Tool (CMT) and the Federation Requirements Tool (FRT), and the Execution Evaluation Tool (EET).
On completion of the 3 year project, in November 2003 a successful demonstration was given to representatives of the participating countries, including high-ranking military representatives, company executives, and leading European scientists in the field of distributed simulation. NLR has made a significant contribution to this final demonstration, by means of various presentations and demonstrations on the work in the project that was led by NLR. The SE community has expressed great interest in



Screenshot taken from the EUCLID 11.13 Conceptual Model Tool (CMT) especially the work done on conceptual modelling and evaluation. This work has significantly reduced a number of SE development and exploitation obstacles identified early in the project.

UAV Simulation

In the context of the EU project USICO (Unmanned aerial vehicle Safety Issues for Civil Operations), NLR has developed a model for UAVs. The UAV model has been incorporated in the NLR existing Traffic Manager and Experimenter (TMX). The TMX is used in many experiments with the flight simulator to enable interaction with other traffic. Scenarios to define the UAV flight profiles will be developed, while an experimenter may interact in real time to adjust the scenarios. For USICO the TMX will be coupled to the ATC simulator of DLR.

ULT-JOIND

In the NTP project ULT-JOIND (Unit Level Trainer-Joint Operations Integrated Network Demonstrator), a consortium consisting of NLR, TNO-FEL and Dutch Space has realised the Netherlands Complex Warfare Demonstrator (NL-CWD). This demonstrator showed the merits of Distributed Interactive Simulation (DIS) in the areas of training, mission rehearsal and acquisition. The NL-CWD consists of a simulated battlefield, where several F-16 Unit Level Trainers (ULTs) of the RNLAF were coupled interactively with other national simulation facilities - including NLR's National Simulation Facility (NSF) - in the same simulated tactical environment. Although the ULTs are prepared for interactive simulation using the DIS protocol, several modifications were applied in order to show the demonstrator as envisaged. The main issues were:

- the design of the network and the security measures to be taken;
- the common terrain database selection, one of the critical issues when performing an interactive simulation with a number of different simulators involved;
- the scenario design, required for showing the capabilities and results of the demonstrator;
- the DIS specification differences (the participating simulators were using different versions of the DIS protocol);
- the demonstration design, showing the right things at the right time.

The project successfully demonstrated the feasibility of the NL-CWD as well as the use of DIS.

Training

Eurotraining

In the area of training development the feasibility of an integrated European training system for jet pilot training for the period 2010-2030 was further investigated in the Eurotraining project.
The first activity of the Eurotraining Feasibility Study has been the Training Needs Analysis. NLR's role in this activity was to provide a modern competency-oriented methodology, to promote the Eurotraining concept, and to guide the team in the analysis process. Six former Air Force pilots provided their operational expertise. The starting point of the competency-oriented methodology was to identify the future systems and operations as well as the associated pilot capabilities. Using such reference scenarios, a global overview of pilot competencies and the performance criteria thereof were identified. Given these operational and piloting needs, a training concept was developed. This concept tries to minimise the national training by preparing the pilot to a higher level of mission capability before entering the squadrons. Within the Eurotraining phases, the full range of training media (Computer Based Training, desktop simulation, Full Mission Simulation, Networked Simulation and aircraft with embedded simulation) is foreseen to be useful. A model using these media for the type of competencies over the phase-periods was provided. An initial syllabus has been developed in order to provide a first indication of the time ratios between the various media.

ADAPT-IT

The EU project ADAPT-IT (Advanced Design Approach for Personalised Training - Interactive Tools) project was part of the 5th Framework IST programme of the EU and supported by DG INFSO and has been co-ordinated by NLR.

The ADAPT-IT project has completed the development of a multi-client tool for training designers active in all types of aviation training. The basis of the training method optimises the integration of its four components into an instructional design (4C/ID) model: whole-task exercises, part-task exercises, supportive information ('theory') and just-in-time information. The tool provides specific guidance to the training design process, including activities of competency-oriented needs analysis and training evaluation.

As a method, many academic cognitive science studies support its power, but ADAPT-IT has also been validated by two operational validation projects as well. In 2003, aircraft maintenance training (by Piaggio Aero Industries) and emergency training for air traffic controllers (by the Swedish ATS Academy) were successfully implemented and evaluated. Both validation partners will continue to use the training modules and apply ADAPT-IT for future training developments as well.

Considerable interest in ADAPT-IT results was shown during a workshop in June 2003 at EUROCONTROL IANS where a short introductory training was given to train providers. The Beta version of the ADAPT System is now used by more than 20 training providers/institutes. The ADAPT System will be on the market in 2004.

Training Media for NH90 helicopter

NHI is in the process of evaluating offers for Training Media for the NH90 helicopter. These training media encompass the full range from virtual maintenance trainers to full flight simulators. On behalf of Stork Aerospace, NLR is participating in the Training Media Task Force. Activities included specifying Terms & Conditions and the evaluation of the received offers on these terms and conditions with a detailed comparison of costs for both development and production phases. Finally NHI will deliver a consolidated offer to NAHEMA.

Crew Interaction and Situational Awareness

Crew Interaction and Situational Awareness (or SA) of the flight deck crew are increasingly recognised as critical elements of aviation safety. NLR is actively involved in research to identify fundamental causes of SA problems and objective means of assessing flight crew SA, and to develop countermeasures against deficiencies.

In the EU project Visual Interaction and Human Effectiveness in the Cockpit, Part 2 (VINTHEC2), such objective physiological measures as eye point-of-gaze are used in conjunction with cognitive modelling of the flight crew tasks, in specifying a set of behavioural markers that can help to assess the team SA in operational flight settings. Dissemination plans call for the VINTHEC2 approach to be promulgated not only to the aviation community. Other domains could be operations on the bridge of a ship and procedures related to medical operations; both share some essential characteristics of the flight crew's task (team interaction, time criticality, complex systems, highly advanced automation, etc).

Human Factors in Certification

In the field of human factors in aircraft certification, NLR participated in a Federal Aviation Administration /Joint Aviation Authorities (FAA/JAA) harmonisation working group that develops new airworthiness rules based on human factors. NLR provided a theoretical framework to analyse amongst others the deficiencies in the rule-making.

3.3 Air Transport

In the year 2003, the European Commission has made significant progress with respect to the institutional aspects of creating a Single European Sky. The NLR Air Transport Division has contributed to this goal by conducting a wide variety of research and development projects in four closely related areas: Air Traffic Management, Airport Operations, Air Transport Safety, Environmental Impact and Policy Support. An overview will be given of the main R&T results that have been achieved. Subsequently, a selection of five projects carried out in 2003 will be discussed.

In Air Traffic Management the focus has been on the design and validation of new ATM concepts, procedures and tools, like the integration of UAVs in the ATM system, a Flight Management System (FMS) for 4D-information exchange in the future ATM system (in a project led by Airbus).
Furthermore, a demonstrator containing Conflict Detection and Resolution aids for tactical and planner air traffic controllers was validated and delivered to Eurocontrol.
In a project, also for Eurocontrol, the workload effects for Dutch controllers following a change in UK airspace definition were assessed during real-time simulator exercises.
Several safety assessments of new and existing ATM operations at Schiphol have been made for the Dutch Air Traffic Service Provider (LVNL), including an assessment of the usage of Schiphol's southern taxiway (see below).
An operational European Gate-to-Gate ATM concept has been developed in a consortium led by THALES ATM.
LVNL and Boeing were supported in determining critical factors associated with the introduction of an advanced ATM concept for inbound priority sequencing.

In the area of airport operations, research was executed on the integration of advanced planning tools like an Arrival Manager, a Gate Planning tool and a Departure Management tool. The research was partially funded by the EU. Air Traffic controllers in the NLR Tower Research Simulator validated the concepts.

Also, NLR took part in the development of advanced approach procedures in the EU projects APPROVE and Sourdine-II. The Total Airport and Airspace Modeller (TAAM) was used to analyse the effects of new noise abatement procedures on capacity. Fast-time simulation models were developed for the Rome Fiumicino en Stockholm Arlanda airports. Both models will be used to assess the feasibility of Refined Flow Control up to the gates on these airports. Assessments made for LVNL on the capacity effects of changes in a number of Standard Instrument Departure (SIDs) are dealt with in the following paragraphs.

With respect to environment activities NLR is involved in environmental impact assessments of the Airport Schiphol. These activities concerned the evaluation of claims from the various stakeholders with respect to the expected noise load overflows due to errors made in earlier environmental assessments. In this respect particular attention was given to investigate possibilities to reduce the noise load in the region around Spaarndam.
NLR provided the Ministries of Air Transport and Defence as well as various airports with advice and the results of the noise load build-up with respect to various airports in the Netherlands.
NLR provided airport noise load committees with information and advise about the noise load and flight track distributions at airports.
Furthermore, NLR is the European partner in the dB Towers initiative in collaboration with Wyle Laboratories and the US Air Force.

In the area of Safety, and within the context of the EU project SHINE, flight tests were conducted with the NLR laboratory aircraft. The purpose was to evaluate the performance of a low-cost navigation platform, based on inertial sensors and Differential GPS technology. Research was also conducted into the performance requirements of precision approach systems, in particular Ground Based Augmentation Systems (GBAS).

For the FAA, support was given to update the JAR 25.1309 regulation regarding system certification. NLR supported the project by developing standard probabilities for specified failure events and by developing a method for giving credits for flight crew intervention in response to system failures. Also

for the FAA, a causal model was developed for the maintenance process.
In close co-operation with the RNLAF, an operation risk management methodology was developed that was validated with an operational case.
Under a contract awarded by Frankfurt Airport (Fraport AG), NLR performed third party risk analyses in the vicinity of the airport Frankfurt Rhein-Main. Development plans of Frankfurt Airport (fourth runway) called for an expert insight in the third party risk around Frankfurt Rhein-Main.
In the REACH project, NLR led a team that studied the aviation safety management in Switzerland. The findings were laid down in a report that was endorsed and publicly released by the Swiss Minister of Transport. More details on the project can be found in a separate paragraph on page 39.

Effects of Modified Standard Instrument Departures (SIDs) on the Departure Capacity of Schiphol Airport

In the course of 2003, the new 5th main runway 36L ("Polderbaan") of Schiphol Airport has become operational. The main reason to build this runway was to alleviate the noise impact on a number of heavily influenced built-up areas around Schiphol and to distribute the noise nuisance more evenly. However, a side-effect of this was that part of the noise impact has been displaced to previously less noise-affected areas, for example the village of Spaarndam. In order to reduce this effect for Spaarndam, a few modifications to the relevant SIDs of runway 36L were proposed.

To investigate whether these modifications could have a negative effect on the departure capacity of Schiphol, LVNL asked NLR to analyse effects for the westbound departures, i.e. the REFSO and BERGI SIDs from runway 36L, see the figures below.

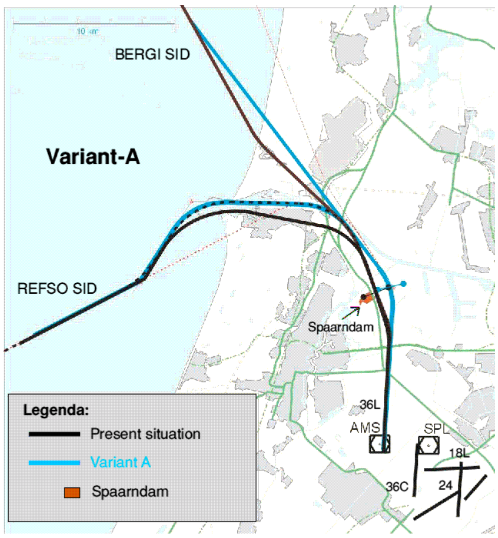
The fast-time simulation results showed that the differences between the investigated route variants in maximum departure capacity are small. The differences in traffic distribution with respect to aircraft type and time of day are much more pronounced.

The variants A and B which avoid Spaarndam produce a small penalty with respect to the maximum departure capacity of Schiphol as compared with the present operational situation.

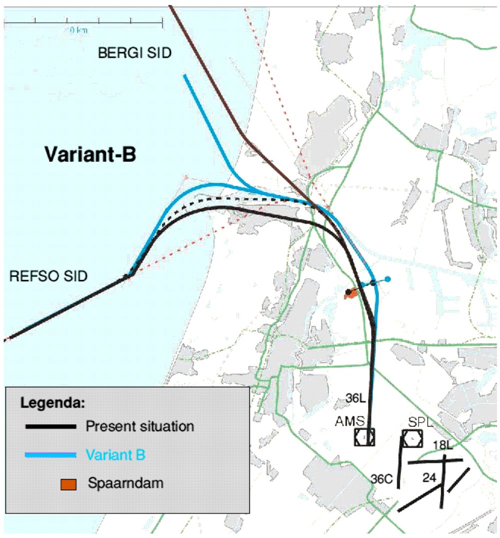
Safety Evaluation of the Usage of the Southern Taxiway

The 5th main runway at Schiphol has attracted much attention. Its capacity and the related environmental issues have been discussed by many, including national newspapers and politicians.

In the context of those discussions, LVNL assessed the performance of the new operation and requested NLR to execute a thorough safety evaluation. Among other things, NLR safety analists were tasked to assess the risks of the simultaneous usage of the "Zwanenburg



Routes for variant-A compared with present routes



Routes for variant-B compared with present routes baan" (for departing traffic to the south, see figure) and the southern taxiway (for traffic taxiing from and to the 5th runway in the following scenario). An aircraft is taxiing over the southern taxiway without a clearance from the runway controller. An aircraft taking-off from the "Zwanenburgbaan" simultaneously might be in a phase where the take-off can not be aborted. In these very unlikely combination of events a potentially dangerous situation might arise.

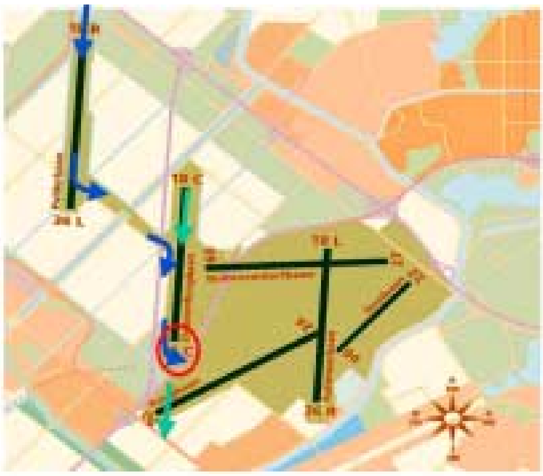
In order to determine this collision risk, several aspects need to be taken into account: visibility, runway lay-out, monitoring behaviour of Runway Controllers, communication between air traffic controllers, size of aircraft, etc. Many interviews with controllers and pilots were executed, several databases were analysed and millions of Monte Carlo simulations were run. The collected information was then put in mathematical models which finally resulted in a risk estimate.

The hazardous encounter described above is just one of many other possible situations that have been investigated. Airport vehicles can also use the southern taxiway leading to other possible conflict scenarios. The "Zwanenburgbaan" can also be used for landings, and this completely changes the above mentioned picture. Finally, the pilots of taxiing aircraft might get lost, ignore an active stopbar and cause a runway incursion. The risks of all possible conflict scenarios have been assessed.

NLR Activities for the Regionales DialogForum Frankfurt

Airport noise remains a major public concern despite major efforts from airport operators, air traffic control organisations and airlines to reduce the effects. In the Frankfurt region, an intensive public debate is going on about the Frankfurt airport expansion plans.

Since aircraft operations follow international guidelines and regulations, the air traffic movements in the vicinity of major airports are systematically recorded and the associated



Artist's impression of the conflict scenario described in the text. The blue arrows indicate a taxiing aircraft coming from the "Polderbaan", the green arrows indicate an aircraft taking-off from the "Zwanenburgbaan".

noise loads are both calculated and measured. In order to structure the public debate on the Frankfurt airport expansion plans, the Hessian government has installed the Regionales DialogForum Frankfurt. In this forum all stakeholders participate, including airlines, airports, industry, local authorities, public organisations and local population.

In co-operation with the Swiss EMPA (Eidgenössische Materialprüfungs- und Forschungsanstalt) and the German GMP (Büro für Geoinformatik, Umweltplanung, neue Medien), NLR investigated for the DialogForum what a transparent, intelligible, credible en manageable airport noise information system should look like.

Specifically, NLR addressed the legal context and regulations, internal methods, means, procedures, and efforts of the Deutsche Flug Sicherung DFS (the German Air Navigation Service Provider) to manage aircraft noise exposure at ground level. The NLR part of the study covered the DFS attention to noise aspects in the planning phases (design of routes, flying procedures and publication thereof), the daily operations (e.g. corrections, reporting of aircraft flying outside corridors), as well as post-analysis of recorded traffic (e.g.

noise exposure calculations and reporting and legal actions towards offenders). In this study, the options for interaction with the Frankfurt community have been given special attention.

As a result of this investigation, DFS decided to upgrade the installed FANOMOS system to include provisions for visualisation of air traffic movements. The aim is to support improved communication with the various stakeholders (including the Frankfurt community).

An Open-air Laboratory for Measuring Aircraft Noise during Flight: the dB Towers Facility

With the dB Towers facility a milestone will be reached to measure in flight aircraft noise with high fidelity and accuracy. This facility, which is planned to become operational by 2005 at the Arnolds Engineering and Development Center (USA), will provide accurate 3-D information on the noise signature of aircraft in various in-flight configurations.

It is expected that the use of this facility will improve measurement technology of aircraft noise and, will support the development of new acoustic models. These models cover different effects such as the directivity or non-spherical spreading, non-linear propagation, weather/turbulence effects, and the effects of terrain cover.

For this dB Towers project NLR closely co-operates with the Air Force Research Laboratory, the Wyle Laboratories and the Penn State University. The Air Force Research Laboratory is proceeding within the USAF to gain the environmental and test site approvals to build the facility at the Arnolds Engineering and Development Center.

The proposed facility basically consists of two 1250 ft towers oriented perpendicular to and 1000 ft away from the centerline of a 6000 x 150 ft runway. Microphones and microphone arrays will be mounted on the towers and arrayed on the ground up to 4000 ft perpendicular to the flight track and 3000 ft before and 3000 ft past the towers along the flight track. At each microphone location there will be a small weather station. Sound sources will also be mounted on both towers to calibrate the air in the vicinity of the towers prior to and after passage of the aircraft. The measurement systems will be linked via high-speed networks. Real-time octave band or possibly 1/3 octave band data will be available to guarantee a data collection with high integrity and quality.

Plans have been discussed to co-operate with the Royal Netherlands Meteorological Institute (KNMI) to extend the research to weather related effects on the noise propagation. This will be supported by the proper integration of meteorological models, meteorological observations at the Cabauw single tower facility in the Netherlands as well as KNMI's experience with infrasound.

NLR Study concerning Aviation Safety Management in Switzerland

In the last five years the Swiss aviation sector has been struck by a series of severe aviation accidents. The tragic sequence of aviation accidents started with the crash of a Swissair MD-11, in Halifax Canada, in 1998, followed by two fatal accidents with Crossair aircraft in 2000 and 2001. Finally, on July 1, 2002, two aircraft crashed near Ueberlingen (Germany) after a mid-air collision in airspace controlled by Skyguide, the Swiss air navigation service provider.

This has led to the perception that there might be structural causes within the Swiss air transportation system, leading to an inadequate level of safety. For this reason the Swiss Confederation decided, that an independent investigation should be performed to determine the effectiveness and efficiency of the processes and organisations, responsible for ensuring and managing aviation safety in Switzerland. NLR, leading a consortium with two external consultants, was subsequently contracted by the Swiss "Department for Environment, Traffic, Energy and Communication" (DETEC), to perform this assignment. NLR was selected because of its track-record in safety research, its broad aviation know-how and its network, combined with the methodical approach proposed. The

investigation addressed all major parties, comprising airlines, airports, ATC, the aviation authority, the accident investigation bureau, unions and DETEC itself. Moreover the study included a benchmark analysis, comparing Switzerland with its neighbouring countries. A large number of interviews have been conducted with representatives of all involved organisations, ranging from top management to actual safety managers and inspectors. In addition, over 300 documents were gathered and studied.
The Minister of Transport publicly released the final NLR report, entitled "Aviation Safety Management in Switzerland – recovering from the myth of perfection" on July 1st, 2003, exactly one year after the Üeberlingen accident. The report shows that the once exemplary safety record of Swiss aviation has deteriorated in the last decade to an average Western standard, with a clear negative safety trend during the last five years. The report clearly identifies the underlying causes, and specifies recommendations (28 in total) to reverse this trend. Main recommendations concern the re-organisation of the aviation authority, strengthening the aviation resources of the Department, changes to the organisation of the accident investigation bureau, and the introduction and/or strengthening of safety management and risk assessment processes within the aviation sector. A number of changes to the legislation are proposed. The results and conclusions of the report have been well received by the Swiss aviation sector, and are fully endorsed by the Swiss Minister of Transport. As a result of the report the Minister has assigned a national safety delegate to implement the recommendations.

3.4 Structures and Materials

Research and development activities in structures and materials were executed in the areas of loads and fatigue, structures technology, and the extension and improvement of laboratory facilities. Investigations and developments in these areas were primarily aimed at issues and themes that reflect the global industrial drive for improved affordability.
Projects under the Fifth Framework Programme of the European Union were continued or finalised.
Projects under the Sixth Framework Programe were started.
The remaining parts of the technology readiness demonstration programme, NVJSF, aimed at Dutch industry participation in the JSF programme, mainly on engine development were finalised. Projects on engine development were continued, to be finalised in 2003.
NLR participated in the development and certification of the fibre metal laminate GLARE that was chosen for the Airbus A380 fuselage structure. The major part of the work was completed. NLR participated in the continuing full scale test, a barrel test, on a large fuselage section with GLARE panels was finalised.
The activities mentioned, together with other contract research in the area of structures and materials, entailed approximately the same amount of work compared to the previous year. Contract research included work for the RNLAF, the RNLN, NIVR, IVW-DL and aerospace and aero-engine industries, mainly from the Netherlands. Work under a large contract for the tear down investigation on a Lockheed P3 Orion fatigued wing was performed.

Loads and Fatigue

Aircraft Loads and Certification
The one-dimensional modelling of atmospheric turbulence for gust loads analysis prescribed in the current airworthiness requirements may not be adequate for future very large aircraft. More realistic modelling that takes account of spanwise variation of gust velocities may be required for the development of large aircraft such as the Airbus A380. Various investigations have therefore been carried out to judge the effects of two-dimensional modelling of vertical turbulence on gust loads on large aircraft. In continuation of research on this subject in the early nineties, work was carried out under contract to Airbus Deutschland.

The computer program for the generation of load sequences for analysis and testing CLASS was further developed to ease the generation of load sequences by Stork Fokker AESP B.V. and Airbus Deutschland.

To support the Dutch industry a basic research project under contract to the NIVR on the prediction of loads and fatigue life on helicopter components was continued.

Certification work for the NH90 helicopter, carried out by the Dutch industry, was reviewed and reported to NHI.

Overview of the tear down of the P3 Orion wing structure

Load and Usage Monitoring
The fatigue load monitoring programme for Lockheed Martin F-16 aircraft of the RNLAF and the Belgian Air Force (BAF) has been continued.

Apart from the F-16 aircraft structure, the engine also is monitored. NLR has developed models to predict the engine life consumption using monitored flight data and engine data. These models were used to analyse the consequences of failures of engines in the USAF fleet.
A project to analyse the fault reports generated during flight was continued.

The load measuring systems installed in two Lockheed C-130 Hercules aircraft of the RNLAF are operational as of this year, in-flight measurements are completed and the data base structure and methods to monitor the aircraft usage are defined.

The load monitoring of the Lockheed P3 Orion aircraft of the RNLN and Spanish Armed Forces was continued.

On behalf of the RNLN, NLR participates in the Service Life Assessment Programme (SLAP) and Service Life Extension Programme (SLEP) for Lockheed Orion aircraft. SLAP/ SLEP is a collaborative programme between the US Navy, the Canadian Forces, the Australian Forces and the RNLN. As part of this programme, a full-scale fatigue test on an Orion aircraft will be performed in the USA. NLR is responsible for the comparison of the flight load spectra of the aircraft of the four participants in terms of fatigue life and damage tolerance behaviour. In addition NLR conducted a tear down of the left wing of the full scale test article. This included a disassembly of the complete wing and an inspection of the critical locations to make an inventory of the damage.

Several NLR departments collaborated with the RNLAF in load monitoring of the Chinook helicopter. Results of test flights carried out earlier are analysed and methods to monitor the usage are under development.

For the fatigue analysis of the NH90 tail structure fatigue loads were calculated by Stork Fokker AESP B.V. To validate these loads test flights will be conducted. NLR defined a test programme, instrumented a helicopter with straingauges and calibrated these gauges. Test flights will be conducted in 2004.

Gas Turbines
Methods and tools to analyse the life of gas turbine components under service load were developed further. In collaboration with the Twente University these methods were applied to a combustion chamber of an F-16 aircraft. In support of Eldim a design analysis was carried out for a gas turbine seal.
For the engine to be used on the JSF, technology maturation programmes have been defined in co-operation with the industry. The programmes deal with advanced thermal barrier coating systems and advanced sealing concepts. Coatings are designed, manufactured and tested. A test facility to measure the performance of a seal under realistic loading conditions was designed and built.

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

Statistical methods have been evaluated for the applicability of risk assessments to cracked structures. A new efficient method was developed, implemented and tested.

The applicability of statistical methods in the design of aircraft structures in relation with the regulations was studied in the EU project Advanced Design Concepts and Maintenance by Integrated Risk Evaluation for Aerostructures (ADMIRE). NLR participates in this project along with all major European aircraft manufacturers.

Space

To support the Dutch industry in the design of spacecraft components, the response of a stiffened component to an extreme thermal loading was analysed using a non-linear finite element model.

