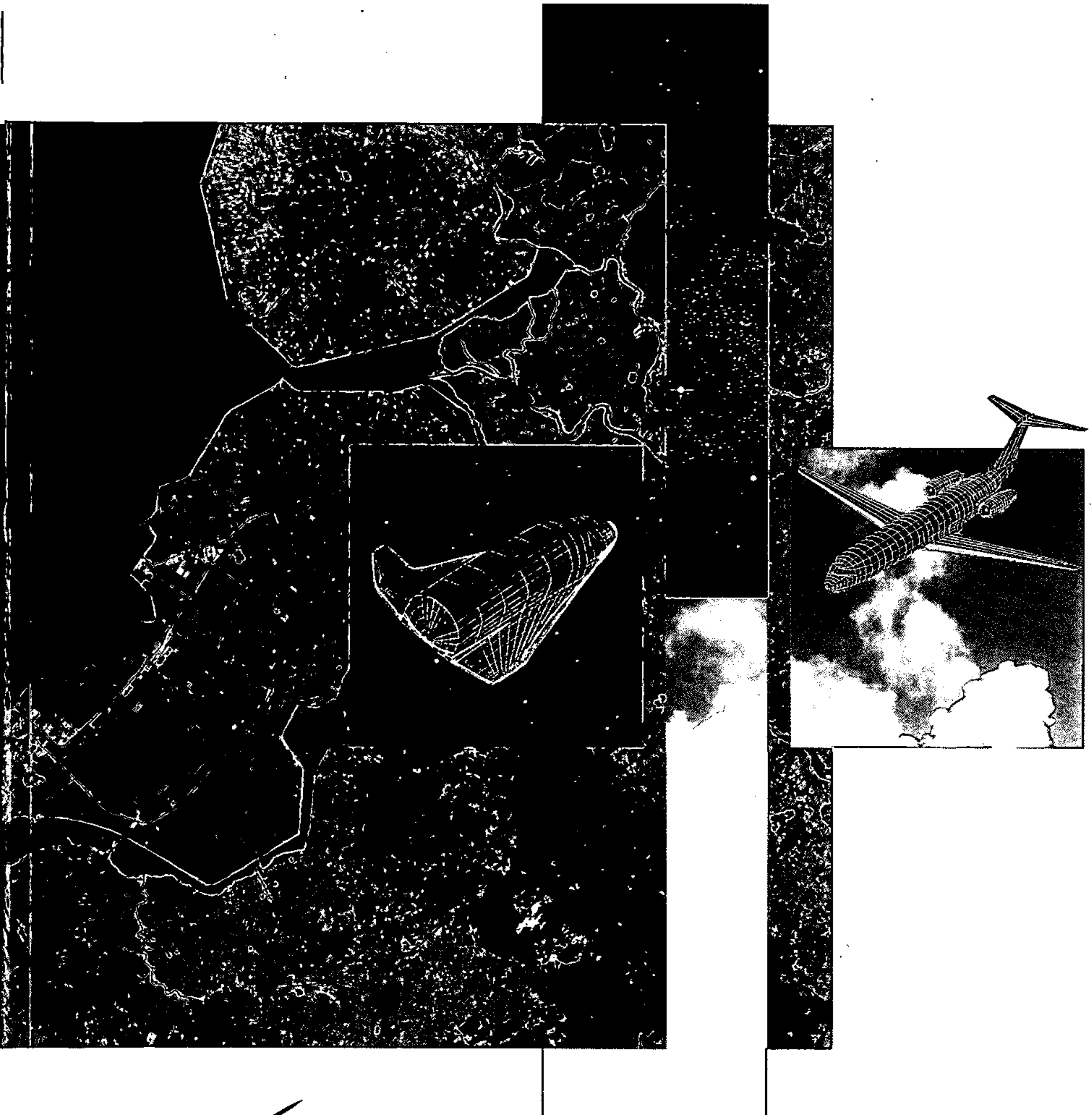
Annual Report 1992

NLR Annual Report 1992



National Aerospace Laboratory NLR

National Aerospace Laboratory NLR

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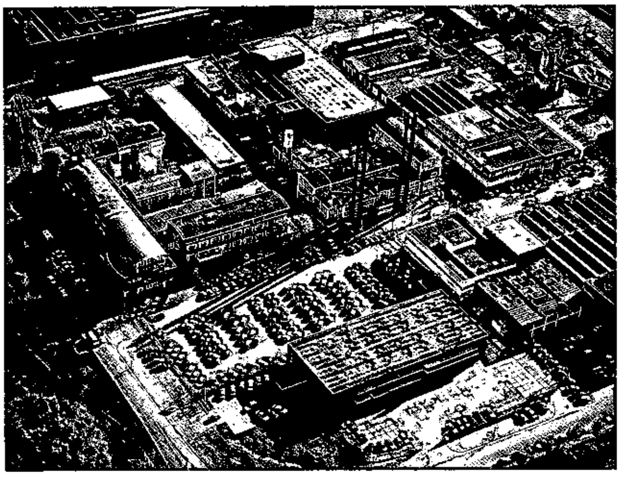
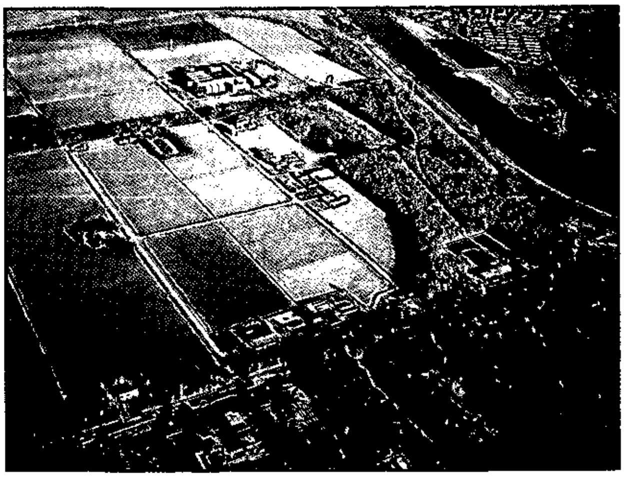


NLR Amsterdam
(Photography: KLM Luchtfotografie)



NLR Noordoostpolder
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Ir. C. Wit	Minister of Transport and Public Works, for the Post Office
Gen.maj. drs. D. Altena	Minister of Defence, for the Royal Netherlands Air Force (RNLAF)
KTZ ir. K. Bakker	Minister of Defence, for the Royal Netherlands Navy (RNLN)
Ir. J.J. Kooijman	Minister of Economic Affairs
Dr. P.A.J. Tindemans	Minister of Education and Science
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Ir. C.M.N. Belderbos	Netherlands Organization for Applied Scientific Research (TNO)
Drs. G.M.V. van Aardenne	Netherlands Agency for Aerospace Programs (NIVR)
E.J. Gerritsen, Gen.maj. RNLAF, ret.	National Aerospace Medical Centre (NLRGC)
Jhr.mr. J.W.E. Storm van 's Gravesande	Board of the Foundation NLR

Drs. A. de Graaff
Secretary

The Board of Directors of NLR *

Dr.ir. B.M. Spee	*General Director*
Prof.ir. F.J. Abbink	*Deputy Director*
J.A. Verberne R.A.	*Controller*

* On 31 December 1992

Table of Contents

1	**Introduction**		7
2	**General Survey**		9
	2.1	Mission and Means	9
	2.2	Activities in 1992	9
	2.3	Organization and Personnel	13
3	**Activities**		17
	3.1	Fluid Dynamics	17
	3.2	Flight	28
	3.3	Structures and Materials	40
	3.4	Space	46
	3.5	Informatics	52
4	**Capita Selecta**		62
	4.1	Research on High-Lift Devices	62
	4.2	Aircraft Load Monitoring	66
	4.3	Air Traffic Management	70
5	**Internal and External Relations**		73
6	**Scientific Committee NLR/NIVR**		75
7	**International Co-operation**		77
	7.1	AGARD	77
	7.2	The German-Dutch Wind Tunnel	79
	7.3	The European Transonic Wind Tunnel	82
	7.4	GARTEUR	82
	7.5	Co-operation with Indonesia	84
	Appendices		
	1	Publications	87
	2	Abbreviations	93

1 Introduction

In 1992 the turnover of the National Aerospace Laboratory NLR was larger than ever, and the test facilities were well occupied. To satisfy the demand for contract work, new staff was appointed. Although a record capacity was needed to meet customer demand, a great deal of work was also carried out under NLR's programme for basic research and for the development of research facilities.

Prospects for the near future are uncertain. Profits of airlines have been decreasing, and the airline industry has accumulated heavy losses. Investments in new aircraft have therefore been cancelled or delayed, and the aircraft industries are only cautiously pursuing development programmes for civil aircraft, reducing their requirements for services from research institutes such as NLR. In the near future, however, airlines will require new, efficient aircraft with a low impact on the environment to replace ageing aircraft and to meet growing demand. Therefore, new aircraft will have to be developed, and prospects for services required from NLR will improve accordingly. By executing its own basic research programme as well as through research and technology programmes sponsored by the Netherlands Agency for Aerospace programmes (NIVR), NLR will continue to maintain and enhance its technology base.

NLR's customers in the area of aircraft operations, mainly consisting of the Royal Netherlands Air Force, the Royal Netherlands Navy and allied forces, although confronted with budget constraints, will continue requiring NLR's assistance.

NLR's research activities in the areas of navigation, air traffic management and the like have been extended in the past few years. For new air traffic management systems to operate safely and efficiently, a great deal of research has to be done, and NLR remains ready to do its share.

The growing co-operation between European aircraft industries will stimulate further co-operation between the European aeronautical research establishments. In this process, the Commission of the European Communities may play an important role, since a strong European aircraft industry is of great importance to Europe.

The Board is confident that the expert knowledge of NLR, the quality of its research facilities and the experience of its organization in carrying out contract research for a variety of customers will enable it to continue playing an important role in aerospace research in Europe and in the world.

J. van Houwelingen, *Chairman*

Mrs. J.R.H. May-Weggen, minister of Transport and Public Works, paid a visit to NLR and DNW. In the front row: Mrs. J.R.H. May-Weggen, Mr. J. van Houwelingen (Chairman of NLR) and Ir. H.N. Wolleswinkel (member of the NLR Board)

2 General Survey

2.1 Mission and Means

The National Aerospace Laboratory NLR is the central institute for aerospace research in the Netherlands. NLR gives scientific support and technical assistance to aerospace industries and organizations, civil and military aircraft operators and government agencies all over the world. NLR is a non-profit organization, and conducts a programme of basic research sponsored by the Dutch Government.
Quality systems according to ISO 9000 are the basis for guaranteed quality, and a tight project control system has been established, for timely delivery of services, within costs.

With sites in Amsterdam and in the Noordoostpolder, NLR operates several wind tunnels, laboratory aircraft and research flight simulators. NLR also has equipment for research in the areas of Air Traffic Control, structures and materials, space technology and remote sensing. NLR's extensive computer network includes a supercomputer, tools for software development and advanced software for computational fluid dynamics and for calculations of aircraft and spacecraft structures.

NLR operates, on an equal base together with DLR, the German-Dutch Wind Tunnel (DNW), located in the Noordoostpolder. Together with DLR, the Ministry of Defence of the UK and the Office National d'Etudes et de Recherches Aérospatiales (ONERA) of France, NLR takes part (6% share) in the construction costs of the European Transonic Wind Tunnel (ETW) in Cologne. NLR holds 7% of the shares of the company ETW GmbH.

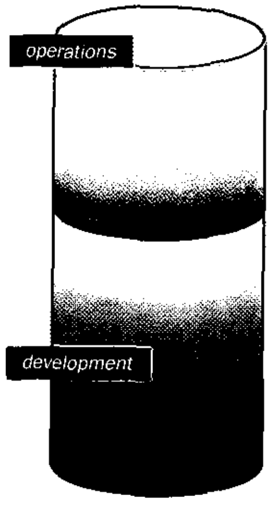
2.2 Activities in 1992

In 1992 NLR's turnover was 141 million guilders compared to 123 million in 1991. The income from contracts was 102 million guilders compared to 85 million in 1991.
In 1992 about 60% of the total of NLR's activities were related to the development, and 40% to the operation of aircraft and spacecraft; 90% of NLR's activities were related to aeronautics and 10% to space. Civil and military research amounted to 70% and 30%, respectively.