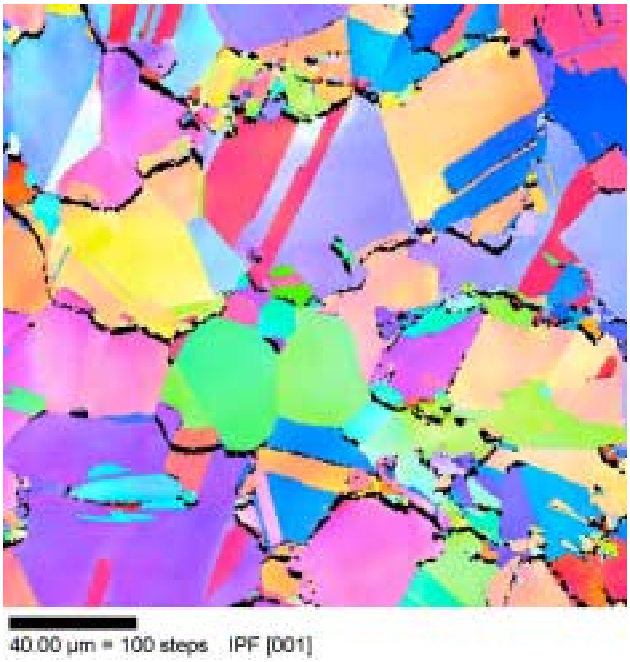
Structures Technology

Research and development has been carried out under contracts from the NIVR, the Netherlands Ministry of Defence, the RNLAF, the national and European industry, the EU, the Netherlands Civil Aviation Authority, the European Space Agency (ESA) and within the framework of the Basic Research Programme.

Aerospace Materials

Metallic, composite and hybrid materials have been evaluated and characterised with respect to their mechanical or corrosion properties. The effect of surface treatments and fabrication processes on these properties were also studied.

For NIVR, the potential of high strength steel alloy Aermet has been investigated for use in landing gears. Presentations were given on the effect of wire electrical discharge machining on the fatigue properties of high strength steel, and on the properties of phosphoric sulphuric acid anodising as an alternative for chromic acid anodising. Several NIVR projects were carried out to support the development of GLARE in co-operation with Stork Fokker AESP B.V., Fibre Metal Laminates Centre of Competence (FMLC), and the TUD. The GLARE Technology Programme was concluded, with projects to establish design allowables and material and splice qualification. Environmentally friendly, chromate-free paint systems have been evaluated for the RNLAF: two paint systems were applied to flying aircraft, and are being evaluated. Advanced, environmentally friendly paint stripping techniques for composite materials have been evaluated, and the results were discussed at an international forum.

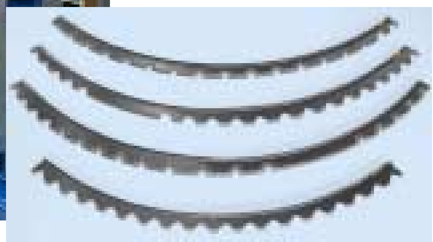


Example of texture measured with Electron Back Scattered Diffraction

For Stork Fokker AESP B.V., the microstructure of chromic acid anodic layers on several aluminium substrates was assessed. A material qualification programme was carried out for Urenco, focused on the composite material used in a filament wound drive shaft. Fatigue properties of 25CrMo4 steel, used in train axles, were determined for NedTrain. For Airbus, material qualification has been carried out, as well as work, focusing on “new” GLARE, on the basis of the “7000 series” aluminium and high-temperature curing epoxy material. For SONACA, qualification tests were conducted on Ti6V4Al

The brazing process for high temperature titanium applications was developed within the framework of the European project HORTIA. Within the framework of the European project BASSA (Bond Assisted Single Step Assembly), a specification was developed for tension tests on bonded and bolted specimens. Guidance was given to a Netherlands Institute for Metal Research (NIMR)-project, sponsored by NLR, to investigate the corrosion protection capabilities of Cd and ZnCoFe coatings on high-strength steel. Methods to determine the characteristics of fracture surfaces of

Fabrication of TANGO-frames in the composites laboratory



TANGO frames for a composite, A-320 sized fuselage "barrel" structure

composite materials were studied in GARTEUR Action Group (SM) AG-27. A study was performed to investigate the influence of texture, determined with electron back scattered diffraction, on the occurrence of Lüder lines as the result of the metal sheet forming process, as used by Stork Aerospace, under the NIVR Basic Research Programme. Under the NIVR Basic Research Programme the friction stir welding process was further evaluated, by participation in a round robin project, and in an exploratory GARTEUR project.

Composites Technology

The development of fabrication technology for composite aircraft structures is a multidisciplinary activity, combining the selection and evaluation of materials, the determination of process parameters, the optimisation of the design parameters, the performance of numerical analysis, and the experimental validation of components and prototypes.

For NIVR, a low cost fabrication concept for the cone cap of the Ariane V was developed and tested, in co-operation with Dutch Space. In co-operation with SP Aerospace and Vehicle Systems and Eurocarbon, six prototype composite trailing arms for the NH-90 were fabricated, in a project for the Ministry of Defence. A composite leading edge was designed and built for radar cross section measurements, and material selection and concept development for integral antennas in composite structures were carried out, within the framework of multi-disciplinary projects on behalf of the Ministry of Defence. Consulting support was given to Stork Fokker AESP B.V. related to the welding process for thermoplastic J-nose components, to be supplied to Airbus, and to the design of doors for the JSF. Several concept studies for new applications of landing gear components, made of composite materials, were carried out for SP Aerospace and Vehicle Systems.

Within EU-project TANGO (Technology Application to the Near-Term Business Goals and Objectives of the Aerospace Industry), NLR developed the technology to fabricate the fuselage frames for a full-scale composite fuselage 'barrel' section. Within the EU-project FALCOM (Failure Prediction in Advanced Low-Cost Composites) process technology has been developed for Resin Transfer Moulding (RTM), related to new material architectures. Within EU-project DART (Development of an Advanced Rotor for Tilt-Rotor), the technology for thick composite components was being developed, focused on the hub of a helicopter. The Department of Applied Mechanics and Composites of Twente University has been contracted to develop the capabilities for automation of the RTM-process. The work, carried out by two Ph.D. students, is focused on the prediction of permeability and on the modelling of process

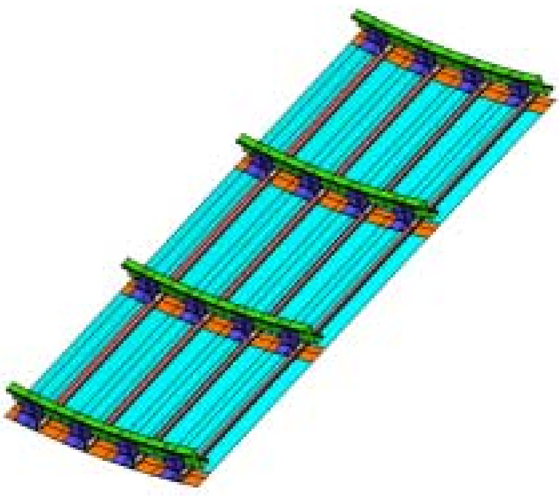
parameters for braiding.
In co-operation with ONERA, a permeability study was carried out for braided composites. The analysis of micro-cracking in thick composites was analysed under the Basic Research Programme.

Structural Design
Design methods were being developed for the aerospace industry, and designs were validated experimentally or numerically.

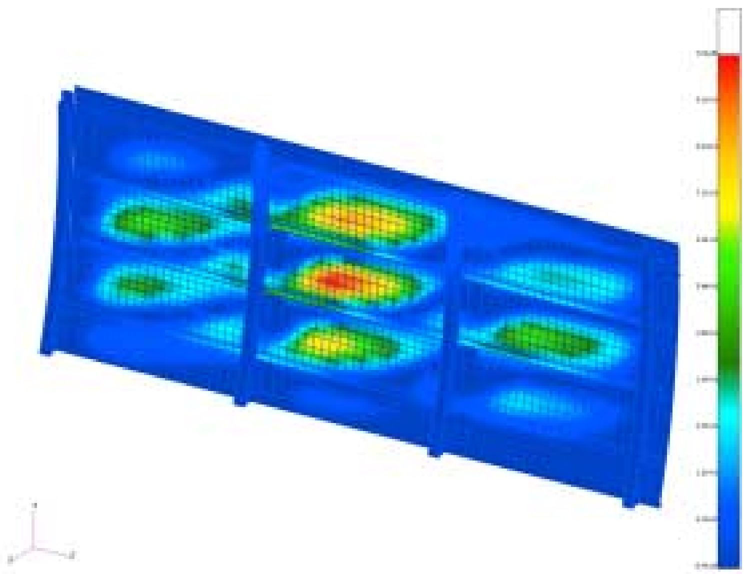
For NIVR, design methods were developed for composite bead-stiffened ribs, for stiffened shear panels, and for compression panels, to be used by Stork Fokker AESP B.V.. Also a programme to develop a computer-assisted structural design environment has been carried out for NIVR. A numerical optimisation capability for the design and maintenance of composite aircraft structures was developed in a 3-national project (DAMOCLES II) for the Ministry of Defence, which includes panels QinetiQ. For Urenco Aerospace, several projects to support the technology development for composite drive shafts were carried out, partly under contracts from the Ministry of Defence and industry. These activities included the full-scale torsion testing of drive shafts, and the preparation for design reviews. Failure criteria for bolted joints were developed in the EU project BOJCAS (Bolted Joints in Composite Aircraft Structures). The design capability for composite structures, accounting for impact damage and repair, is being developed within GARTEUR Action Group (SM) AG-28.

The ability to model the structural response by computational methods is of great importance to speed up the design process, to reduce the technical risk of a selected solution, and to reduce the extent of time-consuming and costly experimental programmes.

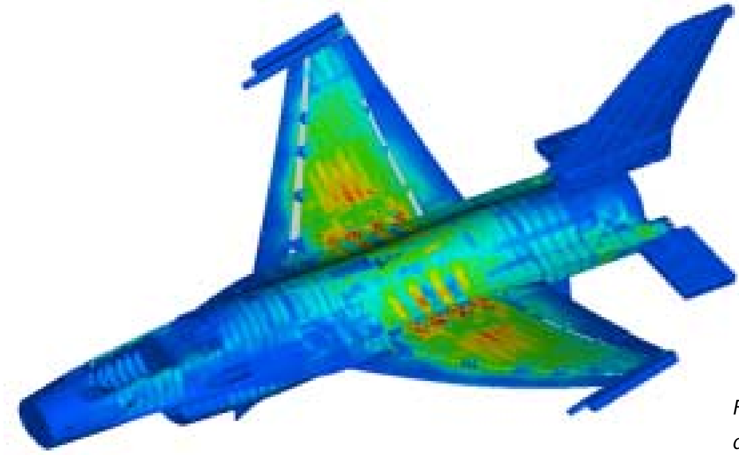
A finite element model for the F-16 “block 10” version was developed for Lockheed Martin on the basis of the model of the “block 15” version. Knowledge acquired in this project was used to provide a VisionSlim course to British Aerospace, for the post-processing of large models. Finite element analyses and life



CAD model of a shear panel



F.e.m. model with buckling pattern due to shear stresses



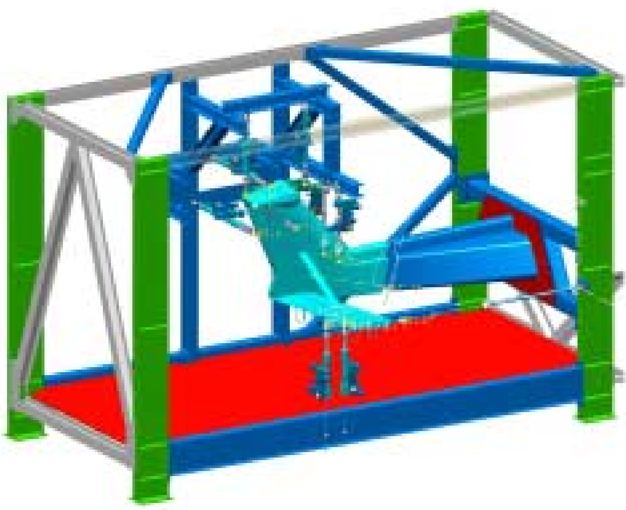
F-16 coarse grid finite element model; stresses and deformations as a result of a 9-g pull-up manoeuvre

prediction were carried out for the drive shaft development of Urenco Aerospace. Within the EU project CRAHVI (Crashworthiness of Aircraft for High Velocity Impact), design methodology was being developed for bird strike on composite leading edges of horizontal stabilisers, three composite leading edges were delivered, and exploitation management was carried out. For the Netherlands Civil Aviation Authority, a computer code was developed to model the collision of an aircraft with approach light structures near runways. A contribution was delivered to the ICAO Aerodrome Design Manual. Expertise of NLR in the areas of fatigue and damage tolerance has been applied in contracts from ESA.

For GARTEUR Action Group (SM) AG-24, bird strike analysis was carried out, and a composite leading edge was delivered, to be tested by QinetiQ. For GARTEUR Action Group (SM) AG-25, addressing the effects of plasticity, mode-jumping and skin-stiffener separation on buckling and post-buckling behaviour, a contribution to the final report was delivered. A contribution to the final report of GARTEUR Action Group (SM) AG-26, dedicated to the development of life prediction methods based on equivalent initial flaw size distributions, was delivered. The B2000 in-house finite element code, used to evaluate new capabilities, has been extended with 3-nodal shell elements. Together with DLR, a study has been performed regarding the implementation of a new B2000 processor, to solve finite element problems consisting of P-version elements. The NASTRAN-to-B2000 interface has achieved an almost 100% compatibility level for linear analysis. Damage and cost constraints have been implemented in B2OPT. Under the NIVR Basic Research Programme, a system for active control of vibrations in rotating, flexible components was developed, in co-operation with the University of Twente

Certification and Qualification Tests

Certification tests on material and prototype of the J-nose of the Airbus A380 and A340-500/600 were performed under contract to Stork Fokker AESP B.V.. Hail impact tests on the A380 J-nose were performed using a hail impacter developed at NLR.



CAD model of the test set-up for the NH90 helicopter

To validate the structural concept of the A380 fuselage applying new materials, such as GLARE, EADS Deutschland in Hamburg performs tests on a fuselage part, the so-called megaliner barrel. NLR gives on-site support to the barrel test activities in close co-operation with Stork Fokker AESP B.V. being responsible for design and manufacture of the GLARE fuselage panels. NLR carried out non-destructive inspections and new inspection methods are being developed.
The certification programme on the GLARE material was continued, and a certification programme on the main landing gear lugs of the A340-500/600 aircraft was completed.

For Stork Fokker AESP B.V. the replacement of redux by an epoxy (AF 163-2K) bonding system was evaluated. Compression tests were carried out on stiffened panels.

Core termination tests have been started for the JSF doors design concepts.

A material qualification programme was performed for dual pack canisters of Stork Fokker AESP B.V.

A test set-up has been built under contract to Urenco Aerospace in order to carry out torsion tests on the fan shaft of the JSF manufactured by Urenco. Further tests on the drive shaft of the Tigre helicopter produced by Urenco were carried out.

A test set-up is designed and constructed for the full scale static and fatigue test on the tail section of the NH90 helicopter under contract to Stork Fokker AESP B.V.

General Support

Intrusion resistance tests were carried out on modified door configurations for the F-28 MK100 and MK70 flight deck door, under contract to Fokker Services B.V.

3.5 Space

The year 2003 has shown encouraging developments, such as the green/white paper publication in the European Commission and the approval of the European satellite navigation programme Galileo, where the first contracts have been signed. Also a positive decision was made about the flight of André Kuipers to the International Space Station; he will be the second Dutch astronaut. NLR actively participated in these developments in two main areas: a technological area focussed on industrial needs with the goal to improve industrial competitiveness and an application oriented area focussed on user needs with the goal to make optimal use of the space infrastructure.
The technological area contains activities related to satellite subsystems and launchers. The application-oriented area is related to remote sensing applications, satellite navigation and space station utilisation.

Satellite subsystems

Thermal Control

In the area of thermal control the NLR activities have been focussed on the application of two-phase flow technology for efficient thermal transport and cooling.

NLR is a member of the Alpha Magnetic Spectrometer (AMS-2) Consortium. Within this consortium NLR is responsible for the thermal control system of the main detector, the Silicon Tracker. A liquid helium cooled, large cryogenic magnet that provides the required magnetic field inside the tracker surrounds the Tracker. In order to save liquid helium the magnet may not receive any heat from the Tracker. This, in combination with the existing mechanical constraints led to the unique, challenging development of an actively controlled two-phase CO_2 loop. In 2003 the detailed design of the mechanical pumped carbon dioxide two-phase loop has been completed. A full-scale bread board model has been built and with this breadboard some limiting thermal cases have been exercised.

NLR has designed and build prototypes of new passive cooling and radiator devices like the Flat Swinging Heat Pipe (FSHP), a cooling concept for high-density electronics, and the variable emission radiator (VARES) for a high efficiency light weight radiator perfectly suited for the demanding telecommunications satellites as well as future deep space missions.

Small Satellites

NLR is the main contractor of Sloshsat FLEVO, a mini satellite for the study of liquid dynamics and liquid management problems in space. The behaviour of water in an instrumented tank in the satellite will be monitored to help understand how sloshing affects the attitude and orbit controls of space vehicles.
Due to the space shuttle problems a new launch opportunity has been investigated, a launch with the Ariane5 is foreseen for 2004.
Based on the Sloshsat experience NLR, together with Dutch Space, has started preparation for the development of ConeXpress, a Geostationary Earth Orbit (GEO) satellite platform for telecommunication payloads.

Satellite Navigation.

In the area of satellite navigation NLR has focussed her activities on verification and validation of the Galileo navigation system. In the area of spacecraft NLR worked on the Galileo B2 System RAMS and System verification under contract with ESA/Alenia Spazio and on the Galileo system verification, methods and tools for ESA/ Astrium D.
The work on EGNOS verification for ESA/ Thales was continued, while activities on the EGNOS-ASQF for ESA/GMV were started.

In order to ensure a strong Dutch position to realise the Netherlands' verification and validation priority area in the European Galileo project, NLR has set up a national consortium with Dutch Space and TNO, called the Valileo consortium.

Space Station Utilisation

Mission Preparation and training equipment

The Mission Preparation and Training Equipment (MPTE) for the European Robot Arm (ERA) is being developed under ESA contract to provide the Russian segment of the ISS with means to prepare, train and support ERA operations on the International Space Station.
Preparation and mission support will take place at the Mission Control Centre and Rocket and Space Corporation Energia, near Moscow. Cosmonauts will be trained for both external and internal control of ERA at the Gagarin Cosmonaut Training Centre in Star City. ESA will use its version of MPTE for instructor training and support tasks such as software maintenance.
The MPTE system has been installed at ESTEC. In 2003 the system has been successfully integrated and will be delivered early 2004.

Delta Mission

Early 2004, the Dutch ESA cosmonaut / astronaut André Kuipers will be launched on board a Russian Soyuz on his way to the International Space Station during the Dutch Soyuz Mission. During this mission he will perform various scientific and technological experiments.
NLR supports the Dutch Soyuz Mission providing a "Dutch Experiment Co-ordinator" as point of contact for experiments in the area of "Physical Science". NLR also participates in the Dutch Project Office (DPO) focussing on the operational aspect of the experiments.

European Drawer Rack Facility Responsible Centre (EDR-FRC)

The EDR-FRC will be part of the European Decentralised Operations Ground Segment of the International Space Station in which many User Support and Operations Centres (USOC) co-operate. NLR represents the Dutch Utilisation Centre (DUC) and works together with the Belgian co-partner SAS on the development of the EDR-FRC. In 2003, NLR contributed to a further definition of the USOC's and NLR's role in it.

Remote Sensing Applications

In the area of remote sensing applications NLR participated in the EU programme PRESENSE (Pipeline Remote Sensing for Safety and Environment). In the project a concept and prototype for a European pipeline monitoring system is developed in co-operation with European Gas Companies to ensure the safety of their pipeline networks in a secure and efficient way.

In co-operation with the Eonic company, NLR on-board Synthetic Aperture Radar (SAR) compressor technology has been developed. The achievements have led to a recommendation of ESA to use this technology on-board the Terrasar-L satellite. The Terrasar-L project is currently in phase B. NLR and Eonic have good chances to be involved in phase C/D.

Remote Sensing ground stations have proven to be of increasing relevance for military operations. Within research projects image processing technologies have been refined and demonstrated. Within the National Technology Project (NTP) framework the GISMO project has been started. The project focuses on usage and integration of satellite imagery in military operations. Existing technologies and equipment, including the RAPIDS and DIRECD ground stations, will be reconfigured and ruggedized.

Within the framework of the Geomatics Business Park synergy plan the Extreme Events Engineering & Monitoring project has been started. The aim of the project is to combine "Global Mapping Services" related to climate changes and "Rapid Mapping Services" related to local conditions leading to extreme events resulting in mapping products.

As part of a national geo-information infrastructure, NLR has worked on the development of a Geospatial Data Service Centre (GDSC) within the Geomatics Business Park.

3.6 Information and Communication Technology

Activities in the area of Information and Communication Technology (ICT) were dedicated to the development, production and life cycle support of information systems for a variety of applications, aimed at national and European aerospace and air transport objectives.

Overview

In the areas of Air Traffic Management NLR has continued the support and development of the ARTAS tracker. To ensure that the ARTAS tracker can be used in today's and future environments, enhancements to the processing of Mode-S radar data and ADS-B data are being added to the tracker.
A tracker for ground movement surveillance is being developed. Tests on a number of data sets from Schiphol airport have shown that this tracker behaves very well. In co-operation with Dutch industry HITT Traffic, the tracker is extended for vessel traffic surveillance (VTS). On a test site along the Dutch coastline the first successful tests with VTS on open sea were performed.

NLR acquired a leading role in the Value Improvement through a Virtual Aeronautical Collaborative Enterprise (VIVACE) proposal, lead by Airbus, for a EU Integrated Project, which is expected to start on 1 January 2004. VIVACE's strategic objectives are contribution to halve the time marketing for new aeronautical products, to increase the integration of the supply chain in the aeronautical network, and to maintain a steady and continuous fall in travel charges.
VIVACE's main result will therefore be an Aeronautical Collaborative Design and Simulation Environment based on a set of reference Processes, Models, and Methods to design and simulate an aircraft, helicopter, and engines.

The EU project Security of Aircraft in the Future European Environment (SAFEE) will provide an advanced aircraft security system designed to counteract on-board terrorist actions. NLR e.g. contributes with the development and application of causal models to identify and assess potential measures to improve the security of the air transport system. The developed systems and concepts

Vessel traffic surveillance test site

of operation will subsequently be tested and evaluated by pilots in the NLR Generic Research Aircraft Cockpit Environment (GRACE).

Under contract to the Netherlands Civil Aviation Authority, the Flight track and Aircraft NOise MOnitoring System (FANOMOS) has been upgraded, to include calculation and monitoring functionality in order to provide the required information related to new regulations set up for Amsterdam Airport Schiphol. NLR has developed several technology components for the growing customer demand to explore object data, such as aircraft movements, in a 4-D virtual world. The 3DFlight application was developed for the IVW-DL in order to access aircraft data using Intra/Internet, and replay them to perform detailed analysis of the actual traffic picture in airspace at any moment in time.

DFS Deutsche Flugsichering GmbH has operated FANOMOS successfully for 15 years. DFS requested NLR to upgrade their systems to include the latest functionality available. After successful installation and acceptance in Frankfurt (June 2003), NLR provided end-user training to DFS staff from all major airports in Germany. To enable FANOMOS users to gain in-depth knowledge on flight behaviour, as well as on the related environmental impact around an airport, the FANOMOS 3DFlight module has been further developed, based on NLR's 4-D presentation technology components .

The demand for data storage capacity shows an annual growth of 74%. In order to enable this growth, a data storage concept has been developed for the coming years. The concept consists of one large central data storage system in each NLR site, complemented with a data back-up system, The first steps of the implementation of the concept have been completed.

Systems Simulation and Engineering

With the release of the EuroSim Model and Simulator Repository (MSR) and the EuroSim Composition Tool (CT) in the beginning of 2003, NLR continued to support the complete life cycle of collaborative systems engineering projects. A number of user-friendly tools are available that allow developers to focus on the task at hand, and that also serve as knowledge base for NLR's systems simulation and engineering expertise. Control engineers, or more general, model developers, can use their favourite COTS tool, such as Matlab/Simulink to develop and test their models. MOSAIC is used to transfer models from COTS tools to other simulation environments. The web-based and secure MSR promotes model re-use by storing these models, including user defined meta-data and making them available to all members of a project or programme.

NLR's simulation paradigm described above proved very successful and – by design – easy to adapt to the demands of users in a wide variety of application projects. Whereas in EuroSim emphasis is on various types of

4-D presentation technology available for analysis of flight behaviour

Integrated Technology Evaluation Platform in FACE

models and on EuroSim simulators, in the FACE project the focus is on several types of very large (raw and processed) data sets. An instantiation of the MSR has been made to accommodate the results of the physical and numerical experiments in an efficient way. Building on the results of the European project ASICA, also the interaction between SPINEware and the MSR has been further improved and they now work seamlessly together.

Optimisation of Aircraft Systems

In several EU projects NLR contributes to optimisation of aircraft systems. In the EU Technology Platform Power Optimised Aircraft (POA), NLR contributes to the reduction of aircraft's fuel consumption by reduction of non-propulsive power through the replacement of mechanical, pneumatic, and hydraulic systems by (partly) electric equivalents. NLR extended its implementation in the MultiFit tool of its approximation model methodology for modelling and subsequent analysis of large, multi-component and/or computationally complex systems, such as the aircraft's non-propulsive power system. With a focus on the pneumatic systems models, NLR contributed to the integration of POA partners' component models into POA's Virtual Iron Bird, which will provide a full-software simulation and optimisation of the non-propulsive power system on aircraft level objectives.