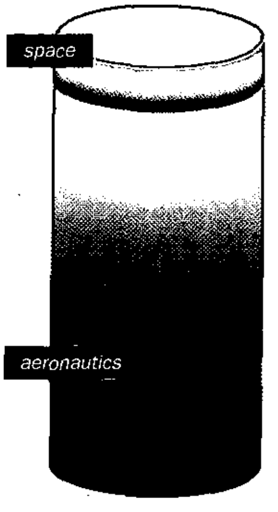
The total costs of NLR, amounting to 141 million guilders, included personnel costs of 87 million and direct costs for customers of 18 million.

Services Provided to Dutch Customers

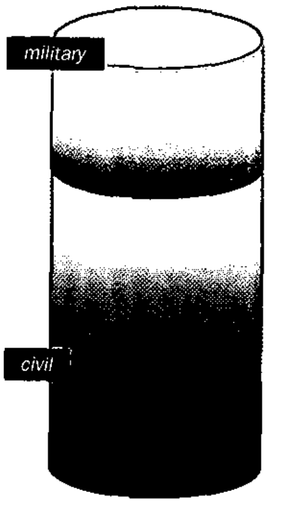
Contracts from Dutch customers amounted to 75 million guilders. These contracts included work for the Netherlands Agency for Aerospace Programs (NIVR), under its programmes for aeronautics and space research and technology and for the development of Fokker aircraft. A great deal of work was done under contract to the Royal Netherlands Air Force, the Royal Netherlands Navy, the Netherlands Department of Civil Aviation (RLD, until 1 January 1993 incorporating Air Traffic Control), Fokker Aircraft and Fokker Space & Systems. NLR also carried out work to support the Ministry of Defence, the German-Dutch Wind Tunnel (DNW), the European Transonic Wind Tunnel (ETW) and several government services and private companies.



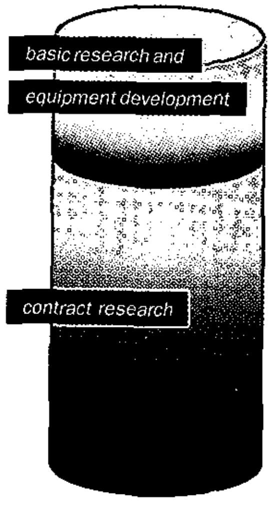
Division of the work into development and operations support



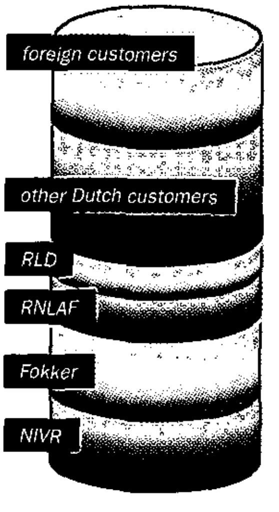
Division of the work into aeronautics and spaceflight support



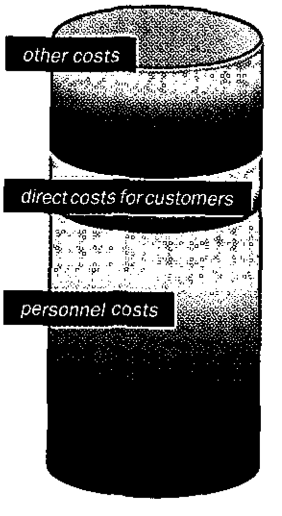
Division of the work into civil and military support



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

Contracts from Fokker concerned the development of the Fokker 70, the further development of the Fokker 50 and Fokker 100, the development of the NH90 helicopter and the development of the Italian-Dutch X-ray satellite SAX. A major part of the work for the RLD was related to studies on airworthiness and regulations, on present and future Air Traffic Control systems and on safety and environmental aspects of aeronautics. Research on these topics was also supported financially by KLM Royal Dutch Airlines and Amsterdam Schiphol Airport.

Services Provided to Foreign Customers

Work carried out under contract to foreign customers amounted to 27 million guilders. Major customers were the European Space Agency (ESA), the Commission of the European Communities (CEC), Eurocontrol, the Indonesian aircraft manufacturer IPTN and General Dynamics (now Lockheed Fort Worth). The contracts for General Dynamics included work for the development of the F-16 Mid Life Update and for the F-16 mission planning system MSS/C.

Research and Equipment

NLR spent 19 million guilders on its basic research programme sponsored by the Government, aimed at preserving NLR's capability to support its customers in the future. Research aimed at the development and modernization of research facilities amounted to 20 million guilders, which for the greater part was spent on the design of the modernization of NLR's transonic wind tunnel HST and on the extension of NLR's research flight simulation facilities with a versatile National Simulation Facility (NSF). A total of 18 million guilders was spent on investments for the modernization of the HST, the development of the NSF, the procurement together with the Delft University of Technology (DUT) of a new research aircraft and further extensions of NLR's computer network, among other things. In addition, NLR acted on behalf of the Government concerning the construction of the European Transonic Wind Tunnel (ETW).

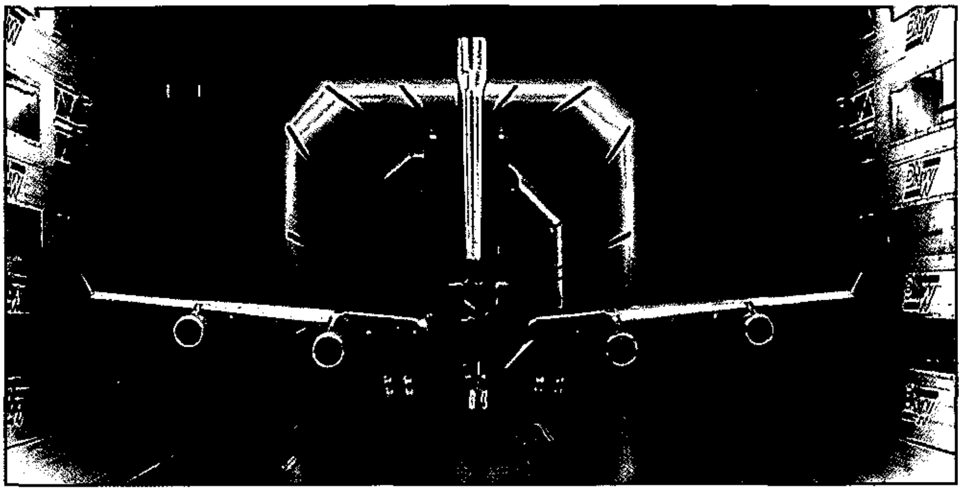
National and International Co-operation

In several projects, NLR co-operates with research institutes and universities in the Netherlands. NLR and the DUT have together purchased a Citation II aircraft, which will be jointly operated as a research aircraft. Several members of NLR's staff are part-time professors of the DUT's Faculty of Aerospace Technology.

As in previous years, NLR has been very active in AGARD, NATO's Advisory Group for Aerospace Research and Development. NLR is represented in most of the AGARD Panels, and participates in the activities of many Working Groups.

A large part of NLR's basic research is carried out as contributions to 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 and Sweden take part. Europe is in the process of unification and the European aerospace industry is restructuring. NLR is involved in discussions with other research institutes on intensified co-operation aimed at improved efficiency in their highly advanced research.

The co-operation between NLR and the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) was extended. Research support was given to the German-Dutch Wind Tunnel (DNW), which was well occupied for contract testing. About 50% of this concerned fixed-wing aircraft testing, 13% on rotorcraft testing, 4% on propulsion, another 4% on missiles and 29% on automobile testing. A great deal of effort was spent in a programme for modernization and extension of test systems and auxiliary equipment.



A 6-m span Airbus A340 model in the German-Dutch Wind Tunnel (DNW)

The European Transonic Wind Tunnel (ETW) sited near Cologne, Germany, was mechanically complete by the end of 1992, and preparations for commissioning and calibration were started.

Following the design and construction of the Indonesian Low Speed Wind Tunnel (ILST), collaborative activities of the research institutes LAGG of Serpong and NLR were continued under an interim Aerospace Programme for Education, Research and Technology (APERT).

Co-operation between NLR and the US National Aeronautics and Space Administration (NASA) included research on air-ground integration for Air Traffic Control. NLR has studied runway capacity, air traffic efficiency and safety, using NLR's Air Traffic Control Research Simulator, data from Amsterdam Airport Schiphol and software for automation (Center Tracon Automation System) developed by NASA Ames.

NLR has been investigating possible co-operation with countries active in aerospace including Czechia, in Central Europe, and China, in Asia.

Relations to the Government

A so-called convenant, a formal agreement, has been established between the Ministry of Transport and Public Works on the one hand and the Foundation NLR on the other hand. Through this agreement, the Ministry will continue controlling the broad outlines of NLR's programmes for basic research and investments. NLR is granted greater financial flexibility in that it is allowed to build up a financial reserve from future positive operating results (a starting fund will be made available by the Ministry), which may be used in case of a negative operating result in another year. This will enable NLR to use its resources more efficiently.

A Position Paper prepared by Fokker, NIVR, DUT and NLR requesting the Government to provide additional funding for an aeronautical technology development programme was submitted to the Minister of Economic Affairs.

2.3 Organization and Personnel

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

The Board decided to dissolve the Board Office (located at Delft) and to integrate its personnel with NLR's laboratory organization as of 1 January 1993.

The activities in the area of propulsion aerodynamics of the Department of Propulsion Aerodynamics and Aeroacoustics were integrated in the departments of Experimental Aerodynamics and of Aerodynamic Facilities. A new Department of Aeroacoustics was formed.

The organization of the laboratory, which is headed by the directors mentioned on page 3, is shown on page 14.

On 31 December 1992 the Heads of Divisions and Services were:

Prof.ir. J.W. Slooff, *Fluid Dynamics Division*
Ir. J.T.M. van Doorn, *Flight Division*
Dr.ir. G. Bartelds, *Structures and Materials Division*
Ir. B.J.P. van der Peet, *Space Division*
Ir. W. Loeve, *Informatics Division*
Ir. G. Brink, *Engineering and Technical Services*
Ir. W.F. Wessels, *General Services*
J.A. Verberne R.A., *Administrative Services*

In 1992, Ing. F.J. Sterk succeeded Ir. D.J. van den Hoek, who retired, as Head of the Support Staff. In 1992 Ir. C.A. Schmeitink, Head of the Space Division, retired. He was succeeded by Ir. B.J.P. van der Peet.

As per 1 January 1993, Drs. A. de Graaff, former Secretary/Treasurer of NLR, was appointed Associate Director, and Mr. E. Folkers, Secretary of the Board of Directors, was appointed Secretary of the Board of the Foundation as well.

At the end of 1992 NLR employed a staff of 919, of whom 350 were University graduates. Of the total, 829 were employed on a permanent basis, and 90 had temporary appointments. About 55% of the staff are posted in Amsterdam, 45% in the Noordoostpolder. A breakdown of the permanent staff is given on page 15.

Organization diagram of the laboratory

Deputy Director
Prof. Ir. F.J. Abbink

General Director
Dr. Ir. B.M. Spee

Controller
J.A. Verberne R.A.