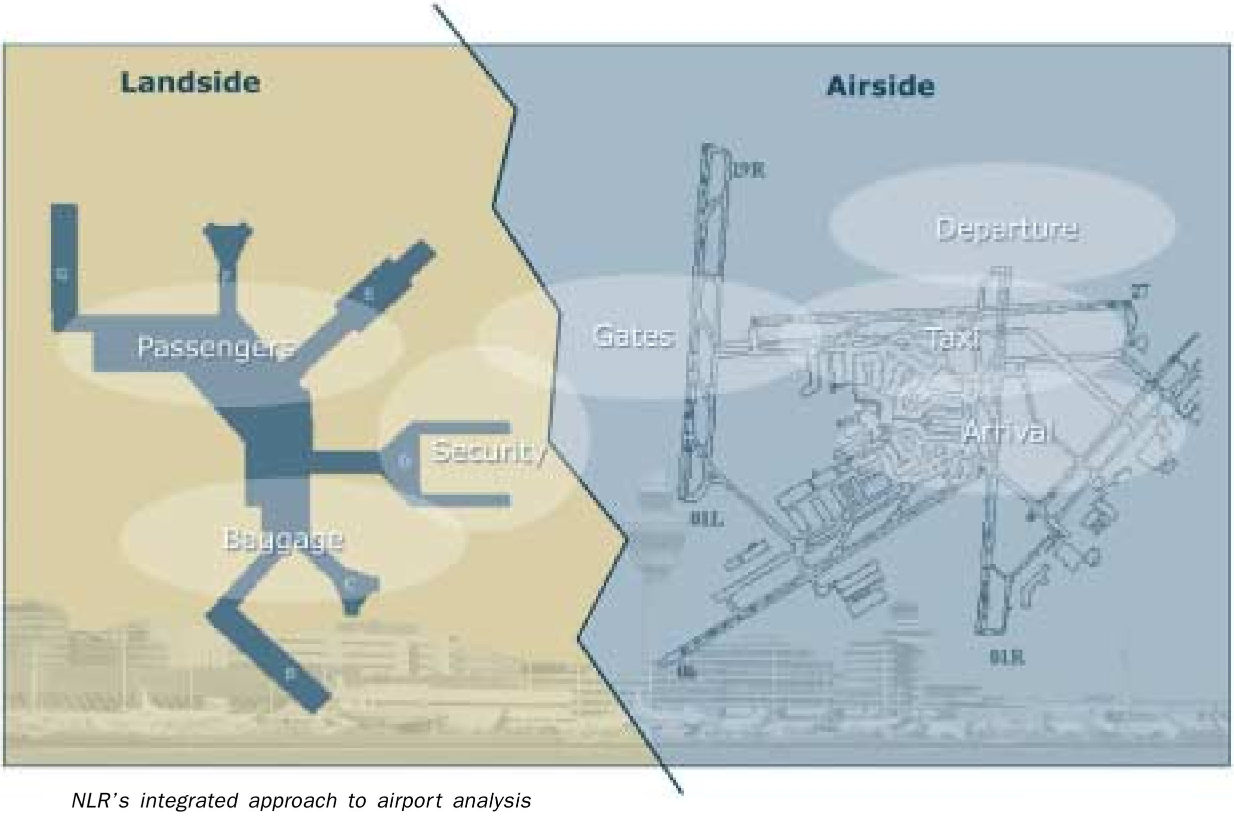
In the EU project FACE (Friendly Aircraft Cabin Environment), NLR has contributed in the design and implementation of the Integrated Technology Evaluation Platform (ITEP) that supports the validation and evaluation of new design concepts that improve the environment on board of aircraft in terms of air quality and noise. The ITEP provides further support on the dissemination of tools and workflows for automatic execution of the evaluation procedures.

In the EU project Automating FMECA for Aircraft Systems (AUTAS), NLR has contributed to the development of a working environment that will enable aircraft industries to perform in an easy way Failure Mode Effects Criticality Analysis (FMECA) of aircraft and rotorcraft systems both in normal and failure conditions. The AUTAS environment and used modeling method have direct industrial application in the process of FMECA analysis.

Airport Decision Making

NLR has continued to deliver substantial efforts in providing decision-support to the aviation community in resolving congestion problems at airports through an overall airport approach, involving all airport stakeholders.

As co-ordinator of the European consortium Supporting Platform for Airport Decision-Making and Efficiency Analysis (SPADE), NLR builds on previous work in ASAP (Airport Scenario Analyses Platform) and EU project OPAL (Optimisation Platform for Airports, including Landside) to help the European airport community to improve its operations with regard to capacity, level of service,



NLR's integrated approach to airport analysis

security, safety, and environmental impacts through an integrated approach. SPADE aims to develop a user-friendly decision-support platform that supports high-level political decisions related to airport planning as well as operations, with respect to a variety of measures of airport effectiveness such as capacity, level of service, safety, security, noise, and cost-benefit.

Recently, (airport) security has received considerable attention in the media. As part of the EU project SAFEE, NLR is already involved in introducing European security improvements in the Netherlands. In addition to SAFEE, NLR is also focusing on improving security measures at airports (i.e., within airport terminals) through SPADE and through INCALA (Improving NLR's Capabilities for Airport Landside Analyses).

In the EU project TALIS (Total Information Sharing for Pilot Situational Awareness by Enhanced Intelligent Systems) NLR is developing an innovative air-transport service concept for collaborative decision making. The TALIS service concept, however, consists of a dynamic and flexible network of air-transport services in which operational information as well as corresponding applications are shared among users such as pilots, station managers, and controllers. As with Internet, a user may obtain on-demand (access) all relevant operational information and install (download) corresponding applications, while maintaining the required level of safety and security. A first prototype system implements the information sharing infrastructure of the TALIS service concept. It receives positive attention from several aviation authorities, industry, service providers, and airlines.

Air Traffic Decision Support and Safety

The EU project Integrated Air Traffic Control Wake Vortex Safety and Capacity System (ATC-Wake) has provided an operational concept for air traffic controllers and pilots to apply dynamic weather/wind based aircraft separation in the airport environment. Key activities of NLR are analysis of the safety and capacity improvements that can be obtained by local implementation of the ATC-Wake concept. ATC-Wake may lead to increasing

A first build prototype of the TALIS service concept

airport capacity while maintaining the required level of safety. NLR supports EUROCONTROL on the issue of development of harmonised new wake vortex safety regulation and the development of risk assessment models to support the safe introduction of new wake vortex alleviation systems and operational concepts. In this respect, NLR's Wake Vortex Induced Risk assessment (WAVIR) methodology tool has been applied, and disseminated within the Thematic Network WakeNet2-Europe and the FAA/EUROCONTROL Cooperative Effort Action Plan 14 Wake Vortex.

The objective of the EU project "Instrumentation systems for on-board wake vortex and other hazards detection warning and avoidance" (I-WAKE) is to improve air transport operational capacity and safety. The system will provide on-board detection of wake-vortices during the approach. NLR has researched the possibilities of fusion of multiple data sources, either supplementary or complementary, from ground or airborne and is furthermore responsible for the system safety assessment.
Enlargement of the capacity of high-altitude airspace and saving of aircraft fuel have been the drivers behind the world-wide implementation of the Reduced Vertical Separation Minimum (RVSM) above FL290. An important part of the decision-making process concerning the implementation of RVSM in a region is a quantitative collision risk assessment. In this context and based on its extensive experience with RVSM in the European and North Atlantic Regions, NLR has been able to support the Middle East Central Monitoring Agency (MECMA) with the implementation of RVSM in the Middle East Region. In addition, NLR has continued to support EUROCONTROL with the statistical analysis of aircraft height monitoring systems and height monitoring data.

3.7 Avionics

The main areas of activities in the field of avionics were research and technology development for avionics systems, design and prototyping of aerospace electronics, and design and operation of instrumentation for flight-testing and wind tunnel testing. These activities required further development of an infrastructure of partly computer-based tools for avionics systems performance assessment, virtual prototyping, systems design, electronics design, and computational electromagnetics. An extensive inventory of facilities for avionics flight-testing provides the means for conducting flight trials for in-house and external customers operating aircraft in the Netherlands and abroad.

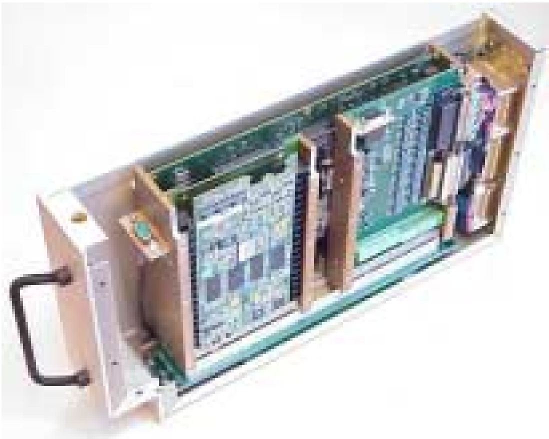
Weapon System Simulation in Flight (WaSiF)

Weapon System Simulation in Flight (WaSiF) or more popular called Embedded Training was successfully demonstrated on the AerMacchi MB-339 CX training aircraft. Within the framework of a EUCLID RTP11.12 project the WaSiF system was developed from the operational requirements to a full functional system. The system was developed by a consortium of 7 companies from 5 nations in which NLR participated in all stages of the development. In the final system NLR contributed specifically to the Embedded Training safety module and the ground threat simulation module. This safety module warns the pilot in case an unsafe condition occurs and eventually shuts down the system when necessary. The ground threat simulation module simulates a ground based air defence threat that stimulates the aircraft's radar warning system. The project was finalized in September 2003 with the presentation of the final report and a promotional film of the successful demonstration produced by NLR.

Integrated Modular Avionics

A consortium of 33 European companies, all part of the avionics/electronics supply chain carries out an EU project named "Validation platform for integration of standardised components, technologies and tools in an open, modular and improved aircraft

The AerMacchi MB-339 instrumented with WaSiF



NLR Input/Output Module developed for VICTORIA

electronic system" (VICTORIA). The project defines the new standards for Integrated Modular Avionics (IMA).

Within the project NLR develops an Input/ Output Module (IOM) which will be integrated in the so-called "Energy Domain Experimental System". The IOM provides a gateway-function between the aircraft Ethernet bus and the other on-board equipment. This equipment is connected via other avionics databuses or uses dedicated signals (digital, analog).

In this context NLR also chairs the EUROCAE Working Group on "Modular Avionics". This working group works jointly with RTCA Standardisation Committee 200 on a guidance document for modular avionics certification. Benefits are expected in performing an incremental qualification approach.

Cockpit Overhead Panels (COCOPAN)

NLR participates in the EU 5th Framework project COCOPAN (COCkpit Overhead PANels) on the development and evaluation of new concepts for cockpit overhead panels for large and regional aircraft. The project is executed in close co-operation with a Dutch industrial partner and other major European aerospace. It addresses safety, weight, operational and maintenance issues. The consortium develops a new digital databus architecture for the communication of the overhead panels with aircraft utility systems and evaluates new Human Machine Interfacing aspects of overhead panels. The latter research task is lead by NLR.

Successful evaluations of several improved concepts have been performed in the NLR Human Factors simulation facility with assistance from airline pilots from several countries. For the evaluation of this innovative concept, a prototype overhead panel has been developed. This panel incorporates state of the art LCD and touchscreen technology combined with NLR's software suite for rapid avionics display prototyping, NADDES II, and an extensive Avionics Simulation model to provide realistic behaviour of aircraft utility systems. The results were positive - in particular the pilots appreciated the panel's ability to display information in a dynamic way, that enhances their awareness of the aircraft's utility systems.

Prototype overhead panel

NH90 Mission System development

NLR participates in the design and development of the Mission System for the NH90 Frigate Helicopter (NFH). The Mission System supports the helicopter crew, in particular the tactical operator, with the tactical management of the mission. Tactical situation awareness is compiled from observations by the mission sensors (such as RADAR, Forward Looking Infra-Red (FLIR), Electronic Support Measures (ESM) and SONAR), from messages received via the data link containing observations by other participating units in the operational area, and by the operator himself. These observations of real-world objects are stored in the Tactical Database in data structures referred to as tracks. Tracks originating from different sources (sensors, data link, or operator) can refer to the same real-world tactical object. Based on, among other things, observed position, course, and speed, the operator can decide that two tracks belong to the same real-world object, and establish a link (cross-reference) between them. To reduce the operator's workload, NLR develops a software module for the Mission System that performs track-to-track matching of tracks generated from surface and subsurface vessels. This relieves the operator from the task of comparing tracks in detail, and only in case of doubt, he has to confirm or reject suggestions made by the software.

The Evaluation & Simulation Phase has been completed. Candidates for matching algorithms have been evaluated; algorithms for partial tasks have been selected and integrated into a complete matching algorithm. This also includes the evaluation of the algorithms on NLR's NH90 test-rig.

The Software Development Phase includes the traditional sequence of software requirement analysis, software design, coding, test & integration, maintenance (software repair), and finally qualification. The software is developed in a number of incremental versions. The final software version became available in the beginning of 2003. The remainder of 2003 was spent on software testing. Testing took place at various levels of integration, i.e., starting at the low-level software procedures, up to a completely integrated Mission System. Experimental flight approval for the final software version is scheduled for the first quarter of 2004

NH90 test-rig for integration testing and operational analysis

Integration of Smart Antennas on Aircraft Composite structures

In the National Technology Project (NTP) "Integration of Smart Antennas on Aircraft Composite structures (ISAAC)", NLR develops technology for smart phased array antennas to be installed on vibrating aircraft structures. The antennas are smart in the sense that effects of structural vibrations on the performance of the antennas are automatically compensated. The influence of vibrations is most significant on array antennas. Examples of such antennas are array antennas for Synthetic Aperture Radar (SAR) mounted on the fuselage or the wing of an Unmanned Aerial Vehicle (UAV). NLR considers several compensation techniques, which are based on electrical compensation and synthetic beam forming. The antenna elements of the phased array are used as sensor elements that measure phase variations of the elements of the antenna array. The variations are measured instantaneously with respect to a reference element. NLR has created a non-airborne demonstrator that consists of a vibrating plate supporting an array of 8 patch elements. This demonstrator can be considered as a generic part of a wing of an aerospace platform.

Vibrating plate for demonstrating smart phased array antenna

Aluminium plate with installed patch antennas for demonstrating smart phased array antenna.

NLR's Electronic Component Obsolescence Centre

Research into strategies for managing the obsolescence risk for electronic components was continued.

Activities were focussed on elevating the awareness level of the obsolescence problems among industrial parties. Additional companies for whom obsolescence is important were identified through a targeted search. Presentations about this subject were well received. The TACTRAC obsolescence management tool, which runs on a server at NLR, provided valuable data both for the benefit of avionics and space projects that were in progress within NLR's Avionics division and for the aerospace industry. Web-based access to this facility was provided to small and medium-sized enterprises in the Netherlands.
A project under contract to the Royal Netherlands Navy was finalises, recommendations were made for achieving a sound obsolescence management structure, with the incorporation of pro-active methods.

A similar project for the Royal Netherlands Air Force was completed. A survey among various RNLAF sections and divisions was made in order to list current practices and problem areas, as well as recommended measures to limit obsolescence risk.

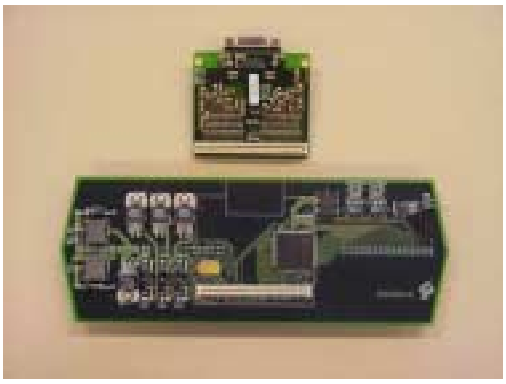
Dedicated Signal Transfer System (DSTS) for the TILTAERO Model

NLR started the development of the Dedicated Signal Transfer System (DSTS), which will be applied for the TILTAERO (windtunnel) model. The main objective of this project is to fulfil the extensive model propeller instrumentation requirements for the TILTAERO model for testing in the DNW-LLF. The function of the DSTS is to digitize, multiplex and transfer 144 sensor signals from the rotating environment to the stationary environment of the TILTAERO Model Propeller. The rotating Front End Subsystem will be located in the rear nacelle section of the model.

DSTS will execute filtering for anti-aliasing purposes, offset compensation, and amplification. These functions, along with the sensor excitation power supplies, will be located in the Rotating DSTS Front End Subsystem (FES). The acquisition concept will be based upon a synchronized sampling concept of all channels, with a high sample rate.

In the Control room all signals will be fed to the DSTS Interface Subsystem and the Set-up and Data Storage PC. The Interface Subsystem consists of a case containing power supplies and data converters. The sensor data will be converted into a special file format and the

In 2003 a Functional Model of the front-end subsystem electronics was developed and tested in order to evaluate the specifications.



Functional Model components of the Front End Subsystem

data will be stored on hard disc. After the test run the stored data can be sent to the wind tunnel data processing system by an Ethernet link.

Arc-tracking

Under contract of NIVR a study of the phenomenon of arc tracking in aircraft wiring has been carried out. Arc-tracking can be characterized as momentary electrical flashover between electrical conductors, due to damaged wire insulation. The resulting high-energy short-circuit currents are usually too short to be detected by the conventional aircraft circuit breakers. A test setup evolved from simple desktop testing to a dedicated arc-tracking facility. Tests have been performed to collect data from arc-tracking events, but also from electrically related phenomena, such as noise from motor brushes, switching power supplies, electromechanical switches, intermittent contacts, etc. These data will be analyzed in a later stage to find a characteristic arc-tracking 'signature' that can be used to distinguish arc-tracking from noise and interference that are common in an aircraft environment.

Avionics for the NH90 Helicopter

In co-operation with national and international partners, NLR takes part in the design and development of avionics equipment for use on the NH90 helicopter.

NLR supports SP Aerospace and Vehicle Systems with the design and development of the controller for the Nose Wheel Steering System of the Nato Frigate Helicopter (NFH). Prototypes of the cockpit panel and special test equipment have been designed and manufactured. All prototype equipment has been subjected to severe qualification testing, to meet the stringent EMI/EMC, shock and vibration requirements. Furthermore NLR continued to carry out all necessary analysis in the field of safety, reliability and testability.

The Remote Frequency Indicator (RFI) is a five-field LED-based cockpit panel for the display of radio frequencies and other communication-related information to the helicopter pilots. In February 2003 NLR organised and hosted the successful Qualification Review (QR) for the NH90/Tiger RFI, attended by Eurocopter representatives. The QR milestone marks the end of the Qualification phase of the RFI Design and Development project under contract to Schreiner Components. During this phase all the RFI requirements were qualified using analysis (reliability, safety, testability, maintainability and others) and tests (functional, environmental and EMC tests).

Tiger version of the RFI

Most of the qualification tests were conducted within NLR facilities. The RFI has entered into series production at Dutch industry.

Under contract of Schreiner Components, activities to support the Fuel Panels prototype design and development as well as the qualification of the Cockpit- and External Fuel Panel were continued.

F-16 MLU Flight Test Instrumentation

Work under contract to the RNLAF for the extension and maintaining of a flight test measurement system in the F-16B MLU "Orange Jumper" aircraft was continued. Throughout the year NLR supported several flight test programs flown from the home base of the aircraft at Leeuwarden AFB. The most extensive was the project for the flight testing for the re-certification of the GBU-10 bomb on the PIDS 3 pylon, later extended to the F-16 Standard Wing Weapon Pylon as well. The basic instrumentation system was adapted according to the requirements for the specific load measurements for this program. The instrumented pylon and instrumented bomb tail were hooked up to the basic flight test instrumentation system. The work was carried out under contract to the RNLAF, under supervision of the F-16 System Programme Office (SPO) of the EPAF countries and in close co-operation with Lockheed Martin, Fort Worth and the USAF Seek Eagle office at Eglin AFB.

For a research project of SP Aerospace Systems and Vehicles NLR's flight test instrumentation system in the F-16 Orange Jumper was used during the demonstration of a titanium matrix composite drag brace for the F-16 undercarriage. During these tests successful use was made of the upgraded on-board instrumentation display system. This new, fully airborne qualified display processor unit, based on PC-104 technology, using display software based on commercially available packages was installed in the aft seat, with an optional facility for copying the display image to the pilot's Multi Function Display. Plots and tables as well as warning and limit control pages are available on the system. Configuration control functions were developed to safeguard the integrity of the system.

Development of a Small Parafoil Autonomous Delivery System (SPADES)

Under contract to Dutch Space NLR participates in a CODEMA program for the Dutch Ministry of Defence for the development of a small autonomously controlled parachute ('parafoil') demonstrator. This parafoil will be capable of delivering loads up to 200 kg from transport aircraft within 150 m accuracy or better. NLR is responsible for the development of the instrumentation package, the computer system and the control laws. The development of the system was completed with extensions for droppings from high altitudes and for passing way points during the descent. The system participated in the large-scale demonstrations that were part of the Precision Airdrop Technology Conference and Demonstration (PATCAD) at the Yuma Proving Grounds of the US Army in Arizona, US. Six flights were performed with droppings from 10.000 ft altitude from C-130 and C-17 aircraft. The system clearly demonstrated its capabilities by achieving a landing accuracy well within its design specification, with a landing distance of 16 m from the target point as the best result. National and international interest in acquiring the system is growing.

Flight Test Instrumentation for Tests with Apache and Cougar Helicopters of the RNLAF

NLR's involvement in the flight testing of RNLAF helicopters is continuously growing. The support to increase the operational capabilities of the helicopters requires dedicated, airborne qualified instrumentation systems for data gathering during pre-operational tests. In 2003 such systems were developed for stub wing load and EW pod vibration measurements on the Apache helicopter and for hover trials with the Cougar. New developments in the field of data processing systems, results from the Avionics Flight Test Facilities project AFTF, which is

Flight test instrumentation for test with the RNLAF Apache helicopter

financed by NLR's internal research program, were successfully introduced during these projects and contributed largely to the shortening of the data turn around time.

Smart Hybrid Inertial Navigation Equipment (SHINE)

As part of the 5th EU Framework program the SHINE project is aiming at the development of a low cost integrated GPS/AHARS receiver. NLR's tasks in the international consortium was to evaluate the performance of the equipment developed by other partners in the consortium both in ground-based tests and in airborne trials. To this purpose dedicated test equipment was developed. The flight test program was carried out using the Metro II research aircraft. The test campaign generated very useful data that allowed the developers to improve their original design.

Embedded Training Demonstrator Project on F-16

The purpose of the Embedded Training (ET) demonstration project is to develop a prototype ET-system, to install it in a RNLAF F-16 and to demonstrate its capability to perform training scenarios in flight by simulating "ground-to-air threats" and "air-to-air threats" fully integrated with the aircraft's mission system. In 2003 the system development was largely completed. Two main units were developed: the ET Computer System (ETCS), running the ET simulation software and the ET Radar Gateway (ETRG), injecting the simulated radar tracks into the mission system. The ET-system was installed in an F-16B. Integration testing, including flight testing, was well underway at the end of the 2003.

3.8 Engineering and Technical Services

The year 2003 was a hard year for the Engineering and Technical Services. External contracts were considerably below the expected level, partly due to delays but also due to cancellations and unsuccesful bids. Work for the German-Dutch Wind Tunnels (DNW) was slightly above planning, and fortunately the work in support of the internal NLR departments was considerably above planning. As a result, about 50 percent of the work was related to wind tunnel testing, the other 50 percent was very diverse in nature.

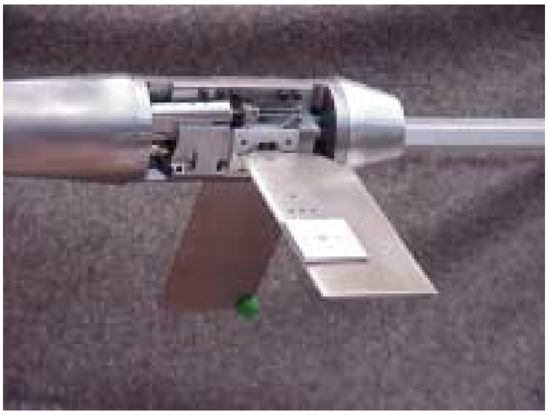
Models and Test Equipment

Work was performed on various wind tunnel models.

A 3D model of an Air Refueling Boom System for CASA/Airbus Spain was completed, to be tested in the DNW-HST. The model was equipped with remotely controlled wings and with 2-component balances to measure lift and torsion on the wings.

Quite a few modifications were made on an existing model of a jet trainer for AirMacchi, in particular on weighted (with balances) control surfaces and stores, also to be tested in the DNW-HST.

For CDI Marine Company, a model was made of a ducted fan for a hovercraft, to be tested in a wind tunnel of the University of Maryland, USA. Because of the relatively high test rpm of roughly 10.000, the propeller was made of carbon fibre composite.



Transonic wind tunnel model of Air Refuelling Boom with remote control mechanism exposed

Work was continued on both a half-span and a full-span model for the European research projects Tiltaero and ADYN. The purpose of the Tiltaero project is to study the aerodynamic efficiency of a tilt rotor wing and aerodynamic wake interaction. For the half-span model (scale 1:2.5) of Tiltaero the design was finished and production started of five rotor blades. These blades were to be scaled down both statically and dynamically such that the actual dynamic behaviour of the full-scale rotor blades would be represented. Two blades will be provided with some 70 kulites to measure the dynamic pressures around the blades when in operation. Similar work was started for the blades of the ADYN half-span model, to be used for research on whirl flutter and aero-acoustics of tilt rotor blades.

Production of both sets of rotorblades will be finished in 2004 to be followed up by wind tunnel tests in the DNW-LLF.

For the full-span model of the Tiltaero tiltrotor airplane, the functional design of the complete model, was finished. The complex model (scale 1:4) incorporates many challenging model aspects, like composite rotor blades, rotating hubs, various balances to measure the loads on the (rotating) rotors, tilting nacelles, inner and outer wings, flaps and flaperons, and tail surfaces. Virtually all moving parts are also remotely controlled to allow quick configuration changes during the wind tunnel test programs to come.

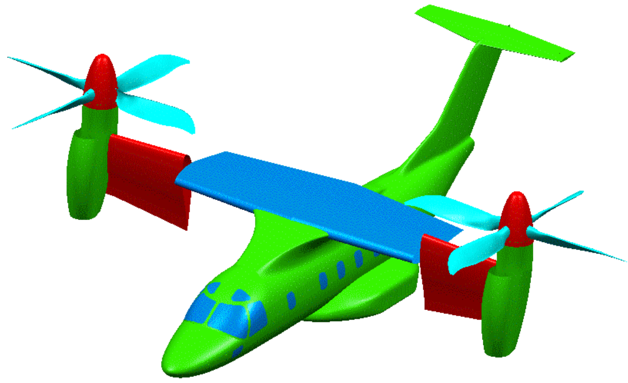
Both for Airbus-France and Airbus-Deutschland various sets of carbon fibre composite propeller blades were made for various models of the Airbus A400M wind tunnel test program. NLR is the supplier of the propeller blades for virtually all the wind tunnel models in this program. In 2005 many more are expected to follow.

As subcontractor of the Fluid Dynamics Division the mechanical control system was designed and built for the wind tunnel tests of a cargo delivery parafoil in the context of the European FAST WING project. Main object of the system was to control and measure the control forces in the lines of the parafoil during the tests, to be performed in the DNW-LLF in early 2004.

An existing model of a guided missile of SAGEM, built by Engineering and Technical Services in 2001, was modified again, this time by installing a remote control mechanism for setting the incidence of the forward canards under full aerodynamic load. The model was tested in the S2 wind tunnel of ONERA.
Only few non-aerospace models were produced in 2003. Some models were made of new buildings and modifications of existing ones, two boats were modified and a floating oil rig was made, all to be tested in the DNW-LST.

Strain Gauge Balances
In the field of strain gauge balances plenty of work was performed, both on internal wind tunnel balances and on model balances; see also Models and Test Equipment. The work on a large (170 mm diameter) six-component sting balance (664) for the Large low Speed Facility (DNW-LLF) was finished, and almost parallel to this, a replacement balance (665) of a previously delivered balance (661) was produced for the transonic windtunnel DNW-HST. Both balances were delivered in time and are performing well.

Wind tunnel model of ducted fan for hovercraft with six-bladed carbon fibre fan



CATIA model of full-span wind tunnel model of tiltrotorcraft for European Tiltaero project

After the delivery and testing in the DNW-LST of the first of five rotating balances, the other four were also manufactured. These balances will be used by Airbus-Deutschland for one of their wind tunnel models of the A400M aircraft, to be tested in 2004 in the DNW-LLF.

For AirMacchi many weighted control surfaces and stores were instrumented, and also for the Maritime Research Institute of the Netherlands, MARIN, quite a few multicomponent balances for drag measurements on ship hulls and components in water tanks were instrumented.

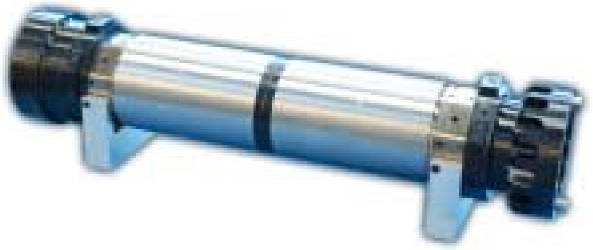
Support
The volume of activities in support of the various departments of NLR was considerably above planning. The largest internal customer was the Structures and Materials Division. Various (RTM) moulds were produced, for various projects (DART, CODEMA), test installations were designed for the FACE project and for JSF weapon bay doors.
Design and producton was continued for a new test facility of the Structures and Materials Division, a seal tester for gas turbine blade seals. The facility allows seals to be tested up to 820ºC, 24 bars absolute pressure, 7 bars differential pressure, at 27,500 rpm. The facility will be finished and put into operation in 2005.
Assistence was given to the tear down of a wing of a Lockheed P3 Orion. The parts will be investigated by specialists of NLR's Structures and Materials Division to determine the amount of fatigue damage after the operational life of this Maritime Surveillance aircraft.

For the Avionics Division, various housings and breadboards for electronic equipment were built. For the Air Reconnaissance Systems Orpheus and Mars, in operation with the Royal Netherlands Airforce, various camera's and film cartridges were maintained and repaired. A flight test nose boom with alpha/beta vanes was repaired and upgraded. Flight test equipment and modifications were made for NLR's test aircraft, the Citation and Metro.

The support to the DNW was more than expected and planned, mainly due to the very high work load of the LLF. Already mentioned was the manufacturing of the large balance (664) for the LLF and the fighter balance (665) for the HST.
The feasibility study on a cryogenic remote control system for traversing flaps, performed in co-operation with DLR was finished and reported. It was recommended to proceed with a demonstrator phase, designing and building a demonstrator to prove the positive conclusions from the feasibility study. If accepted by DNW, this will be performed in 2004.
Apart from the above, many smaller activities were performed to support the wind tunnel operation of DNW.

Research

Research was done on various aspects of remote control mechanisms. The properties of square worm-type transmission systems were studied, a particular type of drive/transmission system for remotely controlled moving parts for wind tunnel models.



large six-component strain gauge balance for DNW-LLF

Previous remote control systems, designed to function at ambient conditions, were tested at cryogenic temperatures to determine the necessary changes for correct functioning at these very low temperatures. Further tests of a specially designed remote control system demonstrator will be combined with the proposed demonstrator tests for DNW.
Also a study was started on a brake system for hinged surfaces, enabling to hold a control surface in its preset position under full aerodynamic load. This is particularly challenging if the mechanism has to stay within the external contours of the generally quite thin control surface.
Various alternative types of angle measurement systems were studied and tested to determine the properties of each system with respect to accuracy, repeatability, hysteresis, temperature sensitivity, etc.
Various types of connections of thin, flat parts (like wings, stabilizers and control surfaces) were designed and tested to determine the optimum solution between strength/stiffness and fast installation/removal requirements as generally demanded for these parts. Lip and swallow type connections were tested.
Material tests were done on a bronze alloy used for a new rapid prototyping technique called 3D Metal Printing. Its material properties were tested with respect to its suitability for application in balances, model balances in particular. Often, these type of balances have to be integrated with a part of a model, and as such, have a quite complicated geometry. Production based on Metal Printing would reduce cost and lead time of these parts considerably.
The behaviour of slender, flexible weighted control surfaces was analyzed, in particular with respect to the 3-component balances in the brackets between the control surface and the (also slender and flexible) model wing.

4 Scientific Committee NLR/NIVR

Advice provided to NLR and NIVR

The Scientific committee provided advice:

- To the Board of the Foundation NLR, on:
  - results of the research NLR carried out in 2002 under NLR's own Programme for basic research and development of facilities;
  - the Plans for the research to be carried out in 2004;
  - NLR's own Programme for basic research and development of facilities for 2005.

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

Membership of the Scientific Committee NLR/NIVR

Prof.dr.ir. M.J.L. van Tooren was appointed by the Board of NIVR so that the vacancy caused by the resignation of Ir. F. Holwerda was closed.

At the end of 2003 the Scientific Committee was composed as follows:
Prof.dr.ir. P.J. Zandbergen, *chairman*
Dr. R.J. van Duinen
Prof.dr. T. de Jong
Prof.dr.ir. G. Ooms
Prof.dr.ir. M.J.L. van Tooren
Ir. G.J. Voerman, *secretary*

Membership of the Subcommittees

Ir. W. Brouwer and Dr. R.P. Slegtenhorst resigned from the Subcommittee for Avionics.
Kol. ir. J.W.E.N. Kaelen resigned from the Subcommittee for Structures and Materials; Maj. ir. F.H.M. Schuurman was appointed as his successor.
Th.C.L.P. Tetteroo, was appointed as a member of the Subcommittee for Avionics.
Dr.ir. H.G. Visser has continued his membership of the Subcommittee for Flying Qualities and Flight Operations/Air Transport.
Dr.ir. N.J.J. Bunnik has continued his membership of the Subcommittee for Space Technology.

At the end of 2003 the subcommittees were composed as follows:

Subcommittee for Aerodynamics

Prof.dr.ir. J.L. van Ingen, *chairman*
Prof.dr.ir. P.G. Bakker
Ing. J. van Hengst
Prof.dr.ir. A. Hirschberg
Prof.dr.ir. H.W.M. Hoeijmakers
Prof.dr.ir. F.T.M. Nieuwstadt
Prof.ir. E. Obert
Prof.dr.ir. E. Torenbeek
Prof.dr. A.E.P. Veldman
Prof.dr.ir. P. Wesseling
Prof.dr.ir. L. van Wijngaarden
Ir. E.P. Louwaard (NIVR)

Subcommittee for Space Technology

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

Subcommittee for Structures and Materials

Prof.dr.ir. H. Tijdeman, *chairman*
Ir. N. Fraterman
Prof.dr.ir. Th. de Jong
Ir. J.B. de Jonge
Ir. A.J.A. Mom
Ir. A.R. Offringa
Prof.dr. A. Rothwell
Maj.ir. F.H.M. Schuurman
Ing. E. van Teeseling
Ir. L.H. van Veggel
Ir. J.J. Wijker
Prof.dr.ir. S. van der Zwaag
Ir. F.J.M. Beuskens (NIVR)

Subcommittee for Information and Communication Technology

Prof.dr.ir. P. Wesseling, *chairman*
Prof.dr.ir. J. Schalkwijk
Prof.dr.ir. J.L. Simons
Prof.dr.ir. H.J. Sips
Prof.dr. A.E.P. Veldman
Prof.dr.ir. M.H.G. Verhaegen
Ir. R.C. Doeglas (NIVR)

Subcommittee for Flying Qualities and Flight Operations/Air Transport

Prof.ir. E. Obert, *chairman*
KTZ b.d. ir. K. Bakker
Ir. W.G. de Boer
J. Hofstra
Dr.ir. R.J.A.W. Hosman
Ir. H.J. Kamphuis
Lt.Kol. H.J. Koolstra
Ir. P. Riemens
Ir. H. Tigchelaar
Dr.ir. H.G. Visser
Ir. G.C. Klein Lebbink (NIVR)

Subcommittee for Avionics

Prof.dr.ir. M.H.G. Verhaegen, *chairman*
Ing. H. de Groot
Lt.Kol. ing. H. Horlings
Ir. S. O. van de Kuijt
Prof.dr.ir. L.P. Ligthart
Ir. P.J.G. Loos
Kol. b.d. ir. E.B.H. Oling
Ir. L.R. Opbroek
Prof.ir. G.L. Reijns
Th.C.L.P. Tetteroo
Ir. A.P. Hoeke (NIVR)

Concluding remarks of the Committee

In its 2003 meetings the NLR-NIVR Scientific Committee has paid special attention to the consequences of the necessary restructuring of NLR, as well as to a simultaneous preparation for audit sessions before the ad-hoc committee “Brugfunctie TNO en GTI’s”, chaired by Dr. Wijffels. For the self-evaluation submitted by NLR to the Wijffels Committee the Scientific Committee has, in close co-operation with the chairmen of the various subcommittees, added its own contribution concerning scientific level of NLR personnel.

The Scientific Committee’s report focused on the NLR reorganisation and right sizing due to reducing national technology development projects, the reduced national subsidies, and due to the need for increased efficiency, in order to remain competitive.

In spite of considerable international appreciation for the quality of NLR’s research, the large majority of the contracts is still provided by national customers. In addition to this, the co-operation with EREA and the further extension of the DNW into Europe is still limited. The Scientific Committee is of the opinion that co-operation with partners outside DNW/DLR ought to be pursued vigorously by NLR

Attention has been devoted to the problem of scientific integrity, a topic addressed because of publications in the press. The Committee supports NLR’s view, that each contractor must be enabled to profit from knowledge acquired by NLR using public financial means, even if the contractors have conflicting interests. The Committee has concluded that in its opinion NLR’s scientific integrity has in no way been jeopardised.

NLR’s intention to further specify internal rules and procedures and make them known to potential contractors is welcomed by the Committee, notably as this manifestly expounds NLR’s independence in scientific matters.

Although Europe is an important market and co-operation area for the Dutch Aerospace institutes and industry, transatlantic co-operation is equally important, because in the USA extensive innovative efforts are currently being made. Ever since its start, the Dutch Aerospace sector has played world-wide a significant role, and it intends to continue to do so.

The Scientific Committee was impressed by the number and quality of the NLR scientific publications and indicated that NLR should pay enough attention to its long-term research programmes to enable it to maintain its quality level in the future.

5 International Co-operation

5.1 Military Research and Technology Organisations

NATO Research and Technology Organisation (RTO)

The NATO Council established the NATO Research and Technology Organisation (RTO), focus of NATO for Defence and Research and Technology activities, in 1996.
The RTO is headed by the Research &Technology Board (RTB). The Netherlands voting member of the RTB was Ir. J.P. Keuning of the Ministry of Defence.

The RTB is assisted by the R&T Agency, which is tasked with day-to-day management of the RTO. The following Panels, with members from defence and research organisations, guided the R&T activities:

- 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)
- NATO Modelling and Simulation Group (NMSG)

NLR Participation

R&T Board

The NLR member of the R&T Board (RTB) was Ir. F. J. Abbink.

R&T Panels
NLR was represented in four panels:

SCI	Prof. drs. P.G.A.M. Jorna
SET	Ir. M.A.G. Peters
IST	Ir. J.C. Donker
AVT	Ir. H.H. Ottens

WEAO/WEAG R&T Organisation

Also in 1996, the Western European Armaments Organisation (WEAO) was established. The existing Western European Armaments Group (WEAG) tasked with establishing R&T programmes, known as European Co-operation for the long term in Defence (EUCLID), was more or less absorbed in the WEAO. The WEAG is headed by the National Armaments Directors, with their Permanent Representatives in Brussels forming the Staff Group. The WEAG Research Cell (WRC) within the WEU structure became the initial executive body of the WEAO. The WEAG chairman in 2003 is Drs. E.A.van Hoek of the Ministry of Defence.

The WEAG has three panels: Equipment Programmes (Panel I), Research and Technology Co-operation (panel II), and Procedures and Economic Matters (panel III). Activities in Panel II, Research and Technology, mainly concern the EUCLID programme, involving industry and research institutes. The following Common European Priority Areas (CEPAs) and subgroup were active:

CEPA 1 –	Modern Radar Technology
CEPA 2 –	Micro Electronics
CEPA 3 –	Advanced Materials & Structures
CEPA 4 –	Modular Avionics
CEPA 6 –	Advanced Information Processing & Communications
CEPA 8 –	Opto-Electronic Devices
CEPA 9 –	Satellite Surveillance and Military Space Technology
CEPA 10 –	Underwater Technology and Naval Hydrodynamics
CEPA 11 –	Defence Modelling and Simulation Technologies
CEPA 13 -	Radiological, Chemical and Biological Defence
CEPA 14 -	Energetic Materials
CEPA 15 –	Missile, UAV and Robotic Technology
CEPA 16 –	Electrical Engineering
	Sub Group on Test Facilities

The programmes and activities are co-ordinated by an R&T Management Committee (RTMC).
The Netherlands members of Panel II and the RTMC were respectively Ir. P.J. Keuning and Ir. N. Pos, both of the Netherlands Ministry of Defence.

NLR Participation

NLR contributed to various Research and Technology Programmes (RTPs) within the CEPAs.

National Co-ordinator

National Co-ordinator of RTO and of EUCLID was Ir. N. Pos, of the Netherlands Ministry of Defence, until 1 March 2003 assisted by Ir. D. Sjerp for NLR.

5.2 German-Dutch Wind Tunnels (DNW)

The main objective of the DNW, being a non-profit organization under Dutch law, is to provide a wide spectrum of wind tunnel test and simulation capabilities to customers from industry, government and research.

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

The Board of DNW

The Board of the Foundation DNW is formed by members appointed by NLR, DLR and the German and Dutch governments. At the end of 2003 the Board consisted of:

Ir. F. Holwerda *Chairman*
NLR
Prof.Dr.-Ing. J. Szodruch *Vice-Chairman*
DLR
Prof. B.A.C. Droste
NIVR
Drs. L.W. Esselman, R.A.
NLR
DirBWB K. Heyer
BMVg
Dipl.-Ing. H. Hüners
DLR
MinR. M. Metzger
BMBF
Secretary: Ms. S. Pokörn
DNW

The Advisory Committee

The Advisory Committee, representing the aerospace industry and research establishments, advises the Board of DNW about long-term needs of the industry. In October 2003 the Advisory Committee consisted of:

Mr. J. Javelle
Airbus France
Dipl.-Ing. A. Flaig
Airbus Deutschland GmbH
Prof. Dr.-Ing. S. Levedag
DLR
Dr.-Ing. E. Krämer
EADS Deutschland
Dr. B. Oskam
NLR
Mr. M. Polychroniadis
Eurocopter France
Prof. Dr.-Ing. C.C. Rossow
DLR
Mr. L. Ruiz Calavera
EADS-CASA

Secretary: Dr.-Ing. G. Lehmann
DNW

The Board of Directors

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

Business Unit NOP

The DNW-LLF, the main facility of Business Unit NOP, reached an excellent occupation, far above the average. The occupation was almost completely originating in the aircraft segment, about equally divided between civil and military aircraft. Tests for helicopters and spacecraft were both only a few percent of the total occupation. This is also true for car and truck testing. In the latter case it was caused by a lack of free capacity. From the two smaller wind tunnels the LST had a poor occupation due to lack of aeronautical tests. The non-aeronautical segment (buildings, ships) was at an average level. The occupation of NWB was somewhat below average, also because of the installation of a heat exchanger into the tunnel circuit that started in 2002 and continued

during the first six weeks of 2003. Beside aeronautical research the car and truck industry is gaining importance at NWB.
In July more than 100 representatives from industry and research institutes participated in the celebration of the 40th anniversary of NWB. The speakers stated their appreciation for the work done so far and gave commitment to further utilization of the NWB.

The major part of the LLF aircraft segment concerned Airbus and Joint Strike Fighter (JSF) models.
Several entries were devoted to the development of the A380, the new member of the Airbus family. Worth mentioning is an ice simulation test campaign with an A380 model. During the last decade at LLF the simulation of critical ice accretions at wings and stabilizers is becoming more and more important for checkout testing of low-speed performance and handling quality of aircraft configurations. In the LLF simulated ice testing is typically done with large low-speed models, which are designed to serve for high-lift performance, engine integration investigations etc. In order to quantify the reduction of the aerodynamic performance with the clean, take-off and landing configurations local ice accretion is represented by mounting strips to the model (on wing slats, flaps, nose parts of the horizontal and vertical tail). The cross sections of these strips are defined by Airbus using a database created by special accretion tests in icing wind tunnels, and by flight investigations. The unavoidable ice accretion was represented and failure situations of the de-icing system of the wing were simulated.
During an extensive test campaign by means of angle of incidence and yaw variations with the ventral sting supported model the ice-dependent longitudinal and lateral characteristics were evaluated and added to the performance database.
Two test campaigns were performed with the same A380 model for engine integration, reverse thrust and ground influence investigations. Therefore the model was equipped with Turbofan Propulsion Simulators (TPS) whereby only the inboard motors could be provided with thrust reverser cascades. For proper ground proximity simulation the dorsal sting supported model was positioned with high accuracy above a moving belt. For different configurations such as take-off and landing, reverse thrust, and engine failure cases a database could be established characterizing the performance and controllability of the new aircraft in ground proximity.

Dorsal sting supported Airbus A380 above the Moving Belt Ground Plane in the LLF

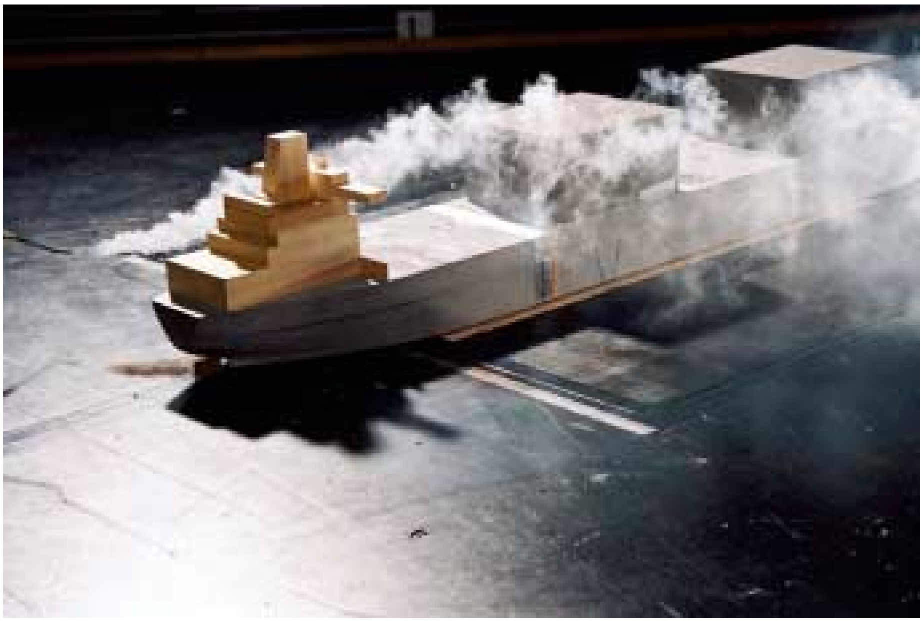
For the second year in succession extensive Short Take-Off and Vertical Landing (STOVL) tests on a 12% scale model of the JSF were performed. They were carried out under a contract between BAE Systems – partner of Lockheed Martin in the JSF program - and NLR, within the framework of the JSF Systems Design and Development (SDD) phase. Tests were performed for speeds ranging from 15 knots up to 240 knots (transient phase). These were enabled by using test sections of different sizes: 9.5m x 9.5m, 8m x 6m and 6m x 6m. The sizes of the test sections are chosen such as to ensure that a chosen speed regime can be realized while the wind tunnel wall effects on the model still can be neglected. As for the earlier SDD phase tests performed in 2002, the present tests were very successful in terms of the productivity realized. The tests will be followed by other entries in the next few years.

In co-operation with MARIN a project was carried out to determine wind and current forces acting on tankers during tandem off-loading. An analytical method was developed together with NLR to describe disturbed wind- and current fields of one tanker and to calculate the integrated forces and moments acting on the other tanker with the help of basic aero- and hydrodynamic coefficients. Extensive wind tunnel tests were carried out to develop and validate the analytical method and to build the necessary database. The tests consisted of balance measurements on full-models and parts of tankers as well as velocity measurements in the wake of the tankers with five-hole pressure probes.

After a period of three months, needed to install a heat exchanger into the tunnel circuit the NWB was back in operation. A major part of wind tunnel tests were further measurements with the Airbus A400M as well as the application of the NWB rotary balance rig mechanism RTD for the DLR Project SikMa. This rolling/spinning device was used for the first time after 20 years.

Business Unit ASD

In a weak market regional aircraft manufacturers delayed the development of new aircraft or derivatives. Therefore it does not come as a surprise that the regional aircraft manufacturers stayed away from testing in the transonic wind tunnel HST. Despite an intensification of the marketing efforts this lack of orders could not be compensated. As a result the occupation of the HST was disappointing.



Flow visualization measurements on a tanker model in the LST

Aermacchi M-346 advanced military trainer in the HST

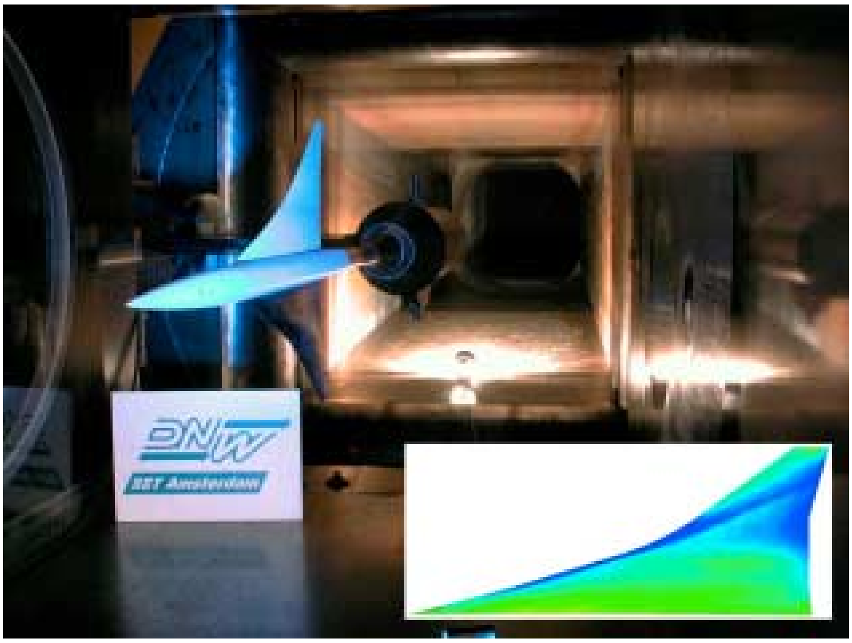
In terms of revenues military aircraft testing contributed to about half of the total, whereas the other half was equally split between projects for civil aircraft and aircraft components. Civil aircraft testing completely consisted of measurements on business jet models.

The major part of the testing of military aircraft concerned the development of the AerMacchi M-346 advanced military trainer. The clean configuration of this model had been tested before, but in this phase of the development the focus was on testing configurations with stores. Measurements included also the loads on control surfaces and stores and the buffet onset boundaries. Buffet onset is calculated from the unsteady signals from a set of wing root mounted strain gauges. For the calculation two standardized methods are applied and in both methods wing tip accelerations in the first bending mode are used as a measure of the response of the model to buffet excitation.

The major part of aircraft component testing was provided by an Aerial Refueling Boom System (ARBS). EADS-CASA is developing an advanced state-of-the-art fly-by-wire ARBS for tail mounting on the multi-role tanker transport versions of the Airbus A310-300 and A330-200 platforms.

Dependent on the objectives of the ARBS tests in the HST a 2D- or a 3D-model was used. The engineering department of NLR designed and manufactured both models. In the first test the profile characteristics of the ARBS boom itself at high Reynolds numbers were evaluated. For this test the half-scale, 2D-model was mounted on the HST 2D-model support. This support system consists of two turntables flush-mounted in the tunnel sidewalls and enables an angle of incidence variation of 50º. For accurate drag measurement a wake rake was mounted on the so-called transonic model support, which is capable of positioning the rake at various positions behind the model.

The second test was performed using a 3D representation (scale 1/8) of the ARBS. This 3D model was equipped with remotely controlled fins with strain gauges to measure hinge and bending moment. This model was mounted on the ventral sting model support through a balance. By using an adapter, a model attitude range of up to 50º could be realized.
The Pressure Sensitive Paint (PSP) measurement method is available on a routine basis in the DNW transonic wind tunnels for several years. One of the reasons to select PSP over the traditional pressure tap method is a reduction in model manufacturing cost. For small- and medium-sized models of supersonic aircraft PSP is the only option because of their



PSP measurements with the Eurosup model in the HST

thin wings where no pressure taps can be drilled. Using PSP in a blow-down wind tunnel like SST is not straightforward because of the short run time and the cooling down of the model after the run. The low model temperature often leads to condensation and condensation may degrade the paint. Using the Eurosup Wind tunnel model, realised in the EU project Eurosup, it was demonstrated that neither the short run time nor condensation are hampering the use of PSP in the SST.