Head Support Staff Ing. F.J. Sterk

Public Relations Ms. J.F. van Esch
Publications Dr. B.J. Meijer
Co-ordinator Defence Projects Ir. J.M.A. van den Heuvel
Co-ordinator EC Projects Ing. F.J. Sterk
Co-ordinator Aircraft Development Projects Ing. P. Kluit
Co-ordinator Spaceflight Projects Drs. J.C. Venema
Co-ordinator Aircraft Operations Projects and -
Co-ordinator Basic Research & Equipment Development Ir. J.A.J. van Engelen
Co-ordinator Quality Assurance NLR H. Blokker

Secretary
E. Folkers
- Filing Department
- Security

Personnel
Drs. H. de Heer

Company Welfare Work
Ms. M.T.F.J. Simons

Engineering and Technical Services
Ir. G. Brink

Technical Projects
Ir. C.C. Groothoff

Technical Design
A. van den Berg

Workshops
Ir. H.T.J.A. Lafleur

Fluid Dynamics Division
Prof. Ir. J.W. Slooff

Aerodynamic Facilities
Ir. F. Jaarsma
Ir. H.A. Dambrink

Experimental Aerodynamics
Ir. A. Elsenaar

Theoretical Aerodynamics
Dr. B. Oskam

Unsteady Aerodynamics & Aeroelasticity
Prof. Ir. R.J. Zwaan

Aeroacoustics
Prof. Ir. R.J. Zwaan

Flight Division
Ir. J.T.M. van Doorn

Flight Testing and Helicopters
Ir. H. Tellegen

Air Traffic Control and Avionics
Ir. H.J. Berghuis van Woortman

Flying Qualities and Flight Simulation
Ir. W.P. de Boer

Operations Research
Ir. G.J. Alders

Aircraft Instrumentation
Ir. R. Krijn

Structures and Materials Division
Dr. Ir. G. Bartelds

Loads
Ir. J.B. de Jonge

Structures
Ir. H.H. Ottens

Materials
Dr. R.J.H. Wanhill

Testing Facilities
Dr. Ir. G. Bartelds

Space Division
Ir. B.J.P. van der Peet

Remote Sensing
Dr. G. van der Burg

Systems
Dr. Ir. H.F.A. Roefs

Laboratories and Thermal Control
Ir. H.A. van Ingen Schenau

Informatics Division
Ir. W. Loeve

Electronics
Ir. H.A.T. Timmers

Mathematical Models and Methods
Dr. R.J.P. Groothuizen

Numerical Mathematics and Appl. Programming
Ir. F.J. Heerema

Computing Centre and Systems Programming
Ir. U. Posthuma de Boer

General Services
Ir. W.F. Wessels

Buildings
Ing. H. van der Roest

Power Station
Ing. J. van der Spek

Power Distribution
A.M.G. Reijntjens

Housekeeping
G. Lipsius

Guarding
G.M. Zwierink

Library and Information Services
Ir. W.F. Wessels

Document Processing
Ing. D.J. Rozema

Administrative Services
J.A. Verberne R.A.

Administration
Drs. B.P.E. Haeck

Stores and Transport
R. Raterink

Purchasing
J.F. Post

Table 1
NLR staff at the end of 1992 (between brackets the numbers at the end of 1991)

		University graduates	Advanced technical college graduates	Others	Total
Board of Directors		3 (-)	- (-)	- (-)	3 (3)
- Support Staff		12 (11)	8 (9)	4 (3)	24 (23)
		15 (14)	8 (9)	4 (3)	27 (26)
Fluid Dynamics Division	A	3 (3)	1 (1)	3 (3)	7 (7)
- Aerodynamic Facilities	AF	11 (12)	22 (20)	29 (26)	62 (58)
- Experimental Aerodynamics	AX	19 (14)	15 (13)	1 (1)	35 (28)
- Aeroacoustics	AK	7 (-)	3 (-)	- (-)	10 (-)
- Theoretical Aerodynamics	AT	16 (13)	- (-)	- (-)	16 (13)
- Unsteady Aerodynamics & Aeroelasticity	AE	7 (9)	3 (2)	- (1)	10 (12)
- Propulsion & Aeroacoustics	AV	- (8)	- (5)	- (3)	- (16)
- DNW	AD	4 (4)	14 (13)	17 (15)	35 (32)
		67 (63)	58 (54)	50 (49)	175 (166)
Flight Division	V	2 (2)	1 (1)	1 (1)	4 (4)
- Flight Testing and Helicopters	VV	17 (16)	6 (5)	1 (2)	24 (23)
- Air Traffic Control and Avionics	VG	26 (22)	5 (5)	- (1)	31 (28)
- Flight Qualities and Flight Simulation	VS	16 (13)	10 (10)	2 (2)	28 (25)
- Operations Research	VO	20 (21)	7 (5)	1 (1)	28 (27)
- Aircraft Instrumentation	VA	15 (14)	32 (31)	6 (8)	53 (53)
		96 (88)	61 (57)	11 (15)	168 (160)
Structures and Materials Division	S	1 (1)	- (-)	1 (1)	2 (2)
- Loads	SB	8 (7)	4 (4)	- (-)	12 (11)
- Structures	SC	10 (11)	2 (2)	1 (1)	13 (14)
- Materials	SM	5 (6)	4 (4)	- (-)	9 (10)
- Testing Facilities	SL	- (-)	8 (8)	16 (16)	24 (24)
		24 (25)	18 (18)	18 (18)	60 (61)
Space Division	R	2 (2)	- (-)	1 (1)	3 (3)
- Remote Sensing	RR	6 (5)	4 (4)	- (-)	10 (9)
- Systems	RS	12 (13)	- (-)	- (-)	12 (13)
- Laboratories and Thermal Control	RL	5 (5)	7 (7)	1 (1)	13 (13)
		25 (25)	11 (11)	2 (2)	38 (38)
Informatics Division	I	2 (2)	- (-)	4 (4)	6 (6)
- Electronics	IE	16 (15)	24 (24)	5 (5)	45 (44)
- Mathematical Models and Methods	IW	10 (12)	- (-)	- (-)	10 (12)
- Numerical Mathematics And Appl. Programming	IN	23 (22)	23 (24)	2 (2)	48 (48)
- Computing Centre and Systems Programming	IR	19 (20)	14 (13)	10 (12)	43 (45)
		70 (71)	61 (61)	21 (23)	152 (155)
Engineering and Technical Services	T	1 (1)	- (-)	1 (1)	2 (2)
- Technical Projects	TP	4 (4)	5 (5)	2 (2)	11 (11)
- Technical Design	TO	- (-)	13 (13)	1 (1)	14 (14)
- Workshops	TW	1 (1)	12 (12)	24 (24)	37 (37)
		6 (6)	30 (30)	28 (28)	64 (64)
General Services	G	1 (1)	1 (1)	- (-)	2 (2)
- Buildings	GC	- (-)	2 (2)	1 (1)	3 (3)
- Power Station	GE	- (-)	3 (3)	10 (10)	13 (13)
- Power Distribution	GS	- (-)	5 (4)	6 (6)	11 (10)
- Housekeeping	GZ	- (-)	2 (2)	29 (28)	31 (30)
- Guarding	GX	- (-)	- (-)	8 (8)	8 (8)
- Library and Information Services	GB	2 (2)	1 (1)	5 (6)	8 (9)
- Document Processing	GT	- (-)	4 (3)	28 (29)	32 (32)
		3 (3)	18 (16)	87 (88)	108 (107)
Administrative Services	O	- (-)	- (-)	- (-)	- (-)
- Administration	OA	3 (2)	14 (16)	11 (12)	28 (30)
- Stores and Transport	OM	- (-)	1 (1)	4 (4)	5 (5)
- Purchasing	OI	1 (-)	3 (5)	- (-)	4 (5)
		4 (2)	18 (22)	15 (16)	37 (40)
Grand total		310 (297)	283 (278)	236 (242)	829 (817)

3 Activities

3.1 Fluid Dynamics

Summary

The emphasis of the research and development activities in the field of Computational Fluid Dynamics (CFD) shifted from methods for inviscid flow, based on the Euler equations, to methods for viscous flow, based on the Reynolds-averaged Navier-Stokes equations. An important activity concerned the development of the ENFLOW system of computer programs for Euler and Reynolds-averaged Navier-Stokes flow computations, which is being carried out in collaboration with Fokker Aircraft, Centro Italiano Richerche Aerospaziale/Alenia and Delft Hydraulics, and is partly funded by NIVR.
Both computational and physical aspects of turbulence modelling for Reynolds-averaged Navier Stokes Methods were studied, in particular in GARTEUR and CEC programmes. The experimental investigation in the low-speed wind tunnel LST of the turbulent shear layer of a swept wing, specifically designed for the development of turbulence models, was continued. Methods for the prediction of the laminar-turbulent transition in boundary layers were being compared.

At the level of the Euler equations, activities were aimed at the validation of ENFLOW in the area of propulsion/airframe integration, and at the validation for supersonic flows.

At the level of potential flow methods, the development of the MATRICS-V computer program system for aerodynamic wing design was continued. The development of the linearized potential flow method PDAERO has resulted in a capability to analyze the overall effect of the propeller slipstream on the subsonic aerodynamic characteristics of aircraft.

Radar Cross Section (RCS) prediction techniques were continued to be developed, for both radar analysis and RCS design of military aerospace vehicles.

Work in the area of configuration aerodynamics included the continued analysis of previously executed wind tunnel and flight experiments on the high-lift characteristics of an Airbus-type configuration.
Under the BRITE/EURAM project ELFIN I (European Laminar Flow INvestigation), the boundary layer stability code COSALX was extended for curvature effects.
The computer program system WINGDES, for the aerodynamic design of wings with prescribed pressure distributions in transonic flow, was extended with a surface geometry smoothing routine.
Propulsion-airframe interactions were investigated both experimentally and by numerical simulation, in collaboration with Fokker Aircraft and as part of a BRITE/EURAM project.

NLR has participated in the BRITE/EURAM project DACRO by executing and evaluating calculations of the aerodynamic forces on rotor sections in forward flight using NLR's ULTRAN-V computer code.

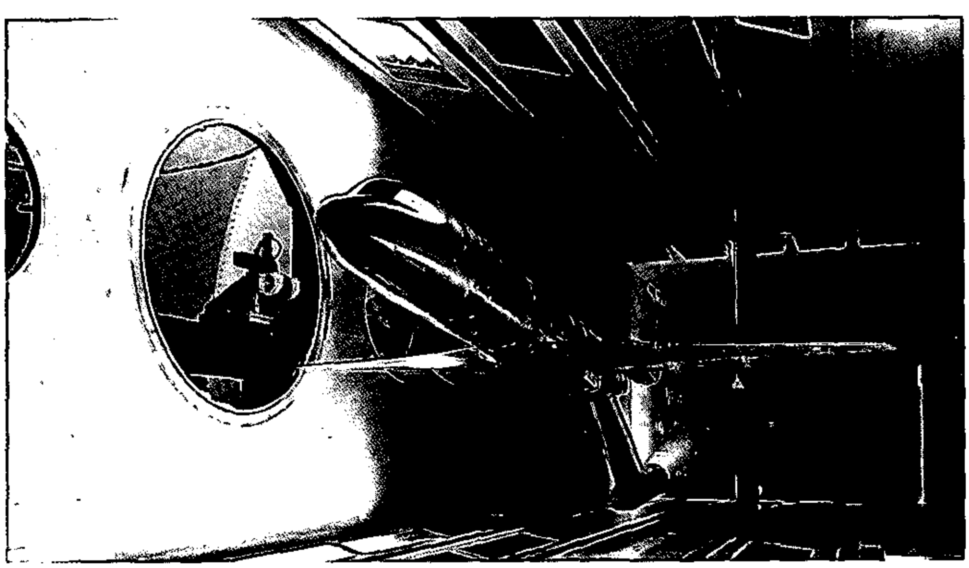
Within the scope of the collaborative research programme of the Independent European Programme Group (IEPG) 'Computational Methods in Aerodynamics' NLR has been verifying and validating the Reynolds-averaged Navier-Stokes method ENFLOW for fighter-type aircraft exploiting high-angle-of-attack vortex lift.

To solve aero-thermodynamic design problems of the HERMES space vehicle, a number of hypersonic flow solutions of the full Navier-Stokes equations have been generated.