Business Unit GUK

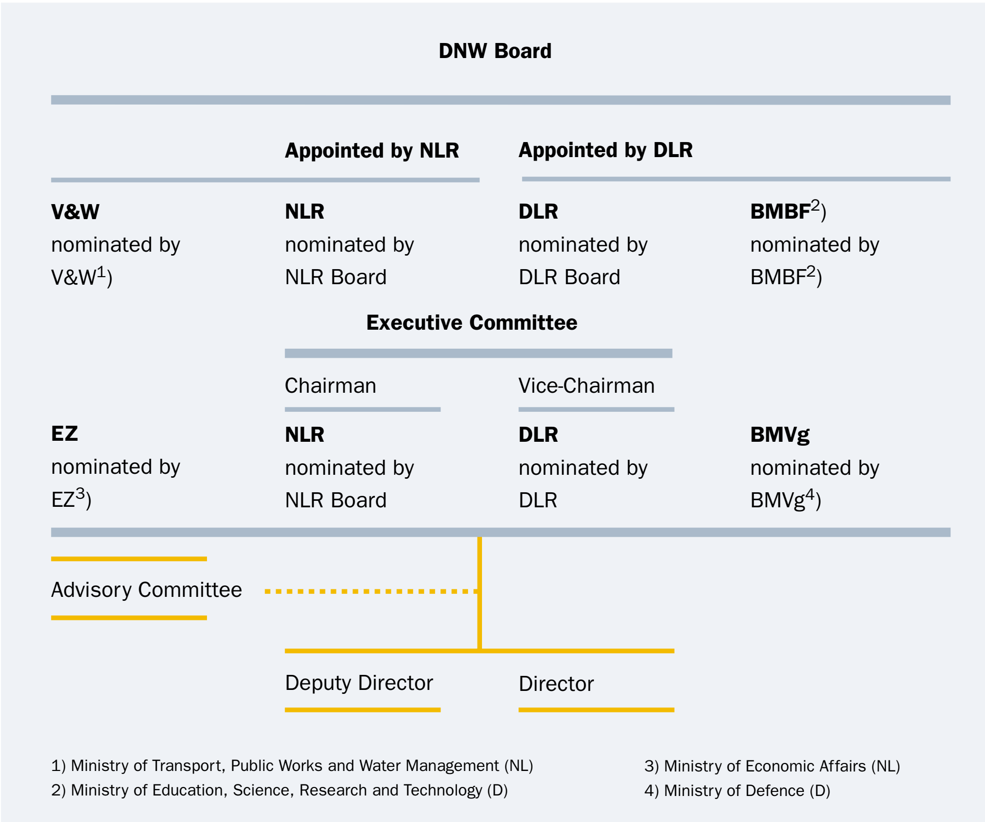
The occupation of the major facilities of GUK (TWG and KKK) was less than average. Tests in all GUK wind tunnels are mainly embedded in fundamental and applied research projects, most of them conducted by DLR institutes. On the one hand this requires high flexibility with respect to complex test set-ups, new simulation techniques, and the integration of testing teams, on the other hand the DNW-team benefits from being involved in the development and application of advanced up-to-date measurement techniques.

Two highlights from the Transonic Wind Tunnel at Göttingen (TWG) illustrate the focal point in research: In one test a pitch and heave oscillating airfoil was equipped with an actively piezo-controlled droop nose to optimize the cyclic properties of helicopter rotor blades. In another experiment the flow-to-structure coupling was examined for a fully dynamic model of a through-flow nacelle, dynamically coupled to an oscillating airfoil. Not only the dynamic simulation but also the simultaneous application of different measurement techniques, including PIV (Particle Image Velocimetry), PSP, and position and deformation measurement, demonstrated the successful cooperation between DLR and DNW.

The joint realization of a multiple-view PSP system of GUK and ASD was completed in the TWG by a successful demonstration with a Phoenix model of EADS-Astrium (now EADS-SPACE) in the whole speed range from sub- to supersonic speeds. In addition to the complete surface pressure distribution by three simultaneously used camera systems, the possibility to determine component loads without pressure holes and component balances is appealing. The hardware and procedure harmonization achieved between business units ASD and GUK allows offering PSP as a standard service even for challenging requirements.

After the 2002 PIV measurements at the leeside of a high-speed train at ambient temperatures, a joint team of DLR and DNW-KKK (Cryogenic Wind Tunnel Cologne) applied this technique under cryogenic conditions to the wing tip vortex flow of a transport aircraft half-model for the first time. The immediate freezing of the injected seeding droplets turned out to be a great advantage. Compared to the originally planned pressure rake tests, PIV provided undisturbed results, higher resolution, and a considerably higher productivity. In the meantime this technique is established as a standard service with standard set-up components integrated into the KKK hardware.

The acceptance by DLR of the High Pressure Wind Tunnel Göttingen (HDG) as a low-cost high Reynolds-number facility for ground vehicles was consolidated. Together with DLR, DNW is in the process of fulfilling the criteria of the Deutsche Bahn AG for a certification wind tunnel. Several standard routines were approved in 2003.



Organisation of the Foundation DNW

5.3 European Transonic Windtunnel (ETW)

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

In 2003 a substantial number of paid tests was executed, including tests performed in relation with European programmes. The tests yielded good results and satisfied customers.

Supervisory Board

At the end of 2003 the membership of the Supervisory Board was as follows:

France	
ICA X. Bouis, Chairman	ONERA
ICA H. Moraillon	DGAC/DPAC
ICA L. de Chanterac	DGA/DSP
	SREA/PEA
Germany	
Prof.Dr.-Ing. J. Szodruch	DLR
MinR. M. Metzger	BMBF
Prof.Dr.-Ing. C.C. Rossow	DLR
United Kingdom	
Dr. R. Kingcombe	DTI
Dr. C.G. Burton	QinetiQ
The Netherlands	
Vacancy	V&W
Ir. F. Holwerda	NLR

The Managing Director is Dr. W. Burgsmüller.

5.4 Group for Aeronautical Research and Technology in Europe (GARTEUR)

The Group for Aeronautical Research and Technology in Europe (GARTEUR) was formed in 1973 by representatives of the government departments responsible for aeronautical research in France, Germany and the United Kingdom. The Netherlands joined in 1977, Sweden in 1992 and Spain in 1996. In 2000, Italy joined GARTEUR as the seventh nation.

One of the aims of GARTEUR is strengthening collaboration in aeronautical research and technology between European countries with major research and test capabilities, and with government-funded programmes in aeronautics. Another aim is to continuously stimulate advances in aeronautical sciences and to pursue topics of application-oriented research in order to maintain and strengthen the competitiveness of the European aerospace industry.

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 an Exploratory Group achieves an agreed proposal, an Action Group is established with participants (research establishments, industries or universities) from at least three GARTEUR countries.

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

Organisation

The organisation diagram shows three levels: the Council/Executive Committee, the Groups of Responsables and the Action Groups. Via the Industrial Management Group (IMG3) associated with the Association Européenne des Constructeurs de Matériel Aérospatial (AECMA), Industrial Points of Contact in the Groups of Responsables and industry participation in Action Groups, GARTEUR has interfaces with the European aeronautical industry.

AECMA has merged recently with the organisations EDIG (defence industry) and Aerospace (space industry) to form the new aerospace and defence organisation ASD (Aerospace and Defence Industries Association of Europe)

Council and Executive Committee

At the end of 2003, the GARTEUR Council was composed as follows.

France

IGA Ph. Ramette *)	DGA
Dr. D. Nouailhas **)	ONERA
ICA H. Moraillon	DGAC/DPAC
ICA L. de Chantérac	DGA

Germany

Dr. J. Bandel *)	BMWI
W. Riha **)	DLR
K. Heyer	BWB
H. Hüners	DLR

United Kingdom

Dr. G.T. Coleman *)	DSTL
T.J. Birch **)	DSTL
D.M. Way	DTI

Spain

A.L. Moratilla Ramos *)	INTA
P. García Samitier **)	INTA
R. Herrero Arbizu	MdCyT

Sweden

Col. A. V. Johnsson *)	FMV
L. Falk **)	FMV
Mrs. C. Looström	FOI
Dr. E. Lindencrona	VINNOVA

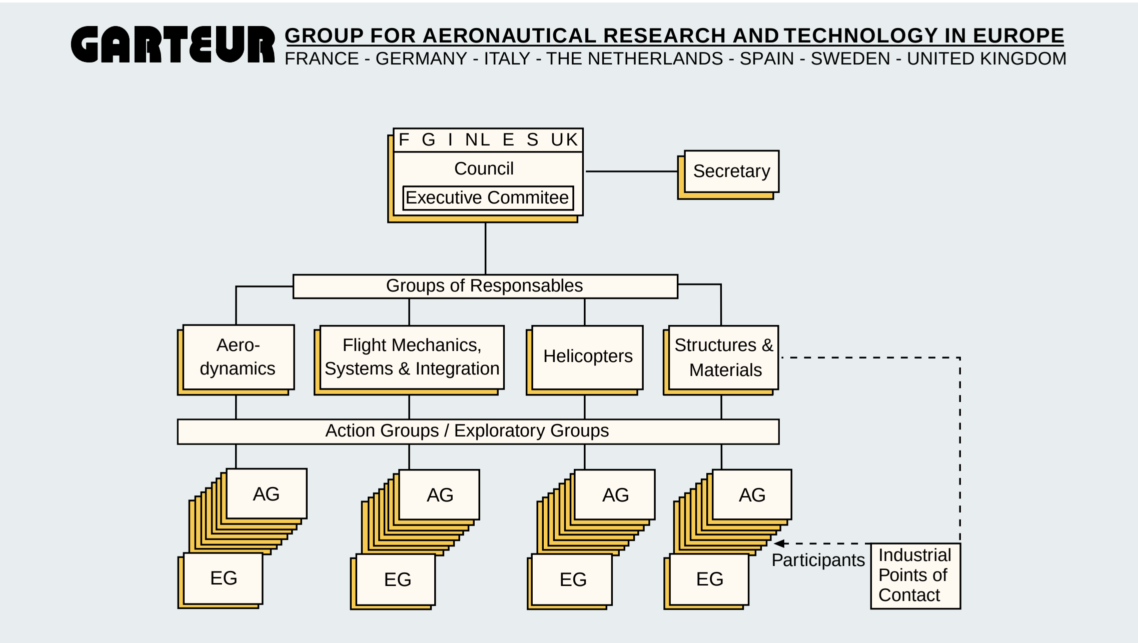
The Netherlands

Drs. E.A. van Hoek *)	MvD
Dr. B. Oskam **)	NLR
Drs. A.A.H. Teunissen	EZ
Ir. F.J. Abbink	NLR

Italy

Prof. S. Vetrella *)	CIRA
A. Amendola **)	CIRA
M. Mazzola	MdR
Col. O. Spedicato	MdDef

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



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

In 2003, Spain provided the Chairman for the GARTEUR Council and the Chairman for the Executive Committee as well as the Secretary. The persons involved were:

Mr. A.L. Moratilla Ramos	*Council Chairman*
Mr. P. García Samitier	*ExecutiveCommittee Chairman*
Mr. F. Mérida Martin	*Secretary*

The GARTEUR Council met in Amsterdam, The Netherlands, and Farnborough, United Kingdom.

The Executive Committee had two meetings.

The NLR members of the Groups of Responsables (GoR) were:

Ir. A. Elsenaar	Aerodynamics GoR
Ir. W.P. de Boer	Flight Mechanics, Systems & Integration GoR
Ir. C. Hermans	Helicopters GoR
Ir. H.H. Ottens	Structures & Materials GoR

NLR Participation

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

Table 1 – Numbers of Action Groups

Group of Responsables	Action Groups	
	Total	NLR
Aerodynamics	11	9
Flight Mechanics, Systems & Integration	2	2
Helicopters	4	4
Structures & Materials	4	4
Total	21	19

5.5 Co-operation with Research Establishments in Aeronautics

DLR/NLR partnership

Background

A formal partnership agreement between the Deutsches Zentrum für Luft- und Raumfahrt (DLR) and the National Aerospace Laboratory NLR has been in force since 1994. The aim of the partnership is to strengthen the ties between the two establishments in order to make more effective use of knowledge and facilities available. A Joint Executive Board (JEB) consisting of representatives of DLR and NLR, guides and controls this task. The JEB meetings were co-chaired by Prof.Dr.-Ing. J. Szodruch (DLR) and Ir. F. Holwerda (NLR). The latter was assisted by Ir. F.J. Abbink and Drs. A. de Graaff.

The DLR-NLR Programme Committee continued to stimulate and monitor bilateral precompetitive research. The NLR representatives were Ir. F.J. Abbink, Dr. B. Oskam and Ir. H.H. Ottens.

Bilateral co-operation covered:

- Development of B2000 Software
- Hybrid RANS-LES modelling
- Investigations of jet-flap interference and thrust vectoring

DLR and NLR held a mini-symposium on noise. This resulted in a project proposal for the 6th EU-Framework Programme and proposal to set up a Garteur Exploratory Group on advanced measurement techniques.

During 2003 DLR and NLR negotiated the integration of their air traffic and airport traffic management research activities into one single organisation, based on proposals made by a joint task force. It is expected that concrete steps for this integration will be made early 2004.
DLR and NLR will continue to look for closer co-operation in other areas of research in 2004.

The negotiations between DLR, ONERA and NLR on closer co-operation in the area of wind tunnels and associated activities also continued during 2003.

Other co-operative efforts

During 2003 bilateral talks with ONERA and CIRA opened the way to closer co-operation and exchange of personnel. The restructuring of the ATM-industry in Europe initiated the restructuring of the PHARE-X co-operation in ATM research between European research establishments and ATC service providers. A co-operation agreement was concluded with the AVIC-1 company in China. Contacts with the Russian research community were intensified.

EREA: Association of European Research Establishments in Aeronautics

Seven European aeronautical research establishments formed the association EREA in order to foster an effective and efficient European aeronautical technology base. EREA aims at improved visibility of the research institutes and ultimately creating a union between regional centres, where strong organisational ties result in integrated management of joint activities, pooling of facilities and the creation of interdependencies and centres of excellence.
In the General Assembly of EREA, NLR was represented by J. van Houwelingen, Ir. F. Holwerda and Drs. A. de Graaff, who was also treasurer and member of the Executive Secretariat.

Activities enabling closer co-operation on an EREA-wide basis were continued. These included the comparison of financial data and procedures, the EREA portfolio and capabilities and internal regulations. An EREA website and intranet became operational. Also proposals for Networks of Excellence amongst EREA partners were developed.

European aeronautical research establishments work together in the Aeronautical Research Group (ARG) to facilitate communication and to promote joint interests with the European Commission and the European industry, as well as promoting information exchange amongst the establishments on EU-related issues. The ARG, chaired by Drs. A. de Graaff (NLR), is incorporated in EREA. Exchanging information and preparing project proposals are the main objectives of the ARG. The ARG maintains links to research organisations and universities outside EREA.

At the end of 2002 the 6th Framework programme of the European Union started with a first call for proposals early 2003. Towards the end of 2003, ARG co-ordinated the preparation of the second call, which will close in March 2004.

5.6 NLR activities within the European Union context

The European Commissioner for Research, P. Busquin, advocated a new approach for the European Union's research programme, amongst others by stimulating the integration and balancing of research activities of the Union with those on the national level and in private European organisations. A Group of Personalities recommended the Commission to embark on a European research approach to satisfy the needs of the air transport sector in future. To this end, an Advisory Council for Aeronautical Research in Europe (ACARE) was established in which J. van Houwelingen was appointed as one of the three EREA representatives. ACARE published a first Strategic Research Agenda (SRA) in October 2002, which indicates the areas of European research. NLR participated in several Working Teams that prepared the SRA.

In order to draft a second version of the SRA, new teams have been established in which NLR participates:

- Subteam 1: technology integration (Drs. A. de Graaff)
- Subteam 2: airport technologies (Ir. J.C. Terlouw)
- Subteam 3: ATM technologies (Ir. H.A.J.M. Offerman)
- Subteam 4: aircraft technologies (Ir. M.A.G. Peters)

The second version of the SRA will be published in the second half of 2004 and will be the guiding principle for an aeronautics programme in the 7th Framework Programme, as well as the national research programmes of the EU-Member States and private organisations.

J. van Houwelingen was elected as chairman of working team 5 of ACARE, which prepares closer co-operation in research and education. Drs. A. de Graaff was appointed rapporteur. He also participates in working team 6, which deals with research co-ordination. To support ACARE, NLR was responsible for several policy studies funded by the European Commission. A European aeronautical research taxonomy was established. Studies on Member State research initiatives, the European technology supply chain and the improvement of the education system were contracted out by NLR.

In 2003 the European Commission increased the co-operation with ESA. The Commission funded some research projects related to the implementation of Galileo and GMES (earth observation). The Commission also published its White Paper on space, advocating a substantial increase in European space activities.

Furthermore, the European Commission announced a research programme to increase the security of Europe. NLR envisages to participate in this initiative in 2004.

Capita Selecta

1 Megaliner Barrel Programme

Summary

Airbus Deutschland GmbH (Airbus) has started a fuselage validation project “Megaliner Barrel Programme”, in which several design concepts and new materials are tested as part of a full-scale fuselage section. Part of this project is the validation of GLARE as a skin material for large aircraft.

Introduction

Airbus is currently investigating the feasibility of bringing an ultra high capacity aircraft to the market. Several aircraft configurations have been investigated with respect to airport compatibility, customer requirements, aerodynamic efficiency, structural feasibility and many other aspects. The most likely configuration will be the double deck design. Airbus has no experience with a double deck design as proposed in this configuration. This results in many uncertainties within the many affected disciplines. One of the aspects that Airbus is unfamiliar with, is the structural behaviour of such a design. How does the aircraft respond to external loads? What is the internal load distribution in the structural parts? What is a weight optimal design for such a configuration? To reduce the risk of errors in the structural design of the fuselage, a fuselage validation programme “Megaliner Barrel Project” has been initiated by Airbus.
As well as validating this new aircraft configuration, Airbus is also looking for improvements through new technologies that have been developed in the recent years. One of the new technologies that Airbus wants to evaluate is GLARE. To perform this evaluation, about 35% of the fuselage skin of the megaliner barrel will be designed and built with GLARE. This material has been developed in the Netherlands, where much experience with designing, manufacturing and testing GLARE has been obtained over the years. For this reason, Airbus has asked the Dutch aerospace community, Stork Fokker AESP B.V. and NLR, to participate in the Megaliner Barrel Programme.

Fig. 1 GLARE section

GLARE

GLARE was developed about 15 years ago at the Delft University of Technology.
The main driver was initially to develop a material with much better fatigue crack growth resistance than the currently used aluminium alloys and yet maintain several of the favourable properties of aluminium alloys (such as machinability and repair capability). GLARE is a laminate that consists of alternating layers of thin aluminium sheets and fibre reinforced adhesive layers. The current GLARE uses grades 0.2 mm - 0.5 mm thick Al 2024-T3 sheets. The fibre-reinforced layers consist of glass fibres embedded in FM-94 structural adhesive, and are supplied in the form of unidirectional pre-preg by Cytec. The laminates are produced by placing the individual layers on top of each other in a mould in the required sequence. After lay-up the laminates are cured in an autoclave at a temperature of 120 ºC.

There are several GLARE grades, which differ mainly in the composition of the fibre-reinforced adhesive layers. For example, in GLARE 3 laminates each fibre-reinforced adhesive layer is built up of two unidirectional pre-pregs. One of the pre-pregs is laminated in the rolling direction of the aluminium sheets. The other pre-preg layer is perpendicular to the rolling direction. This laminate is thus suited for structures that are loaded bi-axially where the expected loads in the two directions are about the same. Another example is GLARE 4. In this laminate each fibre-reinforced adhesive layer contains three pre-preg layers. For two pre-preg layers the fibre direction is the same and for the third pre-preg the fibres are perpendicular to this direction. This laminate is suitable for structures

Fig. 2 Glare panel in C-scan

where the loads in one direction are about twice as high as in the other direction. This is the loading condition that typically occurs in fuselage skins owing to cabin pressurisation. GLARE owes its good fatigue crack growth resistance largely to the presence of the glass fibres, which are practically insensitive to fatigue. When fatigue cracks occur they will be in the aluminium sheets only, and the crack growth rates will be very low, since in the vicinity of a crack the loads are transferred to the fibres, which bridge the crack.
The main disadvantage of GLARE has been the relatively high cost of the laminates, whereas reducing the costs of structures is nowadays one of the main objectives of aircraft manufacturers. A significant cost reduction was achieved by developing a new concept for the production of fuselage panels. The panels are not manufactured from flat sheets, as is done for monolithic aluminium alloy structures, but by laminating the panels directly in moulds that have the required shape. It is even possible to produce panels with slight double curvatures. This process also allows the incorporation of all kinds of local reinforcements during the production of the panels, which further contributes to the cost reduction. The entire laminated panel is cured in an autoclave.
A C-scan check is also part of the process. Another aspect that resulted in a significant cost reduction was the development of the so-called splice technology, which enables the production of very wide fuselage panels, i.e. wider than the width of available aluminium sheets. This reduces the number of (expensive) riveted joints in fuselage structures.

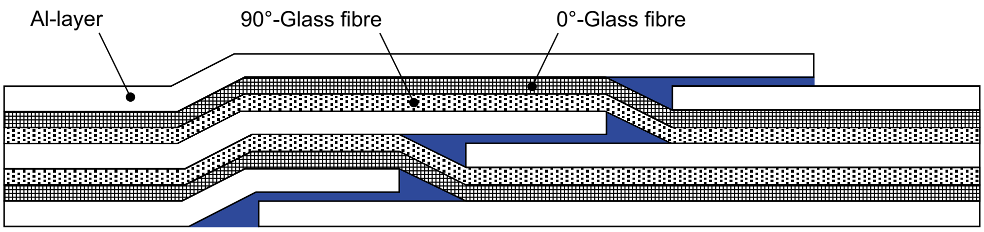


Fig. 3 Principle of the splice technology

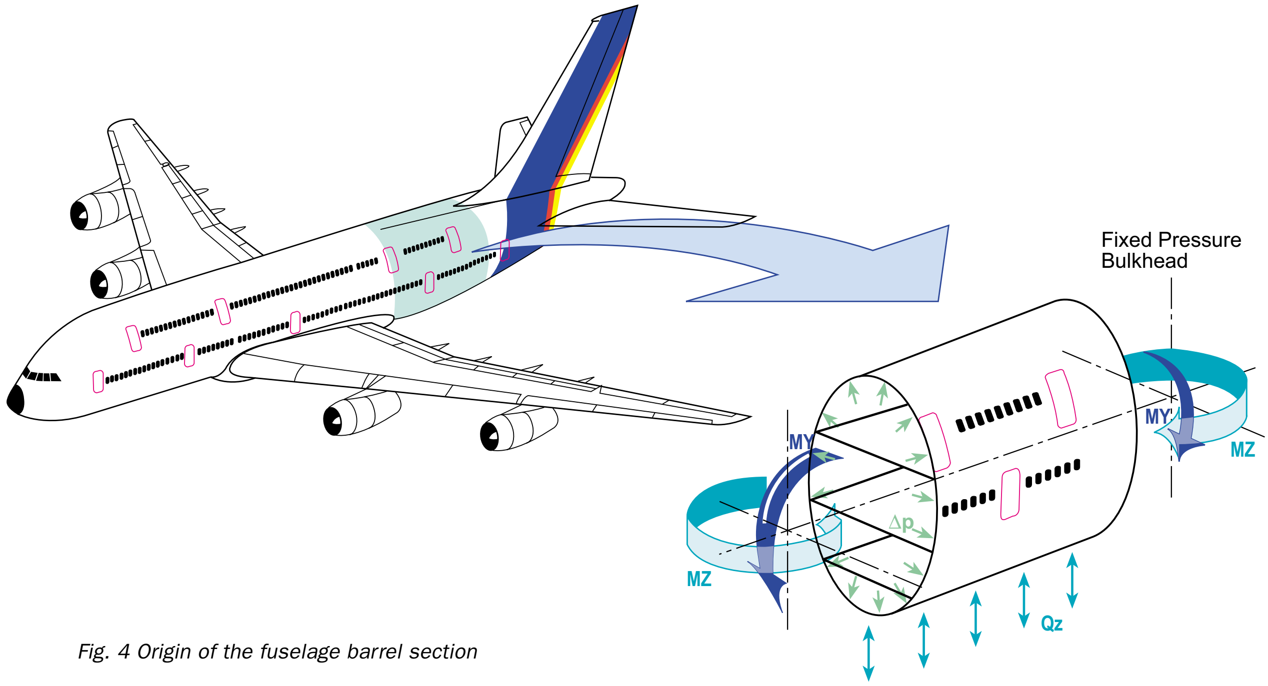


Fig. 4 Origin of the fuselage barrel section

GLARE will be used in the fuselage of the Airbus A380. Stork Fokker AESP B.V. will produce most of the panels. Since 1998, thousands of tests have been done at the NLR in the framework of the material qualification. In addition, all tests that were required for the assessment of the material design allowables were also carried out by NLR in close co-operation with Airbus and Stork Fokker AESP B.V..

Megaliner Barrel Test
Carrying 500 to 1000 passengers in one aircraft required the design of a pressurised fuselage with two passenger decks and one cargo deck. The Megaliner barrel is a rear section of the fuselage. The test rig is situated at the Airbus Hamburg plant. The fuselage barrel is 15 m long, with a maximum horizontal diameter of 7.15 m and a maximum vertical diameter of 8.69 m. Two bulkheads close the fuselage section, a fixed and a free moving one. The fixed bulkhead is mounted to the aft side of the section.

Test Facility
The test facility is situated at Airbus Hamburg. The test department of Airbus Hamburg designed the test set-up which is situated in a specially built test hall. The test hall is provided with a hydraulic system to drive actuators for load application and a pneumatic system to pressurise the fuselage. The fixed pressure bulkhead is integrated with the building.

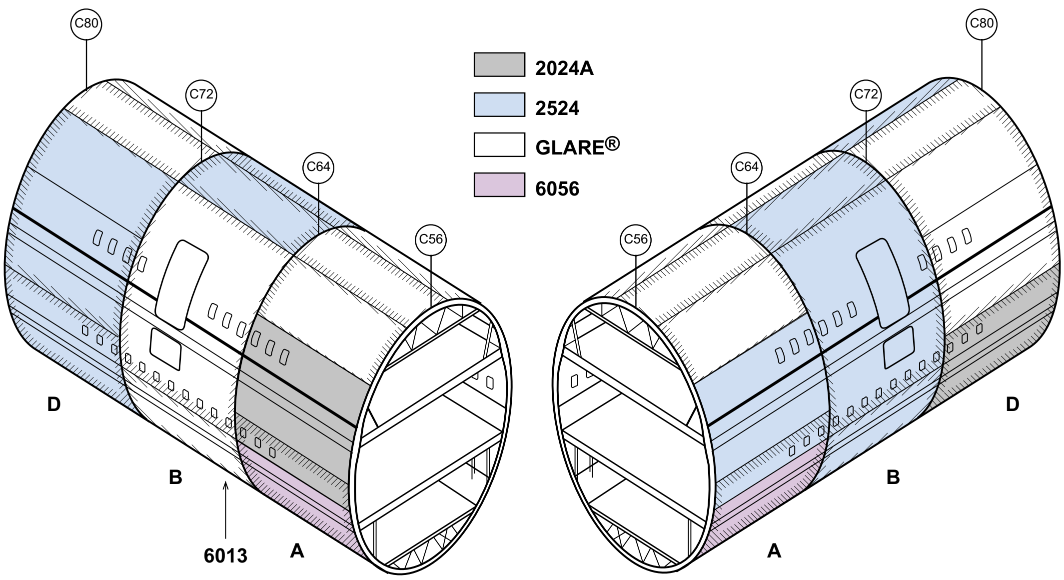


Fig. 5 Barrel composition

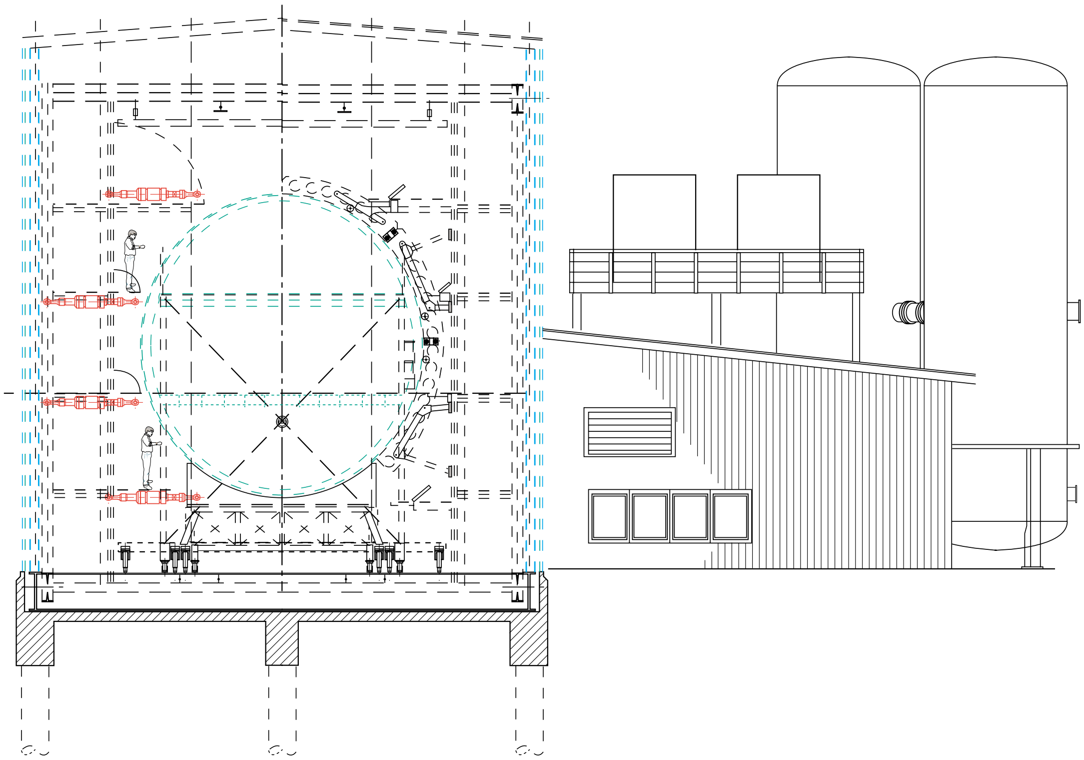


Fig 6 Test building

Purpose of the test

The "Megaliner Barrel Test" has different goals. Firstly, the finite element model used for the stress analyses is verified. Secondly, the design concept typical for large aircraft fuselage was checked. The application of new materials, like GLARE and Carbon Fibre Reinforced Plastics (CFRP) and new manufacturing concepts like welding of Aluminium stringers and Resin Transfer Moulding for CFRP parts was evaluated.

The main parts of the test

The "Megaliner Barrel Test" consists of the following parts.

- Static tests for 25 load cases measured strain and displacements.
- Fatigue tests representing 60.000 flights per day.
- Residual strength tests at the end of the fatigue test programme.

Fig 7 Fixed pressure bulkhead

During all tests visual and Non-Destructive Inspection (NDI) programmes are performed. NLR has provided on-site support by both test engineers and NDI inspectors.

Load introduction

Moments, pressurisation, shear forces and torsion will load the fuselage section. The differential cabin pressure for fatigue is 606 mbar. A total of 30 hydraulic actuators introduce the loads that will be necessary to carry out the flight spectrum. The test programme is based on a 375 minute flight mission.
The spectrum contains basic ground loads, basic flight loads and incremental loads for taxi, rotation, landing impact, vertical and lateral gusts and co-ordinated turns.

Test and evaluation

- The static tests were successfully finalised in January 2002. The fatigue test started immediately thereafter and was stopped in September 2003. At that moment 45.402 flights were simulated. Although the goal of 60.000 flights was not met the fatigue test had given enough results.
- During the test damages were found in the stringer couplings. This was caused by the stiffness differences between the GLARE skin and the Aluminium stringers leading to higher loads in the stringers.
- Different repairs of the damage structure were tested like boarded and rivetted repairs on the GLARE skin and repaired GLARE stringers.

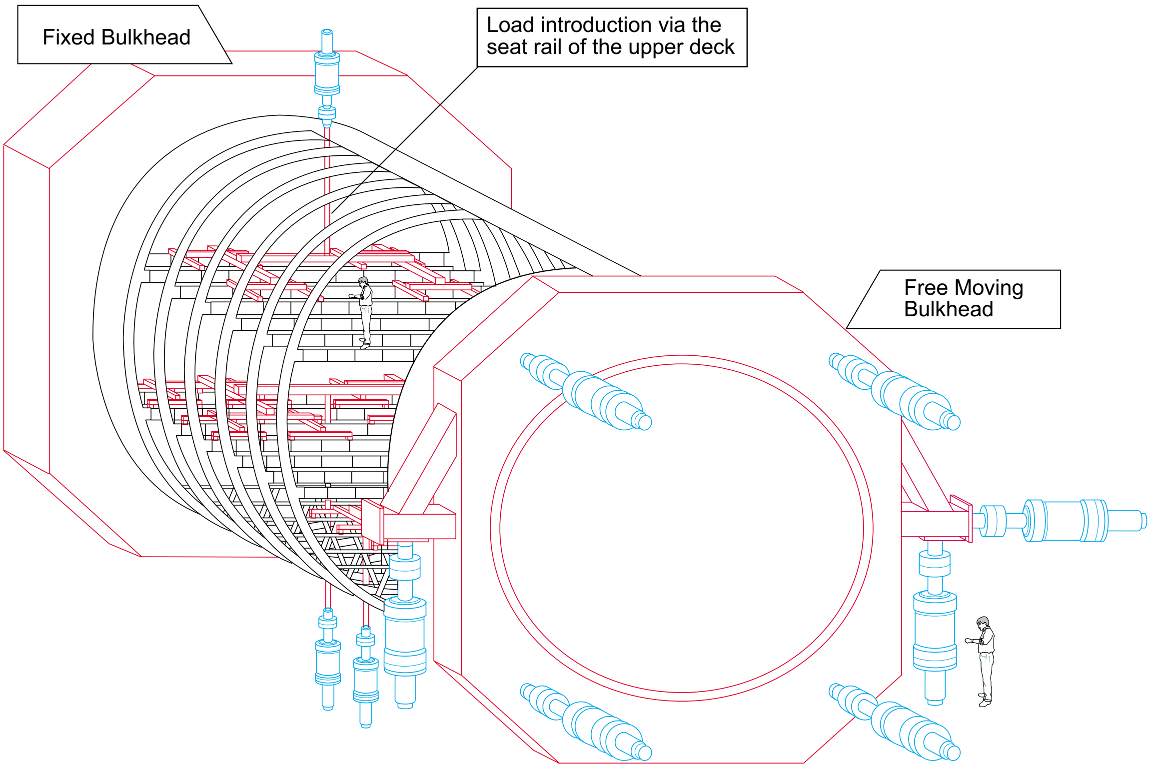


Fig 9 Schematic view of some load introduction actuators

Tear down

After the full-scale Megaliner Barrel fatigue test, additional detail tear down tests are to be conducted on GLARE parts. The tear down tests will be done by NLR on several specimens cut from the Megaliner Barrel.

NDO inspections and residual strength tests will be performed on these specimens in order to learn more about the material behaviour. Additional fatigue tests are intended to determine the fatigue life for certain structural parts. Therefore the real spectrum will be applid on their sub-scale specimens (coupons). In order to check that the same stress in these coupons exist, stress verification measurements have to be performed with strain gauges during the full-scale test.

Fig. 8 An assembled barrel just before the mounting of the free pressure bulkhead

2 Development of an Autonomously guided Ram-air Parachute Delivery System

An aerial cargo delivery system using a ram-air parachute is developed by Dutch Space in partnership with NLR and the French parachute supplier Aérazur. The system is developed to deliver the cargo on a pre-programmed location with high precision. Guidance of the parachute, either by remote control by a man or autonomously using GPS position data, enables the precise delivery, even if the system is dropped from high altitudes. The results of a development, test and demonstration project, named SPADES (Small Parafoil Autonomous Delivery System), showing the capabilities of the system are presented.

Introduction

In a joint effort Dutch Space and NLR observed a need for autonomously guided ram-air parachute delivery systems. Both military and civil as well as national and international interests for such systems were identified. The range of payloads to be delivered accurately is large, the main interest being between 100 and 5.000 kg. Based on the result of the analysis of needs it was decided to ficus initially on the design, test and demonstration of a small-payload system. This small system was to utilise the type of parachute that is in use by the Special Forces in the Netherlands for manned flight. This automatically leads to a payload class of 100 to 200 kg as the goal for the current project. Using this type of parachute means, that in combination with the manned applications, there is an advantage for operational introduction with respect to logistics: same infrastructure, training and instruction, maintenance etc.

The parafoil systems to payloads of 100 to 200 kg can be applied for different types of missions. Two main types have been identified: a system flight in combination with manned drops (supply-mission) or as re-supply mission where the system flies fully autonomous and alone towards a pre-defined landing location. In both cases the system will be able to land within a distance of 150 m from the pre-programmed landing-point regardless of the drop-altitude up to 30.000 feet, and the wind profile.

The Netherlands Special Forces, Korps Commando Troepen, provided valuable input for the design of the system from an operational viewpoint. The Royal Netherlands Army in the framework of CODEMA supports the project. The Royal Netherlands Air Force and the United States Army provided the airdrops and the use of their ranges for the flight tests and demonstrations.

The development program included system design, building of demonstrator systems, laboratory tests, ground tests, simulations, parachute-deployment tests, remotely controlled flight tests, autonomous flight tests and demonstrations of the demonstrator system. A system description, an overview of the development program, an overview of tests and demonstrations, a focus on NLR contributions to the development, some results and an outlook to the future are given below.

The system

A complete unit can be subdivided into three main parts:

- Parafoil
- Control-box with on-board computer
- Payload container

Commercial-off-the-shelf components are applied in the design as much as possible. The parafoil, a 35 square meter G9-Galaxy of Aérazur, is a soft pack mounted on top of the control-box. This box, with dimensions 0.45 x 0.45 x 0.40 m (lxwxh), contains the flight control computer, sensors, batteries and the actuators for the control-lines. The payload is fixed to hooks on the corners of the box. Several types of test-payloads have been flown with the system.

The control-box has two actuators to reel the two control lines of the parafoils in and out, such that steering actions defined by the flight control computer or a remote pilot can be realised. For the flight control computer an

Two integrated test units ready for flight tests in a US Air Force Globemaster C17(right) and a test unit on the ramp of a Royal Netherlands Air Force Hercules C130

advanced algorithm was developed that was named auto-pilot due to similarities with fixed wing auto-pilot functionality. With the algorithm the system frequently updates the best strategy to reach the target point, based on the relative position of the system with respect to the target point and on the calculated wind vector. Position data are retrieved from a GPS receiver and wind data are calculated by processing sensor data, where the GPS and heading sensors are the prime sources for the data.

The current system has a radio link between the control-box and a ground station for remote control. In the ground station key parameters reflecting the status of the system are displayed to a remote pilot, who can override steering commands of the flight control computer with control levers for the left and right control lines of the parafoil. For test purposes the current system has additional sensors and a data acquisition and recording system installed in the control box.

The development program

For the development of the system, a step-by-step approach has been adopted in order to minimise the risk of a system-loss during the tests. After the verification of the parafoil deployment procedure, several tests demonstrated adequate functioning of the remote control system and the execution of pre-defined flight-manoeuvres. The auto-pilot algorithms have been designed based on the flight-data gained from these test-manoeuvres. Fully autonomous flights have been carried out, where the remote-control system could be used to overrule the auto-pilot when necessary (at present, after 25 autonomous flights, it was not necessary to use it).

Based on this philosophy the following development and test program was planned and carried out:

Development of the payload to be installed under the parafoil with Deployment Drop-Tests:
- In-flight verification of parafoil deployment.

Development of the control unit and ground station with Open-Loop Drop-Tests:
- In-flight verification of remote control functionality.
- In-flight characterisation of parafoil(-system) performance.

Development of the guidance algorithm and implementation in the control unit with Closed-Loop Drop-Tests:
- In-flight verification and demonstration of autonomous system performance.

Modification of the parafoil, the control unit and the guidance algorithm for high altitude conditions with High Altitude Drop Tests:
- In-flight verification and demonstration of system performance at high altitudes

The tests and demonstrations

The tests have been carried out in 2001, 2002 and 2003 in a wide range of wind-conditions: from 2 to 6 Beaufort and from drop altitudes between 1000 and 27.000 ft. Two units were used for the tests and the demonstrationsto be normally dropped in separate aircraft passes, but in during one flight. The preparation of the test-units was carried out at the airbase, for the Netherlands in Eindhoven, about 200 km away from the drop-zone, for Yuma on the Proving Ground at about 50 km distance. Based on general available weather forecasts with respect to wind the decisions were taken to perform the tests and drop points were defined for the aircrew. The co-ordinates of a landing-point were passed to the control box.

The execution of these identified tests was in close co-operation with the Royal Netherlands Air Force for the first three phases. The RNLAF provided a Hercules C130 aircraft, as well as the training range 'Vliehors' in the north of the Netherlands. The range was used as drop-zone. The system was also demonstrated to potential users using this aircraft and the range. The High

SPADES system in flight

Altitude Drop Tests were performed on the Yuma Proving Grounds in Yuma, Arizona, USA, where the US Army provided a Globemaster C17 or Hercules C130 and utilisation of facilities for the tests. The system was also demonstrated in Yuma for an audience of about 200 persons at the Precision Airdrop Technology Conference and Demonstration (PATCAD) organised by the US Army from 3 to 7 November 2003.

NLR contributions

NLR responsibility comprised the development, manufacture and test of the avionics and flight test system (hardware and software), the ground station and the guidance algorithm (auto-pilot) for the system. Furthermore NLR provided flight test support and studied future certification aspects.

Avionics

The avionics for the system were required to provide the physical capabilities to guide the parafoil adequately and to navigate the system towards the target point. Furthermore, instrumentation was added to the control box for characterisation of the system during the tests. The system should be reliable, robust for a rough environment, small and cheap. The solution was found in applying COTS (Commercial Off-The-Shelf) components for as much as possible. Key components include a computer based on PC technology, rechargeable batteries, two DC motors with winches to reel the steering lines in and out, equipment for establishing a radio link, a GPS receiver and a heading sensor. Due to extra instrumentation for test purposes and for easy modifications during the test phase the size and weight of the avionics have not been optimised yet.

Software was developed for the computer in the avionics box that enables the real time gathering and storage of information from components, the processing of the information into steering commands using the guidance algorithm, the control of the DC motors for steering actions and communication with the ground station.

Control box of the Spades system (without cover)

Ground station

A ground station was developed to monitor the status and position of the system during flights and to remotely control the system. The remote control functionality has been developed to carry out pre-defined flight-manoeuvres giving data about flight characteristics that are needed for the autonomous guidance and control and to be able to overrule the auto-pilot from the ground for safety reasons. On a display the co-ordinates, altitude and attitude of the unit, as well as the projected trajectory on a local map of the site are shown. Also, the feedback of the deflections of both control lines are displayed. In this way, the controller is in full command of the system without necessarily having visual contact with the system. During several tests this feature has been successfully used since the unit was dropped above or behind the clouds.

When required, this option can easily be worked out for future operational configurations without any technical development risk, since experience has been gained during the tests.

Guidance algorithm

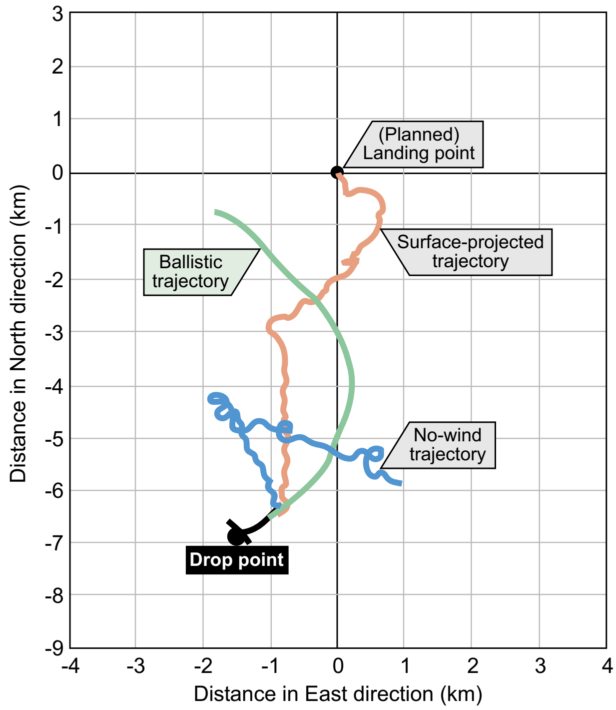
A guidance algorithm is developed to fly the system from a drop point determined by the loadmaster in the aircraft to the target point given to the system. The determination of the drop point is based on general available meteorological data. The landing should be as close as possible to the target point and the landing should be into the wind to minimise the ground speed of the system at the landing. A minimal ground speed reduces the impact shock of the landing. Wind speed and direction are estimated throughout the flight using sensor data in order to establish and to update the planned trajectory. The planning includes a landing into the wind. No a priori knowledge of the wind profile is used in the auto-pilot, so the challenge was to design an algorithm that is as insensitive as possible for wind changes. Flight strategies applied by paratroopers were good leads for the design.

To fly the strategy described above the algorithm should also contain control laws to realise the strategy with the flight characteristics of the system. These flight characteristics were obtained in open-loop flight tests. The algorithm implemented in the flight control computer of the control box gave the proper control of the system during flight.

Results

The 24 autonomous flights until now have a Circular Error Probable CEP of 65 meter. The CEP is defined as the radius of circle around target points where half of the flights landed in and half of the flights landed outside the circle. This is well below the initial goal of 150 m. In this value, established during the test and demonstration phases, several versions of the auto-pilot have been used, where the later versions were much better than earlier ones. In particular the capability to correct for wind changes improved considerably. The CEP of the current demonstrator is therefore better than the 65 meter. In the 8 demonstration flights the CEP of 30 meter was achieved, but statistics for establishing this value are too meagre to use as a system performance.

To illustrate flight characteristics of the system. An example of a trajectory is given below.
In this test-flight the system was dropped at 10.000 feet (3048m), in combination with a stand-off distance of almost 7 km. The resulting (GPS-) trajectory (projected on the surface ofthe earth-surface) is shown in the figure above (red line). In the plot the blue line is the (relative) no-wind line, while the green curve indicates the ballistic wind-trajectory (so with wind, but without velocity of the system with respect to the air). The super-positioning of both latter two trajectories results in the trajectory actually flown.



Example of flight trajectory;
for release at 10.000 ft and almost 7 km stand-off.
Co-ordinates in local reference frame with origin at the planned landing point. X-axis pointing East and Y-axis pointing North.
Each square is 1 by 1 km.

The ballistic trajectory shows that the wind-direction changed considerably during the descent. The wind-direction rotated from 2200 (South-West) at drop altitude to 1200 (South-East) at the surface. In the ballistic wind-trajectory this rotation-effect is easily recognised by the curved shape of the trajectory. Also is clear that the no-wind performance of the system is used by the auto-pilot to compensate for this wind rotation in order to land at the specified landing location.

This example shows that, although the system does not know the wind profile in advance, and even if the wind is not ‘uniform’, the auto-pilot algorithms will react and compensate for it, and will take care that the unit lands on the right place.

Future developments

After a successful development and series of tests and demonstrations, including remote controlled flights as well as fully autonomous flights and drops up to 27.000 ft altitude at stand-offs up to 12 km, it is clearly demonstrated that the technology is available to build autonomously guided ram-air parachute delivery systems. Landing accuracy is far within the targeted 150 m. Reactions of potential customers, including the Special Forces of several countries, are very positive about the performance and the configuration of the system. The next phase will be the industrialisation of the system. NLR will support the industrialisation effort led by Dutch Space.

In addition a next step in the development will be the extension of the present technology towards systems with heavier payloads. Potential customers expressed their interest for such systems. NLR and Dutch Space are eager to develop and deliver the higher-payload systems as well.

Landed near target after fully autonomous flight

3 Designing the Three Large LCD Cockpit

The modern glass cockpit usually features six display units. When one is lost due to a failure, five are still left and continued safe flight is guaranteed. The partners of the NEWSCREEN project propose a cockpit concept with only three display units, with at least the same safety level. This concept could contribute to lower the cost for the airlines, while at the same time it provides built-in growth potential for emerging functions. Innovative display technology and a reconfigurable interface between pilots and avionics allow these seemingly incompatible goals.

Introduction

Commercial airlines operate in a rapidly changing and highly competitive environment. Especially in air transport, cost savings are an important factor for success. Airlines are therefore keen to adopt features that make the operation more efficient. On the other hand, airlines are often reluctant to introduce features which improves safety systems or functions. Despite their safety advantages, such features are often not introduced quickly because the short-term economic benefits are not completely clear.

On the flightdeck screen "real estate" is a valuable commodity. The display units are usually completely dedicated to functions related to flight, navigation, system monitoring and alerting. They leave little or no space for the introduction of new functions that satisfy near-term operational or safety needs. Since the introduction of dedicated display and control devices for these functions is a costly matter, they are usually adopted relatively slow.

The NEWSCREEN research and technology development project takes up the challenge and investigates a novel cockpit concept that primarily aims to reduce costs for the airlines. At the same time it should offer benefits in the safety area and provide the necessary growth potential for implementing emerging new functions.

NEWSCREEN is in part funded by the European Commission and is co-ordinated by Thales Avionics in France. NLR is responsible for designing and evaluating the human-machine interface and acts as the liaison with pilots and civil aviation authorities.

Objectives and scope

The primary objective of NEWSCREEN is to design the architecture of a cockpit display system that could replace the current six display units by three large liquid crystal display (LCD) based display units. Each large display unit should at least be able to present the same displays that are normally depicted on two separate smaller display units. The concept is shown in figure 1.

The proposed display units should reduce maintenance and replacement costs and improve the level of dispatchability of the aircraft. They have a higher reliability, lower weight, lower heat production and reduced power consumption compared to contemporary designs. To airlines they offer the benefit of a considerably reduced cost of ownership.

Usability issues play an important role in the project, since pilots are working with the display

Figure 1 Artist impression of the new cockpit concept with three large LCD based display units.

units in everyday airline operation. Usability is especially important when dealing with display unit failures, since they do not occur frequently, and may come at a critical moment during the flight.

Display unit failures can affect the depicted information in various ways. The failures may thus have an effect on human performance and hence on safety. This is why the display unit degraded modes are the focus of attention.

Design and development activities will result in prototypes of the proposed display unit. Cockpit integration and certification issues are covered. Indeed, NEWSCREEN covers many elements of a product development.

New cockpit concept

In the proposed Three Large LCD Cockpit concept, a display unit should be able to continue displaying information after a single failure. This guarantees continued safe flight and landing. Moreover, it should be possible to continue with the next flight leg without replacing the degraded display unit.

The proposed cockpit display system offers a substantial increase in usable display area compared to the current cockpit. This provides a means to present more comprehensive and more consistent information in case of display unit failures. For example, the proposed display units allow the presentation of a full-size Primary Flight Display (PFD) and a Compressed Navigation Display (CND) after a single failure, while currently a pilot can not see them at the same time after such a failure.

The new concept provides a means to present more information simultaneously than in the current cockpit satisfying near-term operational and safety needs. For example, a vertical profile display could be added without sacrificing display area for existing information. The larger displays provide the natural growth potential needed for accommodating the current or near-future introduction of new information in the cockpit.

The large displays also provide the display area needed for a truly interactive cockpit. Such a cockpit can replace hardware panels – for example radio panels or system panels – and dedicated control and display units for functions such as datalink and the flight management system.

Finally, the larger display units open the way to present displays that would not be optimally displayed on existing smaller screens. For example, a perspective synthetic vision display normally needs a large display area to be effective.

The Airbus A320 cockpit was chosen as a test case for the new concept. The project uses the A320 cockpit philosophy and underlying avionics architecture, and is also aimed at the same type of operations as the A320. The test case brings the potentials and constraints of a real aircraft in the project, which is of great benefit for developing a viable new concept. The A320 was also chosen because Airbus is represented in the project consortium and could bring the required in-depth knowledge about this aircraft.

Methodology

Human-machine interface responsibility

NLR was responsible for the human-machine interface within the project, while specialists from the project partners provided other expert contributions.

NLR investigated the human factor issues associated with the new cockpit concept and – based on the results – designed, prototyped and evaluated the human-machine interface. Thales Avionics provided the required display system expertise. Thales Avionics LCD helped in verifying the evaluation environment, especially the commercial LCD that was employed. Airbus contributed with cockpit integration expertise and company test pilot experience. NLR itself also involved airline, test and certification pilots.

The competent partnership and the distribution of responsibilities allowed NLR to perform its tasks in a realistic manner, right at the link between human factors and systems engineering. The work was performed in close contact with pilots and civil aviation authorities. It proved to be a very efficient and effective team approach.