Aeroelastic work was done both for transport aircraft and for fighter aircraft. A preliminary version of a pilot simulation program for transport aircraft was installed at Fokker Aircraft. The research programme of limit cycle oscillations (LCO) of fighter type aircraft at transonic flow conditions was also continued. The processing of the pressure distribution data and overall loads measured during tests in the HST was completed and the results were analyzed.

Various aeroacoustics calculations and tests were carried out. Results of calculations were compared with the results of acoustic wind tunnel tests on isolated propellers, as part of the activities of a Garteur Action Group.
A calculation method for the acoustics of conventional propellers in a non-axial flow was completed.
An experiment carried out in the LST to investigate the transmission of fan-generated and interaction noise through a rotor was completed.
The applicability of bulk-absorbers as acoustic liners and the theoretical modelling of so-called buzz-saw noise were studied.
An experimental study was conducted to assess the effect of vibration damping tapes on the sound transmission through fuselage panels.

Of major importance for future experimental fluid dynamics research, was the execution of a modernisation programme of the High Speed (transonic) wind Tunnel HST. It involved the modification of the test section and the installation of new model supports and of new, highly-automated tunnel control and model control systems. Simultaneously, the power station was equipped with a new, automated, control system. In January 1993 the HST was back in operation, with Fokker as the first customer.



Fokker model in the test section of NLR's modernized High Speed Wind Tunnel (HST)

Research

Computational Fluid Dynamics

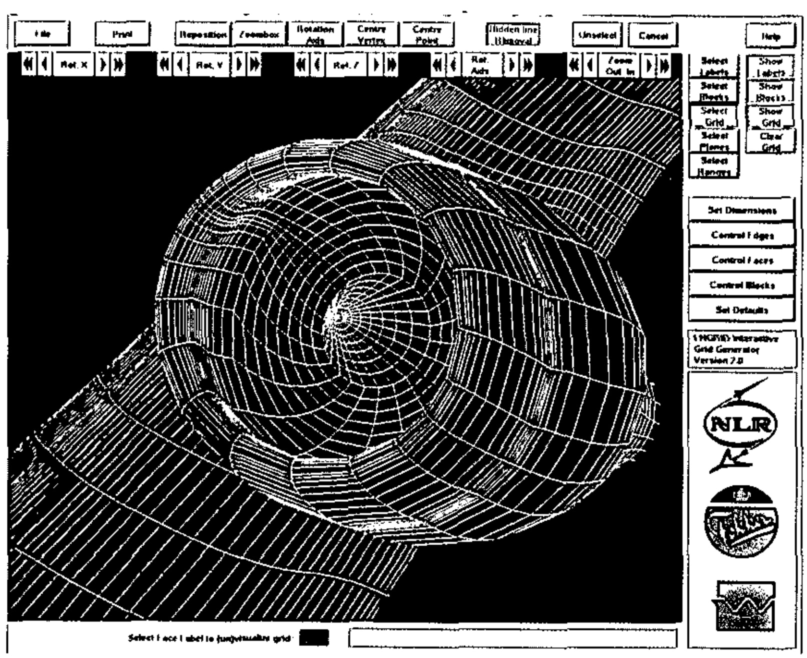
Methods based on the Reynolds-averaged Navier-Stokes equations

The main activity concerned the development of the ENFLOW computer-code system for Euler and/or Navier-Stokes flow computations. The principal objective of ENFLOW is to enable the aircraft industry to improve the aerodynamics design of transport aircraft, including propulsion/airframe integration.

The first solutions of the Reynolds-averaged Navier-Stokes equations for 2D and 3D configurations, including transonic flow solutions for the DLR F4 wing, were obtained in 1992. This step towards the principal objective demonstrated that the basic algorithms, such as

- multi-block grid generation,
- multi-grid Runge-Kutta time integration,
- local grid refinement on block-by-block basis, and
- general block coupling

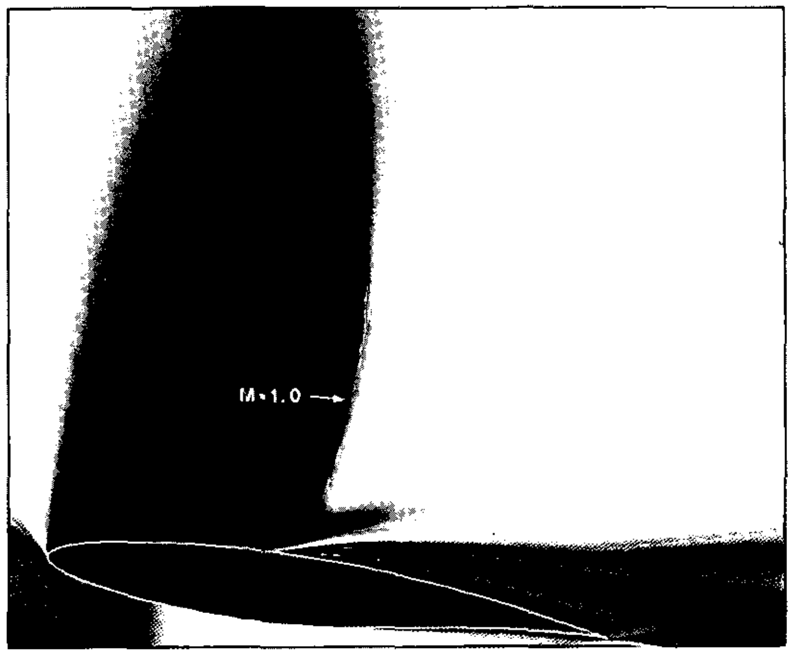
underlying the ENFLOW computer-code system are a sound basis for further development. This research and development is being executed in collaboration with Fokker Aircraft, CIRA/Alenia and Delft Hydraulics, and is partly funded by NIVR.



Graphical user interface of the multi-block interactive grid generator ENGRID, a part of the ENFLOW computer-code system

For the purpose of enabling industrial applications of the ENFLOW system, two subjects have received particular attention in 1992: adaptive grid generation, and computational aspects of turbulence modelling. Solution-adaptive grid generation is a prerequisite for routine industrial applications of Navier-Stokes methods. Exploratory results for both inviscid and viscous flows around two-dimensional airfoils demonstrated that the currently developed grid adaption algorithm is robust and almost fully automatic and that shocks, expansion zones, boundary layers and shear layers are well resolved by the adapted grid.

Computational, and physical, aspects of turbulence modelling in Reynolds-averaged Navier-Stokes methods were investigated in the framework of GARTEUR Action Group 11, and the Brite/Euram project EUROVAL. In AG-11 significant progress has been made in separating the errors due to discretization of the conservation laws (and the boundary conditions) from the errors due to turbulence modelling. The ENFLOW system is designed such that improved turbulence models can be incorporated in the flow solver; results obtained show that improved models are needed, in particular for 3D flows.



Mach number distribution of a transonic airfoil flow including shock-wave-induced boundary layer separation computed on the basis of Reynolds-averaged Navier-Stokes equations in the EUROVAL project

Turbulence Research

The primary objective of the turbulence research of NLR is the development of improved turbulence models for Reynolds-averaged Navier-Stokes methods. The work comprises experimental investigations into the structure of turbulent shear layers as well as theoretical and computational modelling and evaluation efforts. In the framework of GARTEUR AD(AG07), the experimental investigation in the LST of the turbulent shear layer of a swept wing, specifically designed for this purpose, was continued. The measurements on the suction side were completed. Comparisons with similar measurements in the F-2 tunnel of ONERA of France were encouraging. Researchers from FFA of Sweden and DLR of Germany participated in NLR's experiment in the LST by providing and operating equipment for the measurement of turbulence intensity and wall-shear stress. The experiment appears to provide excellent experimental data for turbulence modelling for three-dimensional boundary layers and wakes.

Experimental investigations of turbulent shear layers are also carried out by the Faculty of Aerospace Engineering of the Delft University of Technology (DUT) as part of a research agreement with NLR. In 1992 the DUT performed some additional measurements on the turbulence structures near the trailing edge of an airfoil.

An investigation was started to evaluate the accuracies and the sensitivities of five different commonly used turbulence models for boundary layer computations, to help to define improved models for the future.

A comparison of methods for the prediction of the laminar-turbulent transition in boundary layers is being carried out in the framework of GARTEUR AD(AG) 14.

Methods based on the Euler equations

One of the stepping stones in the evolutionary development of the ENFLOW computer program system is the validation of the system at the level of Euler equations. Activities are aimed at the validation in the area of propulsion/airframe integration both in the case of high-speed propellers and in the case of turbofan engines, and at the validation for supersonic flows.

The time-averaged representation of high-speed propellers at the Euler equation level has been implemented in the form of special propeller through-flow boundary conditions. Comparisons of computational results with experimental data from the HST and with data from the Fokker 50 propeller rig in the LST demonstrated that the time-averaged effect of a propeller slipstream can indeed be modelled at the Euler equation level.

To validate the inlet/outlet boundary conditions for turbofan engines, exploratory calculations have been made for isolated engine nacelles. Geometry modelling, block decomposition and grid generation for the DLR F4 wing/body/pylon/nacelle are in progress.

Further validation of Euler codes for complex geometries representative of integrated airframe/propulsion system configurations for transport aircraft will take place in the framework of GARTEUR Action Group 17, which has been established in 1992.

Validation of Euler codes for supersonic flows is the subject of GARTEUR Action Group 15. NLR is contributing computational results for three common test cases. The analysis of the computational results has shown the results of the ENFLOW system to be in agreement with Euler code results of the other participants.

An exploratory investigation of Euler solvers based on unstructured grid methods has shown that the unstructured-grid approach is particularly well suited to handling complex geometries such as high-lift systems; the geometry-adaptive algorithm can automate the grid generation step. Comparison between computational and experimental results showed that the solution of the Euler equations based on unstructured grid techniques is promising. Extension of the exploratory investigation to the level of Reynolds-averaged Navier-Stokes equations was initiated.

Potential Flow Methods

The main activity in this category is the development of the MATRICS-V computer code system. This system is aimed at being used in the aerodynamic design of wing/body combinations, and in the analysis of aerodynamic forces, such as drag, on wing/body combinations representative of transport aircraft.

The MATRICS-V system consists of a dedicated grid generation code, MATGRID, and a flow solver based on the full-potential equation and boundary layer equations, including a special algorithm to compute aerodynamic forces. The computational efficiency of the MATRICS-V system was improved significantly, making feasible the analysis of transonic drag rise by increasing the Mach number at a fixed lift coefficient, in the sense that the turn-around time satisfies the requirements for industrial application.

Initial applications indicate that accuracy requirements with respect to wave drag and induced drag prediction can only be met by extrapolation to zero discretization error.

Linearized Potential Flow Method

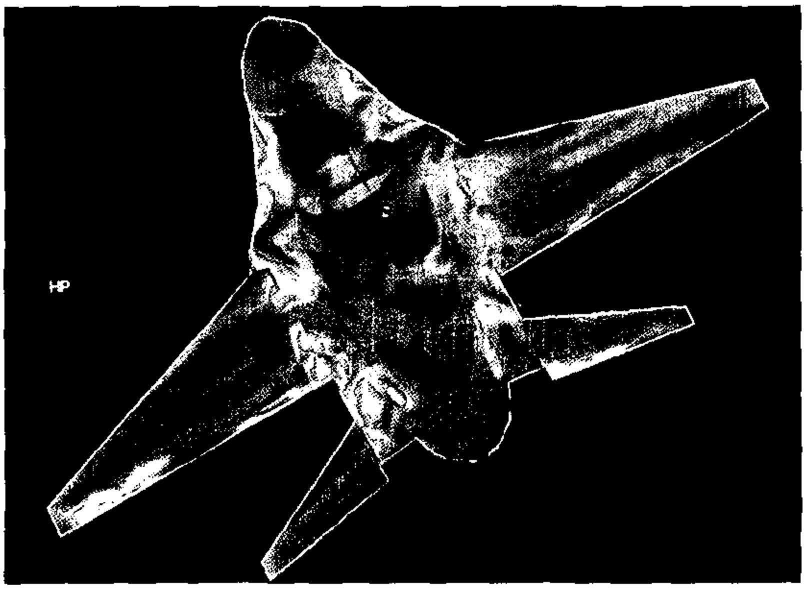
The development of the PDAERO panel method, to support the preliminary design of aircraft, has resulted in a capability to analyze the overall effect of the propeller slipstream on the subsonic aerodynamic characteristics of aircraft. Validation of this panel method capability was done through computations for the Fokker 50 aircraft, and for counterrotating propellers, and comparison with free flight as well as DNW data.

Radar Cross Section (RCS) Prediction Techniques

Radar Cross Section (RCS) prediction techniques are required for both radar analysis and RCS design of military aerospace vehicles. Prediction techniques are under development at three levels of mathematical sophistication:

- High frequency methods based on physical optics.
- Integral equation methods, both 2D and 3D.
- Finite difference methods based on direct solution of the Maxwell Equations (2D), to treat inhomogeneous media.

The development work is carried out in collaboration with TNO-FEL and DASA Military Aircraft. Special attention is being paid to the electric field integral equation method (EFIE3D) and its application to three-dimensional engine inlets. Validation of this method by grid convergence studies and comparison with grid-converged results produced by alternative methods has led to the conclusion that reliable prediction of RCS values requires a high resolution of the electromagnetic waves (seven intervals per wave length).



Electric current on the surface of an F-16A aircraft, computed on the basis of the electric field integral equation method (EFIE 3D) to analyze RCS characteristics

Aerospace Vehicle Configuration Aerodynamics

High-Lift Systems

In the framework of GARTEUR AD (AG) 13, the analysis of previously executed wind tunnel and flight experiments on an Airbus-type of configuration was continued and almost completed. Attention was focused on the mechanisms of Mach number as well as on Reynolds number effects. The analysis was supported by flow computations. The results clearly indicate the importance of compressibility (Mach number) effects on the flow about the leading edge slat. Also, in a collaborative effort with Boeing and IPTN, a design modification was made for an existing high-lift model that will be tested in the Indonesian Low Speed Tunnel in 1993. This experiment is aimed at studying the effect of sweep on slat characteristics.

Drag Reduction through Laminar Flow

Under the the BRITE/EURAM project ELFIN I (European Laminar Flow INvestigation), the boundary layer stability code COSALX was extended for curvature effects. Test calculations were performed for several Fokker 100/ELFIN test conditions.

Wing Design Methods

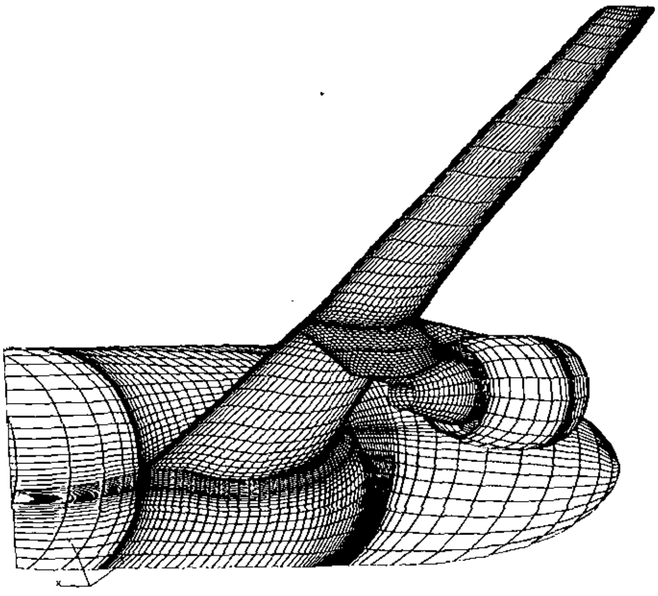
The computer program system WINGDES, for the aerodynamic design of wings with prescribed pressure distributions in transonic flow, was extended with a surface geometry smoothing routine.

One of the objectives of the BRITE/EURAM "Optimum Design" project is the development of a new algorithm to solve the "multi-point" wing design problem. The application of the calculus of variations was investigated.

Propulsion-Airframe Interaction

Propulsion-airframe interactions were investigated both experimentally and by numerical simulation of wing/propulsion system configurations, in collaboration with Fokker Aircraft.

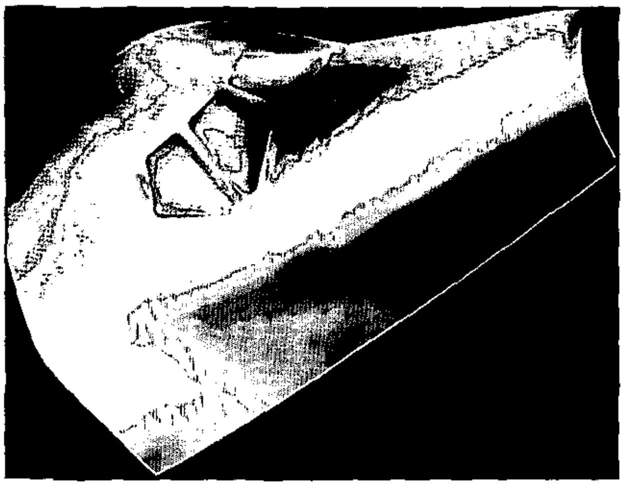
As part of the BRITE/EURAM DUPRIN project of the European Community, NLR calibrated two Turbine Powered engine Simulators (TPS) that were subsequently used in a DNW test.



Surface grid of wing/body/pylon/turbofan configuration employed to validate the ENFLOW computer-code system in the area of propulsion-airframe integration

Aerodynamics of Combat Aircraft

NLR participates in the collaborative research programme of the Independent European Programme Group (IEPG) Technical Area 15 (TA15) "Computational Methods in Aerodynamics". NLR's participation is partly funded by the Netherlands Ministry of Defence. NLR is verifying and validating the Reynolds-averaged Navier-Stokes method ENFLOW for fighter-type aircraft exploiting high-angle-of-attack vortex lift. For some test configurations, computational results are compared with experimental data. One such configuration is a generic fighter-wing configuration with a 65-degrees cropped delta wing with sharp leading edges, featuring a strong leading-edge vortex. For this type of application, the first Navier-Stokes results of the ENFLOW system have been obtained in 1992. The solution of the Navier-Stokes equation was compared with data obtained in the HST. The comparison of the computational results with the wind tunnel data demonstrates the ability of the ENFLOW system to simulate the leading-edge vortex and the secondary, turbulent-boundary-layer separation promoted by the adverse pressure gradient induced by the primary vortex.



Surface temperature on the cabin of the US Space Shuttle Orbiter computed on the basis of the full Navier-Stokes equations including equilibrium chemistry and surface radiation; Mach number: 23.4, angle of incidence: 38 degrees, altitude: 71 km

Helicopter Aerodynamics

NLR has participated in the BRITE/EURAM project DACRO by executing and evaluating calculations of the aerodynamic forces on rotor sections in forward flight using the NLR ULTRAN-V computer code. The calculations were completed and the results were reported.

Hypersonic/Space Vehicle Aero-Thermodynamics

To solve aero-thermodynamic design problems of the HERMES spaceplane, a number of hypersonic flow solutions of the full Navier-Stokes equations, including equilibrium chemistry and surface radiation, have been generated. The aerodynamic heating of the canopy, including the windows, was investigated. The results show that CFD technology is effective in identifying primary mechanisms that cause local hot spots due to aerodynamic heating in the presence of radiative cooling.

A pre-design study was made of an experimental set-up to investigate the characteristics of a boundary layer (including heat transfer) with blowing and/or suction at high Mach numbers. This type of flow will occur on the diffusor following the inlet of propulsion systems of hypersonic transatmospheric vehicles such as Sänger.

Aeroelasticity

The development of a pilot code for the computational aeroelastic simulation of transport type aircraft in transonic flow was continued. The flow is modelled on the basis of a full potential representation. The code was validated for two-dimensional aeroelastic configurations. A start was made with the validation of three-dimensional cases, including the coupling of the flow module with a finite-element method to represent the structural characteristics. A preliminary version of the code was installed at Fokker Aircraft.

The research programme of limit cycle oscillations (LCO) of fighter type aircraft at transonic flow conditions was also continued. This type of oscillations is due to the interaction of shock motions and flow separation. The processing of the pressure distribution data and overall loads measured during tests in the HST in 1991 was completed. The results were analyzed in order to design a phenomenological model for use in a computational simulation method of LCO.

As part of an accompanying research programme, tests were carried out in the HST on a "simple strake" semi-span model, consisting of the outer wing part of the existing LCO model and a new inner wing part provided with a strake. This programme aims at investigating the unsteady flow at transonic speeds due to rapid manoeuvres, when the flow is dominated by strong vortex layers generated by the strake and wing leading edges. A further aim was to produce a data base for computer code validation. The test parameters included high angles of attack, high oscillation amplitudes and stepwise or pulse type manoeuvres. The greater part of the data reduction was completed. As a part of this programme, a flow visualization test was run in which a technique using a laser light screen in combination with water injection was applied.

The "LCO" and "simple strake" research programmes form part of a collaborative agreement with General Dynamics, the US Air Force Flight Dynamics Laboratory and the Royal Netherlands Air Force.

Aeroacoustics

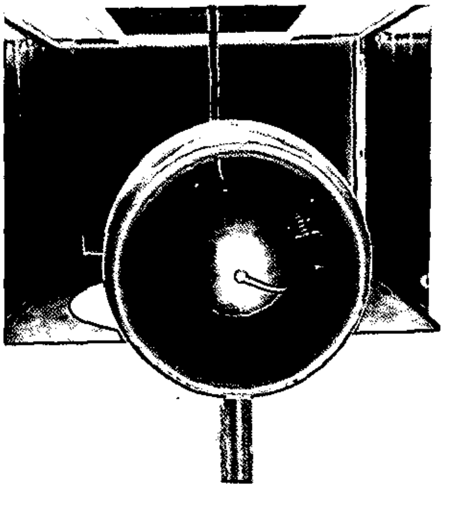
Within the scope of GARTEUR Action Group AD AG-12 "propeller Acoustics" results of calculations obtained by the participants are compared with the results of acoustic wind tunnel tests on isolated propellers. Most of the members, including NLR, completed the acoustic calculations for the selected test cases. A preliminary conclusion is that the NLR results agree satisfactorily with the measured data.

A calculation method for the acoustics of conventional propellers in a non-axial flow was completed. A pilot version of a computer model for the acoustics and aerodynamics of a single-rotating propfan (advanced propeller) was developed, the model being suitable for subsonic helical tip Mach numbers.

An experiment carried out in the LST to investigate the transmission of fan-generated and interaction noise through a rotor was completed. Discrepancies found between the experimental and theoretical results were analyzed, and partly resolved. The computer model was extended to incorporate also the noise caused by the interacting displacement (i.e. potential field) effects of the rotor and stator in addition to the interaction noise caused by the viscous part of the rotor wake. This resulted in improved agreement with the measured unsteady blade pressures.

The applicability of bulk-absorbers as acoustic liners and the theoretical modelling of so-called buzz-saw noise were studied.

In the field of cabin noise control, an experimental study was conducted to assess the effect of vibration damping tapes on the sound transmission through fuselage panels.