Design iterations

The human-machine interface activities comprised several design iterations (see figure 2). Each design iteration started with an analysis of the open issues. This was followed by proposals for improving the human-machine interface or the display unit itself. These proposals were also based on an analysis of the pilot tasks and the required information for these tasks. The most promising proposals were implemented, usually with a few variations. For the human-machine interface this involved adapting displays and (simulated) controls. This was followed by an evaluation with experts.

Input to the first design step was an analysis of potential human factor issues related to the new cockpit concept. The issues were identified by comparing the current Airbus A320 cockpit with the new concept. This is in line with the upcoming regulation on human factors certification.

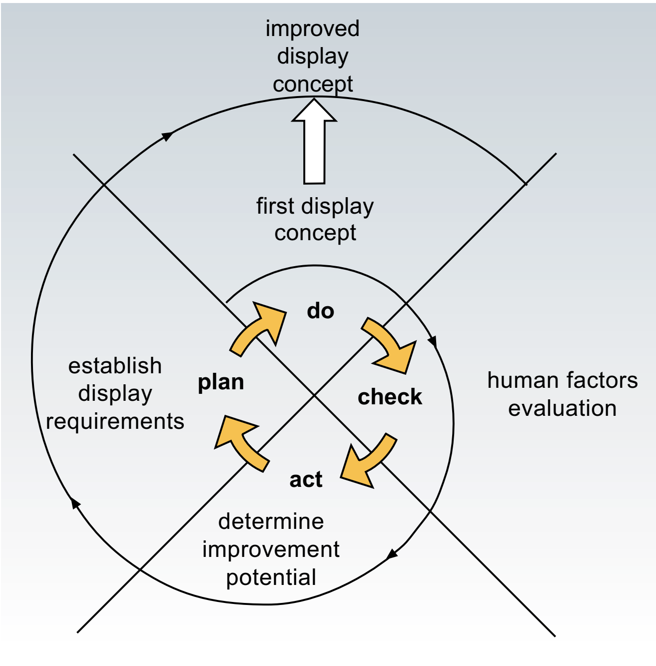


Figure 2 The methodology can be characterised by several design iterations.

In the later iterations, the results of the evaluations were used as the main input for optimising the design. The results were not only used to optimise the human-machine interface, but also to improve the display unit hardware. The activities can be characterised by continuously collecting feedback and consequent and rigorous solving of open issues.

Three phases

The human-machine interface design was split in three phases. The first phase had an explorative nature and was mainly used to find the strengths and weaknesses of the concept and to get a well-founded estimate of its safety potential.

In the second phase the additional screen area offered by the display units was used to counteract the effects of display unit failures by means of display reconfiguration. Main purpose was to design a safe cockpit with an improved level of dispatchability. Changes compared to the Airbus A320 cockpit were kept to a minimum.

In the third and last phase a completely new reconfiguration mechanism and the addition of new functions and interactive features were studied. Also in this phase compatibility with the existing Airbus A320 cockpit remained an important issue, but the design team took more freedom to explore the full potential of the large display units.

Evaluations

During the human-machine interface design several evaluations were performed with a certification pilot, two company test pilots, one airline pilot and a cockpit integration expert. Three of the pilots were (also) flying for a commercial airline. The evaluations were aimed at ensuring the acceptability of the proposed concept in terms of safety impact, usability and application of proper design standards.

The effect of each possible display unit failure was presented and thoroughly discussed in order to arrive at a criticality rating for each failure. The most critical flight phases, usually take-off and landing, were identified and taken into account. This was done for every dispatch case and two independent failures in a row. The general rule in certification is the higher the criticality of its effect, the lower the probability of a failure must be.

The usability of the display unit controls and the displayed information was also assessed. The controls are used to switch the display units on and off, to regulate brightness, and to transfer displays after display unit failures. Pilots frequently adjust brightness to obtain a comfortable viewing environment under varying ambient light levels. On the other hand, display unit failures are very rare, so the intuitiveness of the controls under such conditions is also important.

The basic displays are realistic copies of existing Airbus A320 displays and were therefore not a subject of discussion. However, the way they are presented on the proposed display unit was appraised. Newly added features in the displayed information, for example to recover from display unit failures, were also assessed. A notable example is the compressed ND that appears under the PFD when a full-size ND can no longer be presented.

Evaluation environment

External validity

External validity played an important role in the activities. It refers to the extent to which effects observed in this study truly reflect what can be expected in the real world. Since displays are the focus of attention, human visual perception in a real cockpit environment had to be taken into account. Consequently, representative display hardware and a precise simulation of the displays and their failure conditions in a relevant context were important requirements.

Cockpit mock-up

The evaluations took place in a cockpit mock-up dedicated to development and evaluation of human-machine interfaces.

Two large LCD were installed in a new forward panel, one directly in front of the captain's seat, the other in the center of the cockpit. In addition, the control column was replaced by a side stick in order to get closer to the Airbus A320 layout. Controls for autopilot operation and a basic flight model were already available.

External light, especially direct sunlight, reduces the displays' contrast. Therefore, studio lamps were installed in the cockpit mockup. This way, "night", "dusk" and "day" illumination levels could be simulated, including direct light on the LCDs. This way a first appraisal of legibility and effects of failures under limiting viewing conditions could be performed.

Representative LCDs and displays

Two state-of-the-art commercial LCDs were installed in the cockpit mock-up (see figure 3). Naturally, the commercial LCDs are not intended for avionics applications, but the major visual characteristics show many similarities with the specifications of the display units studied in the project. Together with realistic displays, this allowed judging legibility of the symbology and effects of failures in a credible manner.

Pixel structure and pixel dimensions of the LCDs in the cockpit mock-up are closely matching the specifications of the proposed avionics LCD. Therefore, the fine details of the displays appear identical as to real flightdeck.

It is a characteristic of any LCD that contrast and luminance are reduced and colours may shift under large viewing angles. Although the commercial LCD could not match the avionics LCD in this respect, the usable viewing envelope was sufficient to judge the symbology on the opposite side of the cockpit.

The 20.8" diagonal commercial LCD that was installed in the evaluation environment

Obviously, a commercial LCD can not meet all requirements for an avionics display. For example, the light output and the contrast ratio of the proposed avionics LCD are much better than in the cockpit mock-up. This is clearly a reason also to perform evaluations with the avionics LCD.

In order to assess the legibility of symbology on the new displays units, a highly realistic simulation of the displays was also needed. For this purpose, the standard A320 displays were simulated in a pixel-precise way. Layout and dynamics, but also symbols, texts and colours were all meticulously modelled.

The displays were realized using NLR's in-house developed rapid prototyping software called NADDES (NLR's Avionics Display Development and Evaluation System). This tool greatly helped in keeping the effort manageable, while also allowing to make the displays pixel-precise.

Simulated failures and recoveries

Although the probabilities of failures are low, the new display unit can still fail in various ways. The display unit itself detects most of its failures and automatically takes the required action: the affected part of the display unit is switched off.

Due to the natural redundancy of the LCD – it consists of many columns and rows – and the smart design of the display unit, a single failure affects at most half of the display unit surface. The unaffected part is still perfectly able to display information to the pilots. Obviously, the automatic failure recovery mechanism is exploiting this quality of the display unit: the most important information is preserved by automatically relocating it.

Although the proposed display unit detects many failures, some failures can not be detected in a technically reliable or cost-effective manner. In those cases detection is up to the cockpit crew, as well as taking the required action, for example by switching off the affected part of the display unit. That would trigger the same automatic relocation of information as for the detected failures.

Like the detected failures, the undetected failures affect only a part of the total display unit surface. In the affected part, perception of the displayed information is – to some extent – hampered; the other part is still perfectly usable.

The visible effects of the undetected failures were modeled by Thales Avionics and implemented by NLR as an add-on to the simulated displays. This highly realistic approach allowed judging the effects of the undetected failures on dynamic displays to a pixel-precise extent.

Results

Dispatchability

A very significant result is a reconfiguration scheme that is tailored to the new display units and optimised for the dispatchability and safety oriented objectives of the project.

In case of display unit failures, displays are relocated in a fully automatic way. The information is redistributed over the remaining display area, making use of the flexibility offered by the large display area and by the underlying avionics.

Although the original objectives of the project that dispatch should be possible with a single failure in one display unit, the target was set more challenging to two display units with a single failure. The display reconfiguration mechanism was designed accordingly.
In the evaluations it became clear that the new cockpit concept could indeed offer an improved level of dispatchability compared to contemporary aircraft. This is not only due to the higher reliability of the display units, but also due to extra dispatch options. The demanding design target can actually be met using the latest human-machine interface technology and clever reconfiguration scheme.

Safety

Criticality ratings of all possible failures were established, including an assessment of two consecutive independent failures. The criticality ratings are an important result, and are used in the numerical safety assessment of the new display units. In such an assessment the probability of failures is compared to their criticality. This is to assure that safety is not compromised by the failures, even in critical flight phases.

Compared to contemporary designs, the proposed display unit and its new reconfiguration scheme potentially have a positive impact on safety. The most important information is automatically displayed at all times, and the cockpit crew can easily call up the other information. This remains true, even after several display unit failures. Note that the chances that this will happen are not high, since the probabilities of failures are already low in the proposed display unit.

Usability

A key feature of the new concept is the newly designed Compressed Navigation Display. It takes up half the space of the normal ND and is presented when a full-size ND position is lost. Except for the display's size, the design changes are subtle but effective. This way, the same information can be presented in a highly compatible and compact format.

Some new features in the layout of the human-machine interface and the design of the displays assure that the existing Airbus A320 displays can be integrated in the new framework. The end result is a cockpit where the basic displays appear virtually unchanged, but naturally fit in the new concept.

The new display technology allowed designing an optimised set of controls. The new design features fewer controls than currently, but it still gives the pilots the required command in an intuitive way – also in case of display unit failures.

Future extensions and interactivity

In the third and last design phase four new functions were added to the human-machine interface: a vertical profile display, a datalink display, a display for managing radios, and a security camera display. The latter three displays are interactive, and can be controlled by the pilots with a cursor-control device, for example a trackball. These functions are new designs, but follow the Airbus information coding philosophy. They serve as a demonstration of extensibility only; validation of the new functions was out of the scope of the project.

Figure 4 The new display units allow implementing new functions, such as datalink, in a natural way. Instead of installing a dedicated unit in the cockpit (top), the new function can be added to the display unit's software (bottom)

The new functions could indeed be integrated easily; in a natural way for the pilot and not compromising presentation of existing functions. The new functions could also be included in the automatic display reconfiguration mechanism in a straightforward way. In fact, part of the strength of the final design is the possibility to select information with the cursor-control device. After failures the most important displays are automatically presented, but the pilots can always select the other displays in an intuitive way.

Further steps

The work reported in this paper covers the first and second year of the NEWSCREEN project and concentrates on the NLR activities. At the same time a system study was performed and the various subsystems of the proposed display units were designed and the development was started.

In the third and final year of the project, the subsystems will be completed and two prototype display units will be manufactured. These will be tested in a cockpit mock-up at the Thales Avionics site in Bordeaux. The safety assessment will also be completed. The objective is to obtain a final verdict of the concept, taking into account the goals of the project. Pilot-in-the-loop tests with real hardware under simulated flight scenarios should also confirm the findings presented in this paper.

The results obtained so far are very promising. Because of the realistic nature of the study, the findings could be directly used to develop and certify a product based on the Three Large LCD Cockpit concept.

Conclusion

The objectives of the NEWSCREEN project at first sight seem contradictory. Reducing the number of display units in the cockpit and at the same time increasing the levels of safety and dispatchability are seemingly incompatible.

However, innovations in the area of human-machine interface technology make the Three Large LCD Cockpit an appealing prospect. Smart display units and a clever set-up of the human-machine interface allowed matching and even surpassing the original goals of the project.

An aircraft fitted with the Three Large LCD Cockpit may indeed lower costs for the airlines and result in less disruptions of the operation due to unscheduled maintenance. The latter is also a direct advantage for the air traveller. On the other hand, the new cockpit concept may also provide the cockpit crew with a user-friendly working environment with built-in growth potential for emerging functions. A reassuring thought in the ever more crowded and demanding airspace.

4 Collaborative Decision Making, A classification and its impact on Air Traffic Management

Many different stakeholders in current day Air Traffic Management (ATM) exist, each performing their task based on local information thereby satisfying their own business needs. Interests of one stakeholder may be conflicting with that of another causing every stakeholder to perform a local optimisation of their planning processes. Collaborative Decision Making (CDM) aims to improve the way stakeholders work together and defines collaborative planning processes that lead to an overall optimum within ATM.

NLR noted the importance of CDM and started work on the subject several years ago. It participates in various CDM projects and aims to provide a contribution to national and international research and development initiatives.

Introduction

One of the main reasons to start research into CDM is the current isolated execution of operations planning, performed by stakeholders. For example, present day departure planning by Air Traffic Control (ATC) is done virtually without any knowledge of the status of the departing aircraft.

Executing activities with local information only leads to inefficiencies in the overall ATM process. With the growth in air traffic, a growing delay is foreseen, that cannot be accepted any longer. An obvious solution is improved co-operation, where the local optimisation paradigm is shifted to total ATM system benefit.

Sharing of information will improve the planning processes of the stakeholders by making it less tactical. The expected benefits are increased punctuality, less fuel burn, more capacity, and improved efficiency. These benefits are exemplary for CDM solutions in general but do not even describe them all.

Passengers will experience better punctuality and flight time may be reduced. Improved efficiency will be achieved through reduced buffer times in flight planning, reduced costs, and increased flight performances. Because runway queues and holding stacks usage will be reduced, fuel consumption will contribute to lower costs and emissions. Lower costs will benefit economical performance by airlines, and contribute to improved reliability towards passengers and other users.

In the section below, the different stakeholders that play a role in the CDM process will be introduced. To create a classification of all the different types of CDM activities, a layered CDM model will be presented. It will be indicated how these CDM levels can be applied to different ATM planning processes.

Stakeholders

In Figure 1, the stakeholders, each having a different scope of interest, are shown.

– The scope of interest of an Airline Operations Centre (AOC) is to create and achieve an optimum schedule for their fleet of aircraft flying to destinations and for the flight connections that create a network of these destinations via one or more hub-airports. A growing demand within (groups of) airlines to achieve punctuality for the reliability towards

Figure 1 Stakeholders in ATM

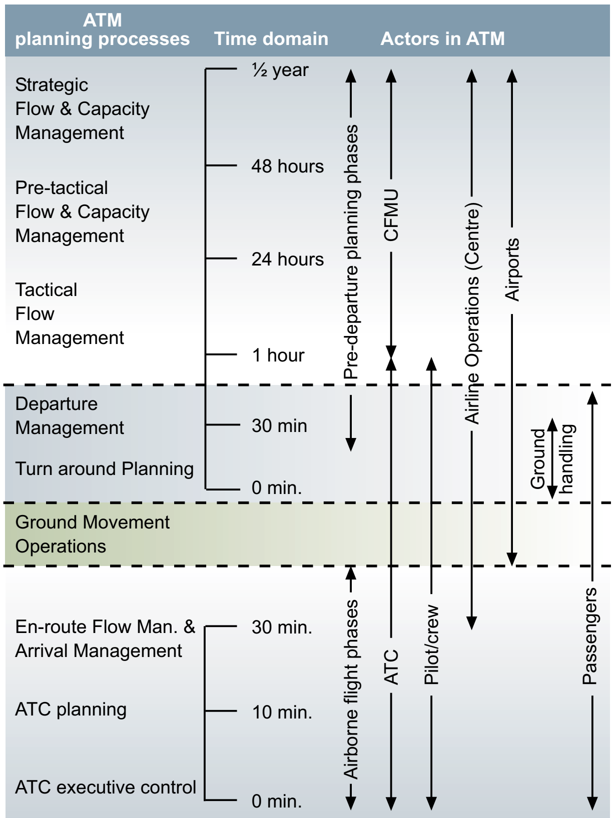


Figure 2 Time frame of the stakeholder processes

customers, and the efficiency to handle transfer-passengers and cargo-load, lead to structural expansion of AOC participation in flight planning activities.

- Since ATC has the main task of guiding traffic safely on a specific airport or some airspace sector, the scope of interest differs significantly from that of AOC. ATC manages an area of airspace or airfield in which they will provide optimal service to aircraft, with the goal of delivering the flight safe and within agreed positional limits to the adjacent sector.

- Pilots fly their aircraft. Their scope of interest is to perform a flight as planned by AOC as efficiently as possible, using services and resources provided by the airport and ATC.
- The airport provides the infrastructure, i.e. the taxiways, runways and gates. Their scope of interest is to optimise these services in terms of efficiency and capacity taking into account environmental nuisance in terms of emissions and noise.
- Ground handling provide services like fuelling, catering, baggage handling, etc. Their goal is to optimise these services and reducing the turn-around times of aircraft at gates.

- Passengers and cargo are the ultimate end users of the ATM system. Their goals are to fly safe, economically and expeditious to their destinations.

- The EUROCONTROL Central Flow Management Unit (CFMU), as the last stakeholder to contribute to flight operations, is founded during the 1990s as an institute regulating traffic flows in Europe. Their global scope of interest is to avoid capacity overloads in airspace sectors within the European airspace. The stakeholders are active at different moments of the flight planning and execution as shown in Figure 2. CFMU and AOC perform Air Traffic Flow Management in an early stage, whereas Airport and ATC enter the process for a specific flight only an hour before operations.

In current day ATM, each stakeholder performs his task based on local information, which leads to execution of his tasks within a limited scope of interest. Interests of one stakeholder may be conflicting with that of another. Information exchange is mostly at the executive level, whereas when strategic information is passed on, it is on an ad hoc basis. Every stakeholder performs local optimisation of the planning process. CDM can benefit by involving other stakeholders in the planning process.

A classification of Collaborative Decision Making

A new concept as CDM, combined with the lack of a fixed definition, surely leads to confusion amongst stakeholders at the operational and technical level. Projects are being designated as CDM for the simplest unsound reasons. On the other hand, stakeholders willing to implement a CDM solution may not know where to start.

Some attempts have been made to make a division in CDM applications, being it all for local (project) purposes. In this section, a classification is proposed that aims to capture the broad nature of CDM, identifies whether a project is considered CDM or not, and gives a level of complexity and operational integration between stakeholders.

First of all, a project is considered a CDM project when it deals with changes to the ATM system in a way that information is shared between stakeholders enabling them to make better decisions compared to the situation where they do not have this information. Key factors that make a project CDM are:

- Sharing of heterogeneous information between different stakeholders.
- Improved decision process concerning planning of traffic (pro-active control).

A layered CDM model is given in Figure 3. It can be applied to individual planning processes within ATM as given in Figure 2. The model shows what options there are to improve the planning process so that it leads to benefits for all stakeholders involved or affected by the process. The options are denoted by 3 levels, where for each level an example is given with respect to the departure planning process. The levels are of increasing complexity in co-ordination, operations and technology.

In the figure, we included a level 0. At this level, information is exchanged, e.g. via datalink, but not (yet) used to enhance the operational process, hence it is not considered a CDM application.

Level 1 is a basic CDM process. In level 1, one stakeholder receives tactical information from another, through which this first stakeholder is capable of making better planning and decisions.

Level 2 CDM is the level where parties involved in the information exchange consider each others objectives. This means that they do not only receive information from another party of a planning process, but also take into account objectives from other stakeholders. All parties involved have the same view on the planning process but one is still ultimately responsible for the planning.

The ultimate CDM concerns the optimisation of the whole air traffic management system, including that of all stakeholders. Plans are made collaboratively in level 3 and each party understands and takes into account other planning processes. It should lead to an overall optimisation of the ATM system

NLR's contribution

NLR contributes to the development of CDM in Europe through participation in several projects in the field. Apart from this, NLR acts as a consultant to several national and international

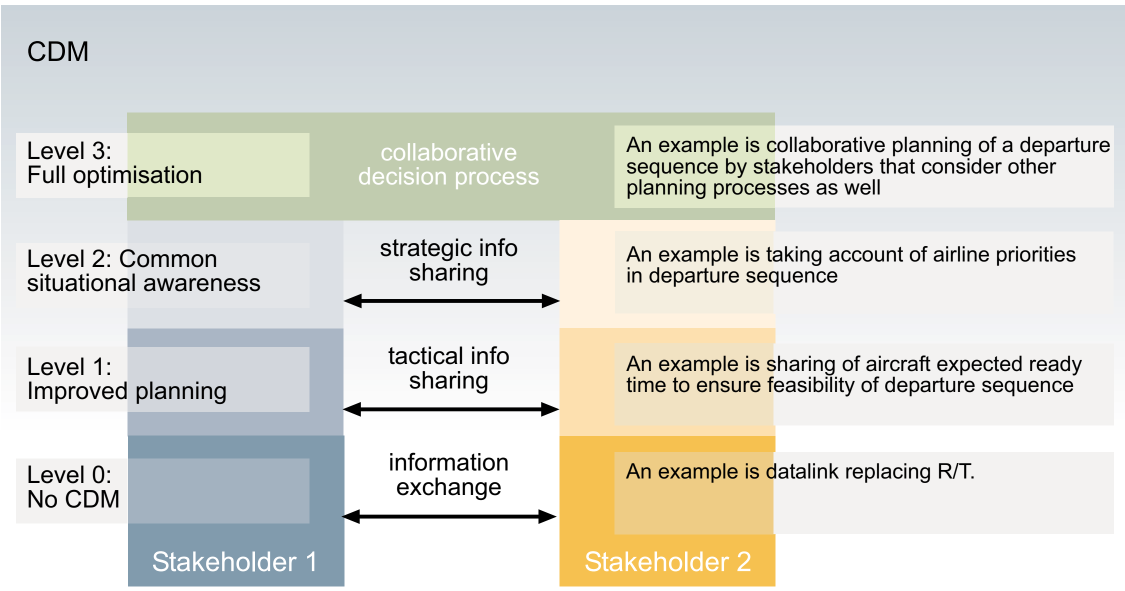


Figure 3 A layered CDM model

bodies in providing expert support. For example, NLR wrote the "Airport CDM Applications Guide" (Ref. 1) under contract with EUROCONTROL, in which a comprehensive overview of CDM is given for every stakeholder that is already working on or considers implementation of CDM. Furthermore, NLR provides support to establish the necessary infrastructure for information sharing, like in the TALIS project (Total Information Sharing Enhanced by Intelligent Systems).

Below, applications of CDM to several planning processes are described. The applications are taken from a variety of recent and ongoing projects executed by NLR. It is noted that all processes can be enhanced by CDM at all levels, but only a few are given that are researched in NLR projects.

Collaborative Decision Making to improve arrival planning

A more comprehensive arrival management concept that adds consideration of wider stakeholder inputs to today's first-come first-served arrival handling is an example of a level 2 CDM application. It has the potential to increase effectiveness of arrival management from both the airline's and ATC's perspectives. It will also reduce the number of departure delays imposed through enabling late passenger connections, improving departure predictability, and helping to smooth airport traffic flows. It is the aim of the Inbound Priority Sequencing Project (IPS).

The IPS project is part of the Dutch "Chain Optimisation" program of the sector partners KLM, Amsterdam Airport Schiphol, and LVNL. This program, which was initiated in January 2003, aims at improving quality of operations at and around Schiphol. Priority sequencing concerns prioritising certain aircraft over others in consultation with all stakeholders involved and is envisioned as a way of moving towards comprehensive and collaborative air traffic arrival management. It can be applied for example to speed up a delayed aircraft that carries a high percentage of transfer passengers.

NLR's contribution to the project includes an initial concept validation via real time simulation. The objective of this simulation experiment is to visualise and evaluate early in the development process conceptual ideas. This allows the work in the later parts of the project to be focussed effectively on concept options that have proven to be operationally feasible.

Collaborative Decision Making to improve flow management

The CFMU regulates traffic in Europe by putting constraints on departure times of flights. The so called slots are currently determined without taking account of stakeholder needs. The flow management process can be improved when more stakeholders influence the critical parameters that are used to calculate the slots.

When the airline has the opportunity to vary flights between available slots, it may choose more optimally for their own operations. The Gate to Gate project describes a process, where AOC-CFMU interaction leads to flexible slot assignment. It can be considered as a level 2 CDM application from the model shown in Figure 3.

The Gate to Gate project also describes the Refined Flow Management concept. CFMU-regulations, through Refined Flow Management, will lead to prioritised planning of flights in compliance with assigned departure slots. In Figure 4 the link between ATC at departure, arrival and CFMU, as flow management stakeholders, can be identified.

The Gate To Gate project, partially funded by the EU, develops a harmonised and integrated ATM concept for Refined Flow Management, pre-flight departure planning, and tactical ATC execution from departure gate to destination gate.

The objectives in this project are:

- To define and describe a new operational concept, consistent with other on-going European Programmes, and with stakeholders' strategic plans, for progressive implementation, from 2010.

– To have the operational concept validated on existing ATM ground simulation platforms by operational organisations and staff.

A related project is the EU project AFAS in a consortium led by Airbus. The AFAS (Aircraft in the Future ATM System) project is focussed on aircraft systems. In the project NLR performed validation activities in its real-time ATC simulation facilities for an advanced on board Flight Management System (FMS).

The objective of AFAS is to evaluate the role and interoperability of this advanced FMS with near-term operational scenarios for short-haul flights in European airspace. Validation focuses on both pre-departure and departure flight phases, where the departure process was prepared and performed until exit of the Terminal Manoeuvring Area (TMA).

Collaborative Decision Making to improve departure planning

Within the Departure management process the roles of the stakeholders AOC, Airport, handlers, and ATC is evolving. In the future, the sequence at the runway will not only be determined by ATC, but gate assignment priorities, airline network priorities, and CFMU flow management requirements will influence the planning process as well.

An example of a level 1 CDM application in departure planning is the provision of the First Off Block Times (FOBT) to ATC. The FOBT is the expected ready time of an aircraft. An aircraft is ready for departure when all ground handlers have serviced the aircraft, crew is present, passengers have boarded, and aircraft doors are closed. The pilot or AOC issues the FOBT based on information from ground handlers and airline staff. Availability of the FOBT to ATC ensures feasibility of the departure sequence.

The AFAS project validated the provision of FOBT via datalink. The concept describes how in the pre-departure phase flights communicate with ATC a 4 dimensional trajectory by making use of the AFAS-defined Pre-flight Trajectory Coordination (PTC) datalink service. The FOBT was included in the PTC service. Experiments have been executed for arrival and departure traffic at Frankfurt Rhein-Main Airport, with assistance of their personnel.