Instrumented fan noise model in the
Low Speed Tunnel (LST)

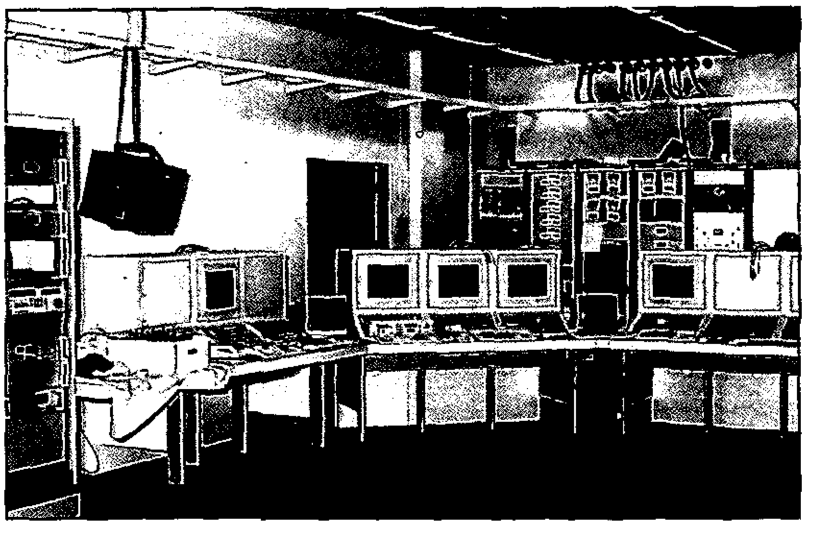
The Transonic Wind Tunnel HST

1992 was the year of the realization of a major modernisation of the HST now featuring a longer and, optionally, higher test section and new model support and control systems, with a larger the envelope of testing possibilities and increased accuracy of testing. Also, the power station was equipped with a new, highly-automated control system for improved efficiency and improved emission/ pollution control.
After being manufactured and tested in the workshop of the contractor Genius, the modified test section and model support system were installed on-site beginning early May. Simultaneously with the mechanical work, the entire electrical and control systems were replaced. Also, the control desk was replaced by a modern one containing man-machine interfaces for computerized monitoring and control of the tunnel and model support. New colour video equipment including a subtitling system for tunnel data was installed.
The compressor of the HST also received a major overhaul.

After "wind-on" in October the flow control flaps and slat extension of the test section were tuned for minimum flow losses in the circuit. From tests in the pilot tunnel, PHST, using a special model to assess wall interference, it has appeared that the slotted wall configuration of the test section should remain unchanged for minimal wall interference effects.
For the various test section and model support configurations, the static pressure distributions on the test section centre line as well as on the walls were measured in a calibration programme. Towards the end of the year, a validation programme took place in which the aerodynamic data of a reference model were compared with similar data obtained prior to the renovation. The comparison of the new with the old data shows only minor differences. Work is going on to assess and possibly correct for the remaining differences and wall interference effects.

In January 1993 the HST was back in operation, with Fokker as the first customer.

Apart from the major modernisation project, a support and traversing mechanism was designed and built to apply the laser light-sheet flow visualisation technique in conjunction with stationary or vibrating models at various pitch angles.



Control room of the modernized High Speed Wind Tunnel (HST)

Low Speed Tunnels

The Low Speed Tunnel (LST) was equipped with a pitch mechanism in the turntable of one of the exchangeable test sections. This pitch mechanism now the allows use of internal balances in models which are supported by a ventral or rear sting providing pitch (-20° to +20°) and yaw (-30° to +30°) movements. This mechanism was successfully used in a series of tests.

The Pilot Low Speed Tunnel (PLST) has been provided with a new multi-purpose test section for basic research activities.

Propulsion and Acoustics Laboratory

Design activities have been executed to upgrade the Calibration Facility for model engines. The balance system of this facility will be upgraded from three to six components. Manufacturing has begun.

In the Engine Calibration Facility, an electronic scanning system for the measurement of pressures and temperatures was successfully applied for a standard cubic nozzle.

The facility for transmission loss measurements at higher frequencies was modified to improve the measurement of high double-wall transmission losses. Furthermore, a test set-up was realized in which fuselage panels can be excited with a plane wave. This will enable transmission loss measurements with a high resolution at low frequencies. Also for this purpose a Fourier Analyzer was expanded from 4 to 26 measuring channels and from 4 to 16 source channels. Also a six-degree-of freedom rotate system was acquired for traversing an acoustic intensity probe.

Instrumentation and Measurement Systems

Work on the development and manufacture of a series of new internal six-component strain gauge balances for NLR's wind tunnels continued. This series will range from very accurate balances, mainly for the symmetrical components, to highly loaded balances, for which the accuracy demands are lower. Particular attention was paid to improve the characteristics of the connection between balance and model. This connection must prevent hysteresis in the attitude of the model relative to the balance.
A second copy of the new high accuracy balance was manufactured to serve as a back-up for the first balance in this series, which was used during the validation programme of the HST.

A so-called rotating balance for propeller measurements was designed, manufactured and tested successfully in the LST. This balance is mounted in the hub of a model propeller. Initially it measured only the axial components (torque and thrust) of an isolated or installed propeller. After a new set of strain gauges was applied, the balance was also used successfully to measure the off-axis aerodynamic components of the propeller (side/normal forces, yawing/pitching moments), by using a Fourier Analyzer for data reduction.

The 64-channel Fourier Analysis system for dynamic measurements, acquired in 1991, was extended to 128 channels. The system was applied successfully in the "simple strake" model test programme. Image processing software was acquired and applied to the results of the flow visualization test with the same model.

3.2 Flight

Summary

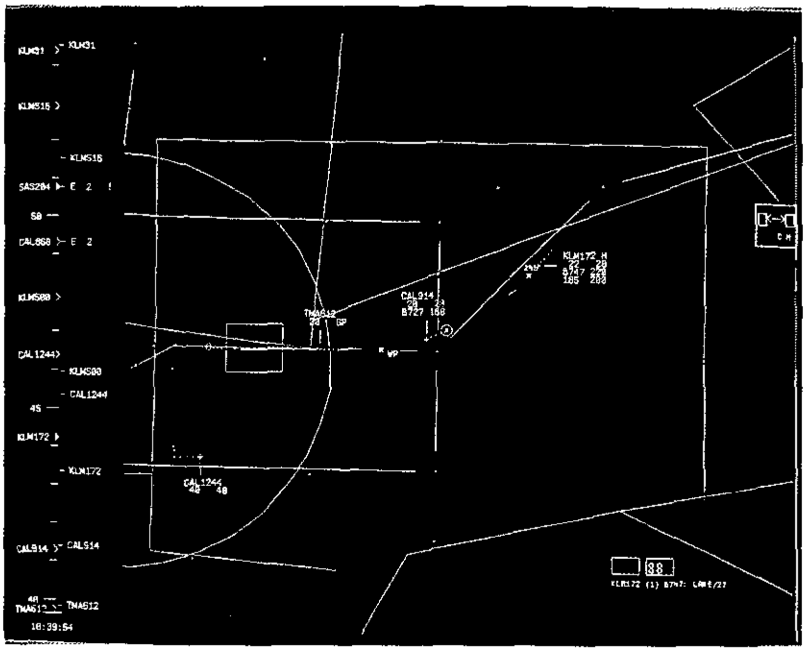
In the field of aircraft development, an important activity in 1992 was the support in the flight testing of Fokker 50 and Fokker 100 aircraft.

Other activities are related to research on flying qualities and flight control systems. The development of low-speed lateral/directional handling qualities design guidelines for future transport aircraft was continued. This research is carried out as a contribution of NLR to a GARTEUR Action Group and is focused on the implementation of advanced fly-by-wire (FBW) flight control systems.

In the field of aircraft operations, the research aircraft Beech Queen Air and Fairchild Metro II were involved in a number of investigations related to the testing of navigation equipment (Global Positioning System and Microwave Landing System (MLS), with flight trials using an experimental MLS installation at Schiphol Airport), Air Traffic Control/Air Traffic Management equipment (tracking radar and data link) and remote-sensing scanners.
In the area of Air Traffic Control (ATC), NLR assisted the Netherlands Department of Civil Aviation (RLD) and Eurocontrol. For the RLD, two automated ATC functions were extensively tested with the aid of air traffic controllers. Simulations with the NLR ATC Research Simulator (NARSIM) were prepared for the Commission of the European Communities' (CEC's) programme Specifications for Working Positions in Future Air Traffic Control (SWIFT).
In the Programme for Harmonized Air Traffic Management Research in Eurocontrol (PHARE), NLR contributed to various activities in the field of Flight Management Systems, automatic tools to assist the air traffic controller and data link messages. NLR delivered its share in the software development for an Experimental Flight Management System, co-ordinated by Eurocontrol.
In the area of aircraft environmental research, numerous calculations were made of the noise loads for various future scenarios for the possible expansion of Amsterdam Airport Schiphol.

NLR supported the RNLAF with improving the operational employment of their assets, including direct support to operational training, planning and assessment of exercises as well as the provision of data logging means and analysis of weapon system performance.
With regard to future procurement and improvement of airborne weapon systems, research was focused on synthetic voice applications in fighter cockpits and management and advisory functions in fighter avionics systems.
A topic related to aviation safety included direct support to the investigation of accidents of military aircraft. In the civil area the methods and the means were developed to quantify the risk associated with airborne traffic to and from airports.
In the field of development, acquisition and operation of helicopters, NLR was extensively involved, together with Fokker and DAF Special Products, in the design and development phase of the NH-90 programme and by the selection of transport and Search And Rescue helicopter for the Royal Netherlands Air Force and the Royal Netherlands Army.

With regard to facilities and equipment, preparations were made for the introduction in March 1993 of the new Cessna Citation II research aircraft, which will be jointly owned by the Delft University of Technology and NLR. Project planning activities took place for the conversion of this aircraft into a testbed for research into fly-by-wire.
The development of the versatile National Simulation Facility (NSF) has been



Final approach spacing tool of NASA's Center Tracon Advisory System

continued. The F-16 cockpit, in Mid-Life Update (MLU) configuration has been shipped to NLR. The transport cockpit of NLR's Research Flight Simulator (RFS) has been upgraded to an "all-glass cockpit".
The development of the NLR Air Traffic Control Research Simulator (NARSIM) was continued, and the data link between NARSIM and the RFS was extended.
Under contract to NIVR and in co-operation with Fokker Aircraft, a new range of flight test equipment is being developed, with major improvements in the fields of flight path measurements, on-board data processing, video equipment and basic data acquisition systems.
Research has started into techniques for measuring in-flight the change due to wing torsion of the local angle-of-incidence and the airspeed in boundary layers by the application of a Laser Doppler anemometer.

Aircraft Development

Flight Tests and Flight Test Instrumentation

Evaluation and Certification of the Fokker 50, 70 and 100

For the flight trials of the Fokker 50 and Fokker 100, the NLR-developed Measurement, Recording and Data Processing system MRVS was used. A team of NLR personnel supported the system and was responsible for the operation of the system during the flight tests that were conducted because of new developments or customer requirements.

Fokker 50

Flight tests with the Fokker 50 prototype P1 were mainly aimed at the certification of the new P&W 127 engine providing improved runway performance in hot weather and at higher altitudes. In these tests, that were conducted at the airfield of Granada, Spain, a flight path measurement method developed by NLR was used.
Other tests were dedicated to the development of 'steep approach' procedures for landing at airfields surrounded by buildings or other obstacles.

For the flight tests of the 'Enforcer', a maritime patrol version of the Fokker 50, a flight test measurement system was designed, developed and installed on board the aircraft. Flight tests started at the end of 1992.

The Production Flight Test system PFT was used for the factory acceptance of all new Fokker 50 aircraft.

Fokker 70

The flight test programme of the Fokker 70 will start in the spring of 1993. The flight test measurement system for that programme will be based on the system used in the second Fokker 100 prototype, and incorporate many newly developed items. Design and development are well under way.

Fokker 100

For the Fokker 100, NLR's flight test system was used for measurements of the high altitude performance of the Rolls Royce Tay 650 engine, for further development of a number of avionics systems, for loads measurements and for the evaluation of ice detection sensors.
A special programme aimed at the reduction of the exterior noise was conducted in Granada, Spain.

The Production Flight Test system PFT was used for the factory acceptance of all new Fokker 100 aircraft. A sixth PFT-system was delivered.

European Laminar Flow INvestigation (ELFIN)

After the flights in 1991 it was decided to continue flight tests after improvement of the shape of the glove on the wing of the second Fokker 100 prototype in order to increase the Natural Laminar Flow area. As a subcontractor to Fokker in this project, that was part of the BRITE/EURAM programme of the EC, NLR took care of the measurement of hundreds of pressure tabs. A second system, incorporating a high speed digital data recorder capable of recording well over 100 Mbits/s, was used for the high-frequency measurements of the hot-film anemometers.
After a total of five flights, the project was completed and all data were made available to the ELFIN-partners after pre-processing at NLR.

MRVS-90

Under contract to the Netherlands Agency for Aerospace Programs (NIVR) and in co-operation with Fokker Aircraft, the MRVS-90 project was continued. It is aimed at modernizing the instrumentation capabilities and facilities for flight test purposes. In 1992 the development phase was started. Main improvements are in the field of flight path measurement, on board data processing, video equipment and basic data acquisition systems. For flight path measurement during runway performance and autoland testing the new system will use differential phase tracking GPS. Accuracy requirements are in the 15 cm range. For on-board processing, all data is made available on a high speed data bus capable of handling 10 Msamples/s.
The first application will be in the Fokker 70 certification programme.

Military Flight Test Support

NLR assisted the Royal Netherlands Air Force during flight tests with F-16 aircraft and during air defence flight trials.

For a foreign customer a flight test instrumentation system was installed in an F-16 and operated during a missile certification programme.

Measurement and Analysis Techniques for In-flight Research

Research has started for the development of a technique to measure in flight the change of the local angle-of-incidence of a wing due to torsion. A video and a accelerometer based system concept are selected for further experiments.

The feasibility of the application of a laser Doppler anemometer for non-intrusive airspeed measurements in boundary layers was demonstrated in two flights of NLR's research aircraft.

Flying Qualities and Flight Control Systems

Flying Qualities

Research for the development of low-speed lateral/directional handling qualities design guidelines for future transport aircraft was continued, particularly taking into account the influence of advanced, fly-by-wire lateral/directional flight control systems.
The Garteur Flight Mechanics Action Group FM AG04 finished its activities (Phase I) in December 1991. In March 1992 the follow-on action Group FM AG06 started their activities to perform Phase II to IV, as recommended in the final report of AG04. The new Action Group has completed the design of the flight control systems and has set up a piloted preparatory investigation that will be executed on DLR's fixed-base simulator at Braunschweig (Germany). Subsequently, the main investigation will be performed using NLR's Research Flight Simulator.

Mathematical Models of Aircraft

The determination of the aerodynamic model of the Fairchild Metro II research aircraft is a co-operative project of NLR and the Faculty of Aerospace Engineering of the Delft University of Technology. A Non-Stationary Measurement Method (NSM) and sophisticated parameter identification techniques are used in this project. In 1992 a comprehensive analysis of the symmetrical aerodynamic model of the aircraft, based on the preliminary results of earlier flights, has been conducted. The analysis explicitly deals with the engine model, the stall model and the impact of fuel displacement on the results.

Take-Off Performance Monitor (TOPM)

Research into Take-Off Performance Monitors (TOPMs) is being carried out under contract to NIVR. TOPM systems are aimed at improving crew situational awareness by presenting real-time performance information on the status of the take-off. They could enable the crew to take corrective actions in a timely manner in case take-off conditions are adversely affected. Three types of TOPMs were developed. They range from a Type I system, which displays the difference between actual and expected performance, to a Type III system, which continuously predicts the abilities of the aircraft to continue and to abort the take-off. The objective of the study is to examine the potential safety benefits of such systems. Recent Human Factors studies employed a powerful IRIS workstation to scrutinize pilot performance when conducting take-offs with each of the three TOPM types as well as in the present situation without TOPM. Results indicate that the capability of detecting sub-standard performance is improved by all three TOPM types, and that a Type III system might provide the largest safety benefit.

Windshear

Under a Windshear Masterplan, supported by the Netherlands Agency for Aerospace Programs (NIVR), the Netherlands Department of Civil Aviation (RLD), KLM Royal Netherlands Airlines and the Royal Netherlands Meteorological Institute (KNMI), windshear research was conducted in several disciplines. Flight data recorded by the Aircraft Condition Monitoring System (ACMS) on board Boeing 737 aircraft, during landing approaches or take-offs where a windshear alert had been recorded, were provided by KLM and were analyzed for the occurrence of windshear. By using data processing programs that include Kalman filtering and smoothing, and a windshear-model identification program, two cases of microburst-like phenomenae were identified: a very strong one and a weak one. A study was made into the feasibility of obtaining atmospheric windshear turbulence characteristics from the ACMS data. Developments in the area of "forward-looking" windshear detection and windshear guidance were continued. A start was made with the development of models of ground-based and airborne windshear detection systems, to be used in flight simulation research.

The GARTEUR Flight Mechanics Action Group AG05 "Flight in Windshear Conditions" continued its work. Research will be done into various aspects of forward-looking windshear detection. A study was made of the feasibility of developing a numerical meteorological weather (windshear) simulation model, based on the specification of the so-called TASS model of NASA.

Application of Voice in the Cockpit

In a National Technology Project the TNO Institute for Perception and NLR carry out research into possible use of voice for control functions in military cockpits. This research focuses on the application of state-of-the-art voice recognition systems, and aims at achieving maximum 'head out' time for the pilot while reducing workload.

Crew Assistant

NLR applies its expert knowledge on military operations, mission preparation systems, artificial intelligence and real-time software for airborne applications in its participation in EUCLID CEPA Research and Technology Project 6.5 (Crew Assistant). NLR supported the Ministry of Defence in the defining of this Project.

Human Factors

Man-machine integration studies are required to ensure that human operators can effectively use advanced systems. The effectiveness of information presentations has been studied with graphical display formats that integrate information such as aircraft status, ATC clearances, routing options etc, from multiple sources. Tunnel-in-the-sky concepts were adapted to include new ways of negotiating and representing flight profiles in a format easily accessible for the pilot. These studies are co-ordinated with the Delft University of Technology. Cockpit automation can change the sources of information available to the pilot. Installing non-moving throttles can save weight but deprives the pilot of information on the controlling of the thrust levels by the autothrust system. Potential benefits of such information for pilot performance were investigated.

New communication means including a data link were implemented in the Research Flight Simulator (RFS) to allow extensive pilot evaluations of different cockpit device designs. Scenario generators were developed ensuring adequate replication of the test situations and comparability of the traffic developments. NLR's ATC research simulator (NARSIM) was connected to the RFS. Future ATC ground systems require man-machine interfaces that allow the controllers to handle increased traffic. The basic ergonomic design of a controller's working position was completed and evaluated.
Design activities require evaluation and validation tools. NLR is working on the development of a workload toolbox with theoretically sound measurement techniques. Physiological measures of operator workload were applied to the practical setting of glass cockpits, and proved feasible in day-to-day operations. The development of a demonstrator Workload Assessment for Pilots (WASP) was begun. This project is aimed at providing military pilots with hands-on experience of the detrimental effects of task-loading or saturation of information processing capabilities on their performance.

Aircraft Operations

Research Aircraft

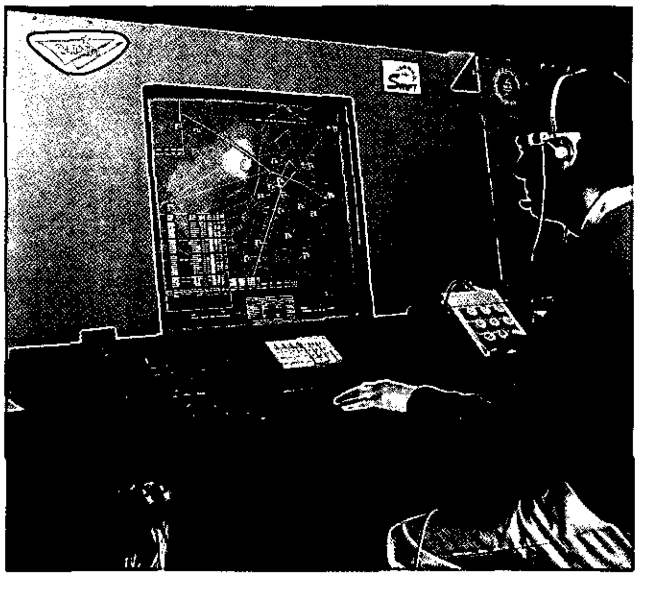
Beech Queen Air 80

With the Queen Air research aircraft, several flights were made to test special GPS navigation procedures to be used during research flights, in particular remote sensing flights.

The aircraft was also used in preliminary tests with a ground-based tracking radar. Such radars are intended to be used in future to track airway traffic to determine deviations from the nominal track and the assigned altitude or flight level.
In an ongoing series of tests the approach and runway lights of ILS runways were recorded with a video camera to determine the quality of the systems.
Some forty flights were flown for the practical training in flight test procedures of aeronautical students from the Delft University of Technology.

Fairchild Metro II

In the beginning of the year a series of microgravity manoeuvres was flown to test equipment to be used in space flights.
One flight was made to test equipment to be used for data link communication to and from aircraft.
As with the Queen Air, several GPS test flights were made. The Metro II was also used for filming approach and runway lights.
Remote sensing flights were made with the optical scanner CAESAR over different areas in the Netherlands. With the PHARS synthetic aperture radar, a series of measurement flights were flown over the North Sea, operating from Nordholz Air Base in North-West Germany.
A few flights were made to test new airborne systems, including a video quick-look system to be used in remote sensing flights (scanner and radar) and a Laser Doppler system for boundary layer measurements.
A series of MLS-flights at Schiphol was started using the experimental, programmable EFIS display.



Controller working position of the NLR ATC Research Simulator (NARSIM)

Air Traffic Control

Research and development in Air Traffic Control has been carried out under contract to Luchtverkeersbeveiliging (ATC The Netherlands), and, mostly in co-operation with European industries and other Research Institutes, for Eurocontrol and the European Communities (EC). Activity areas were: aircraft and radar models, surveillance, ATC simulation and automation, controller working position, aeronautical telecommunication, data link and man-machine interface/human factors.

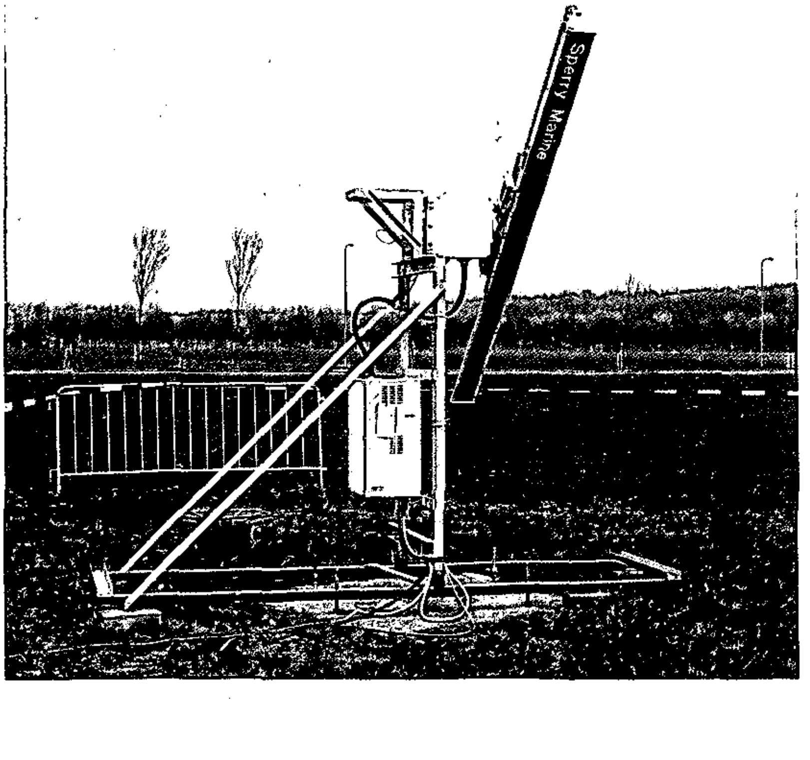
Experimental Flight Management System (EFMS)

Within the framework of the 'Programme for Harmonized Air traffic management Research in Eurocontrol' (PHARE), NLR is contributing to the development of an experimental flight management system. Other participants in the EFMS Development Group besides Eurocontrol are DRA of the UK, DLR of Germany and CENA of France. The contribution of NLR is in the field of data link communication and pilot-EFMS interface.
All software modules, written in the Ada computer language, were delivered to the EFMS integration site in Bedford, UK. The EFMS will encompass a Primary Access Terminal featuring a colour touch screen for control of the system.
An enhanced conventional Primary Flight Display (PFD) in combination with a navigation display were implemented in NLR's programmable Electronic Flight Instrument System (EFIS). The required data flows between the EFMS and the EFIS were defined and a link was implemented. At the same time, lay-outs for advanced four-dimensional navigation displays were prototyped and demonstrated to future users. The main focus was the interactive use of the displayed information by the pilot. Collected comments will be used to revise the initial prototypes and to enhance the airborne EFIS implementation.