The Triple-I project (Intelligence Instead of Infrastructure) investigated potential benefits of FOBT provision at Schiphol Airport. Triple-I is a project subsidised by the department of Economic Affairs that is carried out in co-operation with industrial partners. Three controllers participated in a real time simulation experiment where a departure sequencing tool

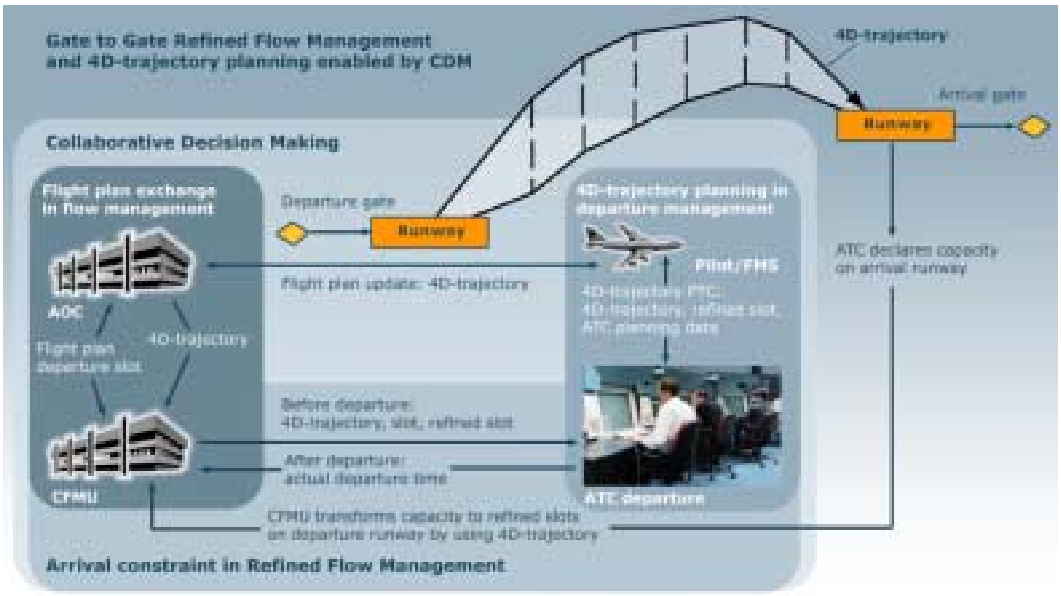


Figure 4 Layered 4D-planning in Gate To Gate

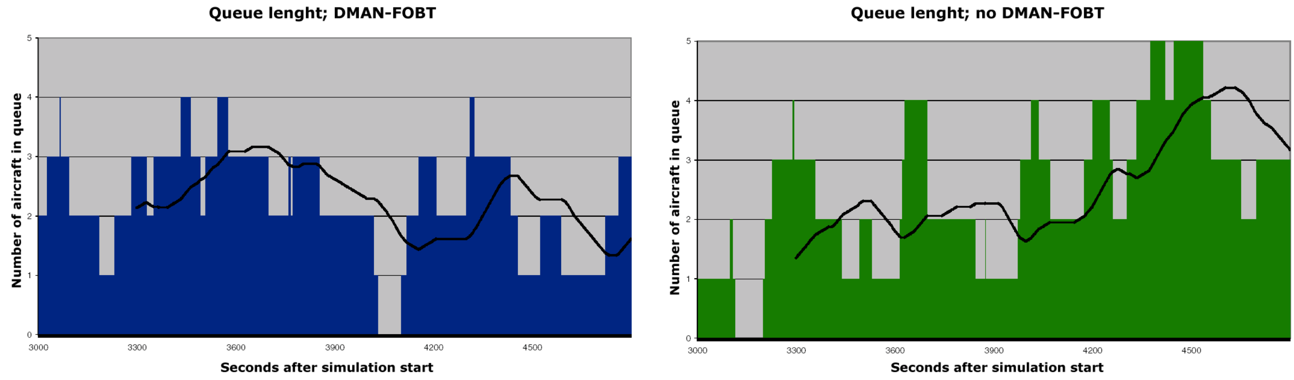


Figure 5 Number of simultaneously taxiing aircraft (left with FOBT; right without FOBT)

assisted them in planning departure traffic. Pilots were assisted with tools to determine an FOBT. The results showed an increase in traffic throughput at the runways and a decrease in queues at the runway holding position. Also, due to FOBT availability, the traffic flow was smoother and fewer aircraft were taxiing simultaneously (see Figure 5).

In a concept where stakeholders are assisted with planning support tools, AOC will be able to modify the sequence of one airline's flights, while ATC will ensure the interests of other airlines. The airport will contribute by ensuring gate availability, while flow management is ensured by CFMU inputs. Data from many different stakeholders are used and priorities of other'sare taken into account, make this a level 2 CDM application.

From these projects, it can be concluded that the departure management process is evolving towards a level 3, where it no longer is exclusively ATC who will determine the sequence, but Airport, ATC, and AOC interactively and collaboratively decide how the departure sequence will be build.

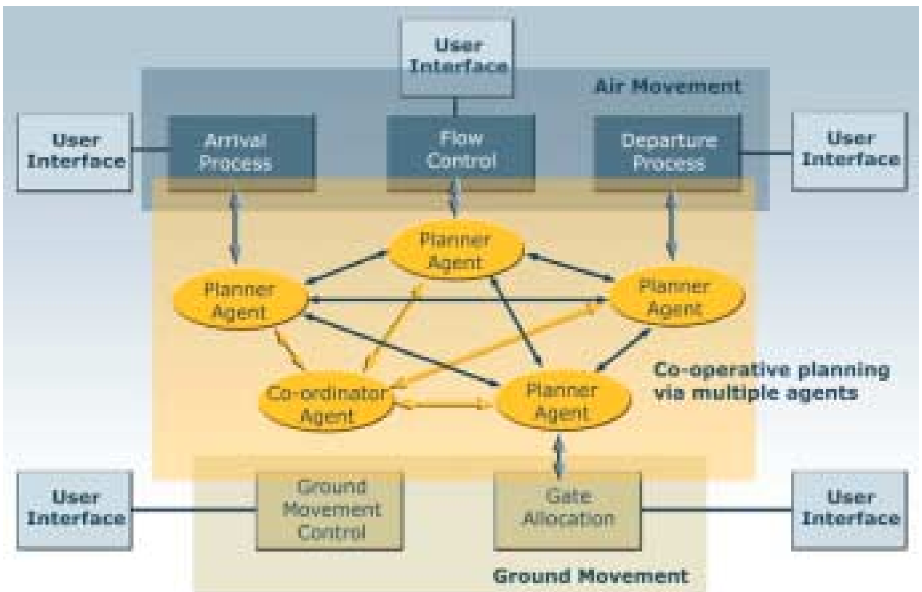


Figure 6 CDM intelligent agent architecture

Collaborative Decision Making to improve airport planning

The airport is a complex environment where several stakeholders are active. The handlers, airport authorities, ATC, and airlines are all dependent on each other's performance and many CDM options exist to improve the operation.

In the EU project LEONARDO (Linking Existing ON-ground Arrival and Departure Operations) project, a novel technology is combined with finding new scenarios for managing airport traffic in a collaborative sense. All stakeholders negotiate with each other about their plans. A software architecture based on intelligent agent technology was designed to support the negotiation (see Figure 6). Although the concept and implementation did not fully cover all stakeholders at the airport, LEONARDO can be considered as a level 3 CDM application.
Intelligent agents are autonomous software parts that are able to communicate and negotiate with each other. For every stakeholder, one intelligent agent was designed to support his task and tested in the NLR facilities for air traffic control simulation.

LEONARDO is a project patially funded by the European Commission with participants mainly from Spain, France, and The Netherlands. NLR performed a benchmark study that aids the other partners in the project to carry out their CDM implementations at Madrid Barajas and Paris Charles de Gaulle airports. The benchmark study was executed on the NLR Tower Research Simulator simulating Schiphol Airport.

The simulations performed at NLR show new possibilities for co-operation between stakeholders, where each stakeholder is assisted by an intelligent software agent. Planning conflicts, e.g. a gate for an arriving aircraft still being occupied, could be solved through co-operation between the arrival planner, departure planner, and gate planner. The agents detected the conflicts and suggested resolutions to the humans, who eventually decided on a course of action.

Perspective

Collaborative decision making has caught a lot of attention in the air traffic management world and is regarded one of the key factors in increased efficiency of operations at airports and in the air. Until recently, implementation of CDM was considered as far ahead and difficult to achieve. Today technological developments and a positive collaborative attitude from the stakeholders, enable the implementation of many different applications.

We expect collaborative decision making to be not just a fashion word, but a new development of stakeholders willing to co-operate and willing to share information, once they realise the positive impact this has on total efficiency of the air transport system. Stakeholders are realising this need for CDM at which NLR may assists them in evaluating concepts and tools and in demonstrating new possibilities. The model proposed in this text gives parties the possibility to grasp the concept and start thinking of CDM in pieces that can be handled. The model gives stakeholders that already collaborate in CDM projects and implementations a direction to explore one level in depth or to move to the next level.

NLR is at the forefront of CDM developments. In an early stage, NLR participated in European programs that set the course for CDM. Since then, NLR has been involved in many projects that created new concepts and new technological solutions for improving efficiency of air transport operations. The role of NLR is to be a leading organisation at all levels of CDM in order to support stakeholders. In the NLR research simulators, NLR demonstrated a glimpse of future technology with the implementation of the highest levels of CDM while it also demonstrated potential short term benefits.

Appendices

Appendices

1 Publications

In 2003, NLR produced a total of 701 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

NLR-TP-2002-289
Material-based failure analysis of a helicopter rotor hub – Revised edition
Published in the Journal Practical Failure Analysis
Wanhill, R.J.H.

NLR-TP-2002-443
Combining interacting multiple model and joint probabilistic data association for tracking multiple maneuvring targets in clutter
Presented at the FAA/Eurocontrol ATM 2001 seminar, at Santa Fe, New Mexico, USA, 3–7 December 2001
Blom, H.A.P.; Bloem, E.A.

NLR-TP-2002-444
Conflict probability and incrossing probability in Air Traffic Management
Presented at the 41st IEEE Conference on Decision and Control, Las Vegas, USA, 10–13 December 2002
Blom, H.A.P.; Bakker, G.J.

NLR-TP-2002-445
Interacting multiple model joint Probabilistic data association avoiding track coalescence
Presented at the 41st IEEE Conference on Decision and Control, Las Vegas, USA, 10–13 December 2002
Blom, H.A.P.; Bloem, E.A.

NLR-TP-2002-521
Milestone case histories in aircraft structural integrity
Published as Chapter in Volume 1: Structural Integrity Assessment – Examples and Case Studies, of the Elsevier Science treatsite “Comprehensive Structural Integrity”
Wanhill, R.J.H.

NLR-TP-2002-540
Simulators in support of the ERA operational phase
Presented at the 7th International Workshop on Simulation for European Space Programmes - SESP ‘2002, at ESTEC, Noordwijk, The Netherlands on 12–14 November 2002
Pronk, Z.; Wokke, F.J.P.; Knobbout, H.A.; Vidal, R.

NLR-TP-2002-575
NLR contribution to the PLANET newsletter
Published as an article in the PLANET newsletter published by the European Network of Excellence on AI Planning
Seljée, R.R.; Hesselink, H.H.

NLR-TP-2002-595
OPAL - Optimisation platform for airports including landside
Published in the International Airport Review (Volume 6, Issue 3, pages 59, 61 and 62), September 2002
Eenige, M.J.A. van

NLR-TP-2002-597
Deformation modelling of the single crystal superalloy CM186 LC
Presented at the COST Conference “Materials for Advanced Power Engineering 2002”, Liège, Belgium, 1 October 2002
Daniel, R.; Tinga, T.; Henderson, M.B.; Ward, T.J.

NLR-TP-2002-613
Enhancements to EuroSim
Presented at SESP 2002: 7th International Workshop on Simulation for European Space Programmes at ESTEC, Noordwijk, The Netherlands, 12–14 November 2002.
Vries, R.H. de; Keijzer, J.; Lieshout, F. van; Dam, A.A. ten; Moelands, J.M.

NLR-TP-2002-628
MOSAIC: Automated model transfer in simulator development
Presented at SESP 2002, ESTEC, Noordwijk, The Netherlands, 12–14 November 2002
Lammen, W.F.; Nelisse, A.H.W.; Dam, A.A. ten

NLR-TP-2002-646

Transfer between training of part-tasks in complex skill training – Model development and supporting data

Published in the proceedings of the Human Factors and Ergonomics Society - Europe Chapter, annual meeting 2002, Dortmund Germany.

Roessingh, J.J.M.; Kappers, A.M.L.; Koenderink, J.J.

NLR-TP-2002-650

Mission preparation support of the Europena Robotic Arm (ERA)

Presented at the ASTRA 2002 Conference, ESTEC, Noordwijk, The Netherlands, 19–21 November 2002

Doctor, F.; Glas, A.; Pronk, Z.

NLR-TP-2002-689

Accident risk assessment for airborne separation assurance

Presented at the Advanced Workshop on Air Traffic Management (ATM 2002), Capri, Italy, 22–26 September 2002.

Everdij, M.H.C.; Blom, H.A.P.; Bakker, G.J.

NLR-TP-2002-693

Skill-transfer of PC-based simulation to real flight – A comparison of in-flight measured data and instructor ratings

Presented at the 12th International Symposium on Aviation Psychology, Daytona, Ohio, USA, 14–17 April 2003

Roessingh, J.J.M.

NLR-TP-2003-001

AMS-2 tracker thermal control system: design and thermal modelling of the mechnanically pumped two-phase CO_2 loop

Presented at the 41st AIAA Aerospace Sciences Meeting & Exhibit, 6-9 January 2003, Reno, NV, USA (AIAA-2003-0345). A short version, published in the AIP Proceedings of the Space Technology & Applications International Forum, STAIF-2003, was presented at the Thermophysics in Micro-Gravity Conference, 2–5 February 2003, Albuquerque, NM, USA.

Delil, A.A.M.; Pauw, A.; Woering, A.A.; Verlaat, B.

NLR-TP-2003-037

Tutorial on quantification of differences between single- and two-component two-phase flow and heat transfer

Presented at the Fundamentals of Two-Phase Flow and Heat Transfer Session of the Conference on Thermophysics in Microgravity, held during the Space Technology & Applications International Forum in Albuquerque, USA, 2–5 February 2002.

Delil, A.A.M.

NLR-TP-2003-054

Design and testing of a composite bird strike resistant leading edge

Presented at the SAMPE Europe Conference & Exhibition, Paris, France, 1–3 April 2003

Ubels, L.C.; Johnson, A.F.; Gallard, J.P.; Sunaric, M.

NLR-TP-2003-091

Modelling a spiraling type of non-locally reacting liner

AIAA paper 2003-3196

Presented at the 9th AIAA/CEAS Aeroacoustics Conference as AIAA Paper 2003-3196, Hilton Head, South Carolina, USA, 12–14 May 2003

Sijtsma, P.; Wal, H.M van der

NLR-TP-2003-100

Towards affordable CFD simulations of rotors in forward flight – A feasibility study with future application to vibrational analysis

Presented at the 59th American Helicopter Society Forum, Phoenix, Arizona, USA, 6–8 May 2003

Ven, H. van der; Boelens, O.J.

NLR-TP-2003-104

Influence of wire electrical discharge machining on the fatigue properties of high strength stainless steel

Presented at Thermec 2003, Madrid, Spain, 7–11 July 2003

Velterop, L.

NLR-TP-2003-123

Corrections for mirror sources in phased array processing techniques

AIAA paper 2003-3308
Presented at the 9th AIAA/CEAS Aeroacoustics Conference as AIAA Paper 2003-3196, Hilton Head, South Carolina, USA,
12–14 May 2003
Sijtsma, P.; Holthusen, H.

NLR-TP-2003-124

Wake modelling accuracy requirements for prediction of rotor wake-stator interaction noise

AIAA paper 2003-3138
Presented as AIAA Paper 2003-3138 at the 9th AIAA/CEAS Aeroacoustics Conference, Hilton Head, South Carolina, USA, 12–14 May 2003
Sijtsma, P.; Schulten, J.B.H.M.

NLR-TP-2003-193

A computational design engine for multi-disciplinary optimisation with application to a blended wing body configuration

Presented at AIAA/ISSMO 2003, Atlanta, USA, 4–6 September 2002
Laban, M.; Arendsen, P.;
Rouwhorst, W.F.J.A.; Vankan, W.J.

NLR-TP-2003-202

A new facility for hot stream acoustic liner testing

Presented at the Tenth International Congress on Sound and Vibration, Stockholm, Sweden, 7–10 July 2003
Rademaker, E.R.; Idzenga, S.T.;
Huisman, H.N.; Nijboer, R.J.; Sarin, S.L.

NLR-TP-2003-210

Phosphoric sulphuric acid anodising: an alternative for chromic acid anodising in aerospace applications?

Presented at Aluminium Surface Science and Technology, in Bonn, Germany, on
18–22 May 2003
Velterop, L.

NLR-TP-2003-220

Sound diffraction by the splitter in a turbofan rotor-stator gap swirling flow

Presented at the Tenth International Congress on Sound and Vibration, Stockholm, Sweden, 7–10 July 2003
Nijboer, R.J.

NLR-TP-2003-228

Real-time cloud sensing for efficiency improvement of optical high-resolution satellite remote sensing

Presented at IGARSS 2003, Toulouse, France, 21–25 July 2003.
Algra, T.

NLR-TP-2003-231

Development of different novel loop heat pipes within the ISTC- 1360 project

Presented as paper SAE-2003-01-2383 in the Tow-Phase Technology Session at the 33rd International Conference on Environmental Systems, Vancouver, Canada, 7–10 July 2003
Delil, A.A.M.; Maydanik, Yu.F.; Gerhart, C.

NLR-TP-2003-243

S-Wake assessment of wake vortex safety – Publishable summary report

Bruin, A.C. de

NLR-TP-2003-248

S-WAKE final report for work package 4 probabilistic safety assessment

Speijker, L.J.P.

NLR-TP-2003-251

Review of aeronautical fatigue investigations in the Netherlands during the period March 2001 – March 2003

Presented at the 28th ICAF Conference in Lucerne, Switzerland, 5–9 May 2003
Ottens, H.H.; Wanhill, R.J.H.

NLR-TP-2003-262

Embedded Training – An explorative study providing requirements for the display of virtual targets on a helmet mounted display in simulated air-to-air engagements within visual range

Roessingh, J.J.M.; Sijll, M.C. van;
Johnson, S.P.

NLR-TP-2003-266

Transforming air transport into a concurrent enterprise – Technical, safety and security perspectives

Presented at ICE 2003, Espoo, Finland, 16–18 June 2003

Kesseler, E.

NLR-TP-2003-274

Application of the LCL method to measure the unbalance of PLC-equipment connected to the low-voltage distribution network

Presented at the International Electrotechnical Commission (IEC), International Special Committee On Radio Interference (C.I.S.P.R.), Subcommittee I (Interference Relating To Multimedia Equipment), Working Group 3 (Emission From Information Technology Equipment), held in Red Bank, New Jersey USA on March 4, 2003.

Verpoorte, J.

NLR-TP-2003-300

Air transport, from privilege to commodity – A COTS enabled paradigm shift

Presented at the World Congress Aviation in the XXIst Century, Kyiv, Ukraine, 14–16 September 2003

Kesseler, E.

NLR-TP-2003-317

Crashworthiness research at NLR (1990-2003)

Presented at the 4th International Krash Users Seminar, IKUS4, Amsterdam, 2–4 June 2003

Wiggenraad, J.F.M.

NLR-TP-2003-339

The acquisition of complex skills and the linear rate model

Presented at The colloquium of the Stochastics and Optimization Group, Department of Mathematics, Utrecht University, 15 January 2003

Roessingh, J.J.M.; Koenderink, J.J.; Kappers, A.M.L.

NLR-TP-2003-342

Space-time discontinuous Galerkin finite element method with dynamic grid motion for inviscid compressible flow – A VKI course

Presented at the 33rd Computational Fluid Dynamics Course “Novel methods for solving convection dominated systems”, as lecture notes of an invited lecture series, Von Karman Institute, Brussels, 24–28 March, 2003.

Vegt, J.J.W. van der; Ven, H. van der

NLR-TP-2003-357

Paint stripping techniques for composite aircraft components

Presented at the RTO/AVT Specialists Meeting on “Advanced Paint Removal Technology”, 6–10 October 2003, Warsaw, Poland.

Hart, W.G.J.’t

NLR-TP-2003-369

Approximation models for multi-disciplinary system design – Application in a design study of power optimised aircraft

Presented at the Eurogen 2003 Conference, CIMNE, Barcelona, Spain, 15–17 September 2003

Vankan, W.J.; Kos, J.; Lammen, W.F.

NLR-TP-2003-371

Enhancing diagnostics through the visualization of air vehicle data

Presented at AUTOTESTCON 2003, Anaheim (CA), U.S.A., 22–25 September, 2003.

Vollebregt, A.M.; Ost, R.C.; Donker, J.C.

NLR-TP-2003-378

Consistent safety objectives and COTS versus fragmented certification practices and good safety records – Air transport dilemma in need of innovation

Presented at the 3rd IEEE Conference on Standardization and Innovation in Information Technology SIIT 2003, Delft, the Netherlands, 22–24 October 2003.

Kesseler, E.

NLR-TP-2003-396

Simulation of vortical flow over a slender delta wing experiencing vortex breakdown

Presented at the 21st Applied Aerodynamics Conference, Orlando (FL), U.S.A., 23–26 June 2003

Soemarwoto, B.I.; Boelens, O.J.

NLR-TP-2003-397

Towards the simulation of unsteady manoeuvre dominated by vortical flow – Common Exercise I of WEAG THALES JP12.15

Presented at the 21st Applied Aerodynamics Conference, Orlando (FL), U.S.A., 23–26 June 2003

Soemarwoto, B.I.; Boelens, O.J.; e.a.

NLR-TP-2003-475

Optimisation of airport taxi planning

Published in the European Journal of Operations Research.

Smeltink, J.W.; Soomer, M.J.; Waal, P.R. de; Mei, R.D. van der

2 Abbreviations

ACARE	Advisory Council for Aeronautical Research in Europe
AECMA	Association Européenne des Constructeurs de Matériel Aérospatial
AFB	Air Force Base
AOC	Airline Operations Centre
ARBS	Aerial Refueling Boom System
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATM	Air Traffic Management
BMBF	Bundesministerium für Bildung und Forschung
BMVg	Bundesministerium der Verteidigung
BMWI	Bundesministerium für Witschaft und Technologie
CDM	Collaborative Decision Making
CFD	Computational Fluid Dynamics
CFMU	Central Flow Management Unit
CIRA	Centro Italiano Ricerche Aerospaziali
CODEMA	Commissie voor de Ontwikkeling van DEfensie MAterieel
COTS	Commercial Off-The-Shelf
DGA	Délégation Générale pour l'Armament
DGAC	Direction Générale de l'Aviation Civile
DGL	Directoraat Generaal Luchtvaart (Directorate General of Civil Aviation of the Netherlands)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)
DNW	Duits-Nederlandse Windtunnels (German-Dutch Wind Tunnels)
DSTL	Defence Science and Technology Laboratory (UK)
DTI	Department of Trade and Industry
EADS	European Aeronautic Defence and Space Company
EMI	Electro-Magnetic Interference
EREA	Association of European Research Establishments in Aeronautics
ESA	European Space Agency
ESTEC	European Space and Technology Centre
ETW	European Transonic Windtunnel
EU	European Union
EUCLID	European Co-operation for the Long term In Defence
EUROCONTROL	European Organisation for the Safety of Air Navigation
EZ	Ministerie van Economische Zaken (Ministry of Economic Affairs)
FAA	Federal Aviation Administration (USA)
FANOMOS	Flight track and Aircraft NOise MOnitoring System
FEL	Fysisch Elektronisch laboratorium (TNO) (Physics-Electronics Laboratory)
FOI	Swedish Defence Research Agency
GARTEUR	Group for Aeronautical Research and Technology in Europe
GPS	Global Positioning System
GRACE	Generic Aircraft Cockpit Environment

HST	Hoge-Snelheids Tunnel (High Speed Wind Tunnel)
ICAO	International Civil Aviation Organization
IVW-DL	Aviation Division of the Transport and Water Management Inspectorate (Ministry of Transport, Public Works and Water Management)
JAA	Joint Aviation Authorities
JAR	Joint Airworthiness Requirements
JSF	Joint Strike Fighter
KLM	Koninklijke Luchtvaart Maatschappij N.V. (KLM Royal Dutch Airlines)
KNMI	Koninklijk Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
LCD	Liquid Cristal Display
LLF	Large Low-speed Facility
LST	Lage-Snelheids Tunnel (Low Speed Wind Tunnel)
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control The Netherlands)
NATO	North Atlantic Treaty Organization
NHI	Nato Helicopter Industries
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programmes)
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory NLR)
NSF	Nationale Simulatie Faciliteit (National Simulation Facility)
ONERA	Office National d'Etudes et de Recherches Aérospatiales (Aerospace Research Institute of France)
PSP	Pressure Sensitive Paint
RNLAF	Koninklijke luchtmacht (Royal Netherlands Air Force)
RNLN	Koninklijke marine (Royal Netherlands Navy)
RTCA	Requirements and Technical Concepts for Aeronautics
RTO	Research and Technology Organisation
SID	Standard Instrument Departure
SST	Supersone Snelheids Tunnel (Supersonic Wind Tunnel)
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
TUD	Delft University of Technology
UAV	Unmanned Aerial Vehicle
V&W	Ministerie van Verkeer en Waterstaat (Ministry of Transport, Public Works and Water Management)
WEAO	Western European Armament Organization


NLR Amsterdam


NLR Noordoostpolder

photography: KLM Aerocarto

NLR Amsterdam

Anthony Fokkerweg 2
1059 CM Amsterdam
P.O. Box 90502
1006 BM Amsterdam
The Netherlands
Telephone: +31 20 5113113
Fax: +31 20 5113210

NLR Noordoostpolder

Voorsterweg 31
8316 PR Marknesse
P.O. Box 153
8300 AD Emmeloord
The Netherlands
Telephone: +31 527 248444
Fax: +31 527 248210

E-mail: info@nlr.nl
Web site: www.nlr.nl