Support to Luchtverkeersbeveiliging (LVB)

The evaluation of area conflict detection and flight plan monitoring functions has resulted in validated specifications for the Amsterdam Advanced Automation (AAA) system. Prototyping work was done for displays and input devices for this system. Research has started for automation support to Luchtverkeersbeveiliging for the period after acceptance of the AAA system. Means to improve the runway capacity at Amsterdam Schiphol were studied.

On behalf of the RLD, NLR took part in activities of a number of international organizations. NLR is a member of the SSR Improvement and Collision Avoidance Systems (SICAS) Panel of ICAO. This panel is responsible for the development of standards for the Aeronautical Telecommunication Network, of which the SSR mode S data link is a part.



Field test at NLR Noordoostpolder with a marine radar used for aircraft height monitoring

Support to Eurocontrol

In co-operation with other European institutes, NLR contributed to the definition of the PHARE Common Modular Simulator and the development of PHARE Advanced Tools. Theoretical support was provided for the Vertical Separation Studies Group.

In order to support the safe implementation of the reduced vertical separation of aircraft above FL 290, data collections of the height-keeping behaviour of aircraft at cruising levels are required.
Under contract to Eurocontrol, field test were performed to investigate the feasibility of a concept for a height monitoring system using two closely positioned and synchronized standard marine radars. The results show that an accuracy of 15 or 30 metres could be obtained over 3x3 or 3x10 km areas, respectively.

Support to the EC

NLR is subcontractor to PA Consultancy in the EC ATLAS Study (Layered Safety Concept and Collision Risc Study) and to Thomson-CSF in the EC SWIFT project (Preparation and Validation of European Specifications for a Controller Working Position).

In the European Communities' programme EURET, NLR participates in the activities related to the European Aeronautical Telecommunication Network (EURATN), which will comply to the draft ICAO Standards. The main objective is to realise an experimental air-to-ground communication system. EURATN will be used to validate proposed standards and will also be used for experiments within PHARE with advanced automation tools.

Co-operation with NASA

A study funded by Schiphol Airport *and NLR was made on several* concepts for *the automation of the NASA Center Tracon Advisory System (CTAS). Simulation studies were performed on the arrival traffic for one runway on Schiphol Airport* to determine potential benefits of CTAS on capacity and efficiency, with constant level of safety.

Aircraft Environmental Research

Calculations of Noise Loads

Noise loads were calculated for the actual situations at the large civil airports and at several military bases in the Netherlands. In addition, calculations were made for future situations at Amsterdam Airport Schiphol, several military airbases and airfields used by general aviation. Most of the calculations were made under contract to the Department of Civil Aviation and the Ministry of Defence.

Noise Monitoring

Under contract to the Ministry of Housing, Regional Development and the Environment, NLR took care of the management of the noise monitoring networks near the airbases of Geilenkirchen and Brüggen. Amsterdam Airport Schiphol was assisted in the design and realization of a noise monitoring network.

Calculation of Air Pollution

Under contract to the Netherlands Department of Civil Aviation, investigations were made of the emission of exhaust gases by engines of several aircraft types in various stages of flight. Under contact to the national government, NLR took part in international consultations on air pollution by aircraft.

Landing Aids

MLS

In the context of on-going activities regarding the ICAO Future Area Navigation Systems (FANS) and the ICAO All Weather Operations Panel (AWOP), the Netherlands Department of Civil Aviation (RLD) has installed an experimental Microwave Landing System on runway 01R of Amsterdam Airport Schiphol. NLR conducted initial flight trials to quantify the beam-holding characteristics of approaching aircraft using MLS guidance only to Category II levels. In addition, data are collected which will allow a comparison between ILS, MLS and differential GPS.

Automatic Approaches, Manual Landings under Cat III Conditions

Under contract to the Netherlands Department of Civil Aviation (RLD), NLR has conducted an investigation into the feasibility of "economic Category III operations", which would enable small and medium-size aircraft without autoland systems to perform landings under Category III visibility conditions.
The first objective of this investigation was the assessment of factors that play important roles in pilots' decisions when performing such approaches under Category III visibility conditions.
The second objective was to determine the feasibility of an automatic approach followed by a manual landing under Category III weather conditions.
To achieve these objectives, NLR's Research Flight Simulator was used to fly approaches under various conditions. Major test parameters included Runway Visual Ranges (RVRs) between 150 and 250 metres, varying crosswind conditions and a fixed Decision Height of 50 ft: The autopilot Minimum Use Height was 40 ft.
One conclusion of the investigation is that the autopilot system should be capable of delivering the aircraft within a narrow window at Decision Height with a very large probability of success. In addition, either an Align mode or a restriction on the maximum allowable crosswind is necessary for such a procedure.

Accident Investigations

NLR has supported the RNLAF in the investigations of accidents of their aircraft. NLR staff take part in the investigation teams, mainly to investigate possible technical causes of the accidents. Technical investigations were carried out for several accidents. In addition, instruction material was prepared for RNLAF pilots, to provide 'lessons learned'.

Risk Analyses for Airports

NLR is developing a method for the determination of the risk, including the calculation of the distribution of individual risks and the determination of group risks. The method has been conceived in 1992, computer programmes have been written and the method is expected to be complete early 1993. It will be used to calculate risks for Amsterdam Airport Schiphol, as required for the 'Milieu Effect Rapportage' procedure.

Training and Instruction

The RNLAF is routinely receiving support from NLR in operational training. NLR staff participate in exercises such as TACPOL, INTERPOL and REDFLAF. The support consists of assistance with the preparation and organization of the exercises, the evaluation and debriefing of the missions flown, and of briefings on topics relevant for the specific exercise. After the exercise, the results are analysed and documented.
NLR staff also provide instruction at the Royal Military Academy. A course on air-to-surface missions was given.

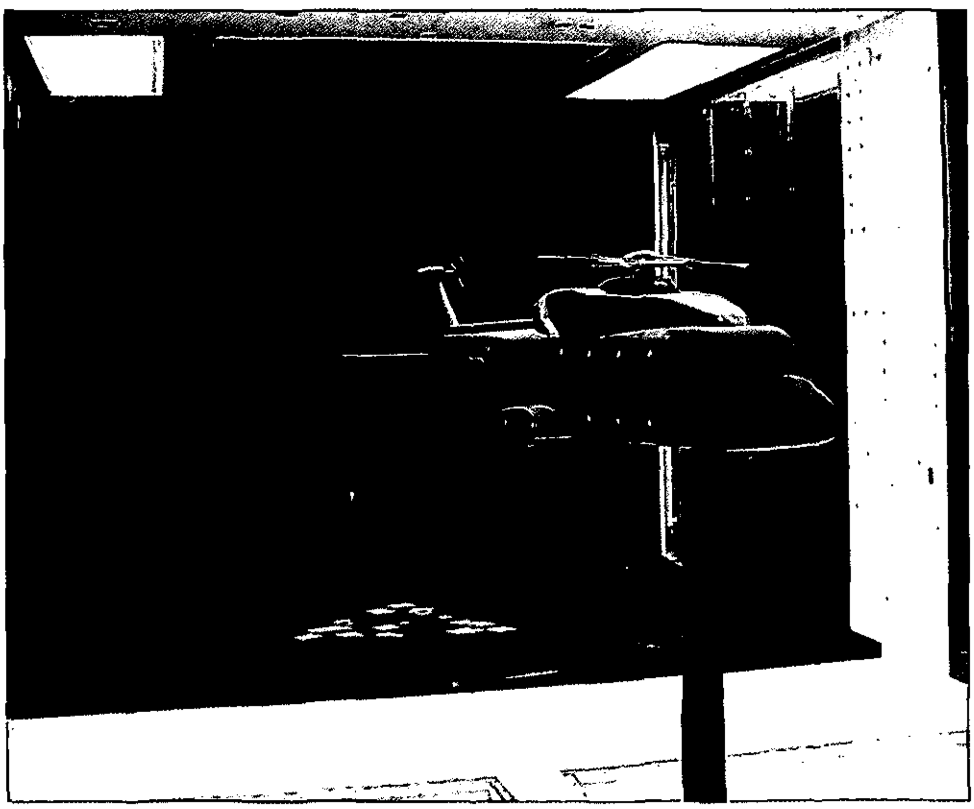
Helicopters

NLR participated in the activities of the GARTEUR "Helicopter Group of Responsables". Contributions were made to HC AG-06, "Mathematical Modelling for the Prediction of Helicopter Flying Qualities", HC AG-07, "Helicopter Performance Modelling" and HC EG-12 / AG-08, "Helicopter Vibration Prediction and Methodology".
The RLD was supported in connection with the Helicopter Airworthiness Study Group (HASG) for drafting JAR 27 and 29.

Together with Fokker and DAF Special Products, NLR has taken a share in the Design and Development phase of the NH90 programme, for a NATO helicopter for the nineties. A wind tunnel test was conducted in the LST using a model designed and manufactured by NLR. Supporting activities were carried out for the Programme Office NH90.

The Royal Netherlands Air Force and Army were assisted extensively in the activities related to the transport helicopter acquisition programme.
The RNLAF was supported similarly, with respect to a "Search and Rescue" helicopter acquisition programme.

For the Royal Netherlands Navy (RNN) a test program including flight testing at sea was carried out in order to certify helicopter operations on board the RNN M-frigate.



Model of NH90 helicopter, designed *and manufactured by NLR, in the* Low Speed Tunnel (LST)

Facilities and Equipment

New Research Aircraft

The purchase contract for a new research aircraft – a Cessna Citation II – was signed with the Cessna Aircraft Company. This aircraft will be owned and operated jointly by the Aerospace Faculty of the Delft University of Technology and NLR. In frequent communications with the manufacturer the special requirements – mainly based on the use of the aircraft as a research tool – were detailed. Regular contact was maintained with the Netherlands Department of Civil Aviation regarding the certification of the aircraft in the Netherlands. Preparations for taking delivery in March 1993 were started. The training of flight crew and mechanics was planned, the acceptance procedures were discussed and the planning of the ferry flight was started.

NFT (National Fly-by-wire Testbed)

The Citation II research aircraft will be converted into a test-bed suitable for fly-by-wire research. The project is in its definition phase.

Research Flight Simulator

The transport cockpit of NLR's Research Flight Simulator (RFS) has undergone a major upgrading in order to meet the requirements of present and near-future ATC-related projects. A total of six programmable Cathode Ray Tubes (CRT's) have been installed to arrive at a "full glass cockpit" configuration, as installed in modern transport aircraft such as the Fokker 100 and the Boeing 747-400. In addition, a programmable Flight Management System has been incorporated, and the system for communicating with NLR's ATC Research Simulator, NARSIM, has been extended and improved. Right after completion of the upgrading, a project aimed at improved ground-to-air data-link communication was started, under contract to RLD and the US FAA.

Interior of the upgraded transport cockpit of NLR's Research Flight Simulator (RFS)

National Simulation Facility (NSF)

NLR has continued the development of a flexible and versatile National Simulation Facility (NSF) as an extension to its existing flight simulation facilities. User requirements and system functional requirements have been defined.
An F-16 cockpit, in Midlife Update (MLU) configuration, has been completed by General Dynamics and shipped to NLR. The procurement of the computer-generated visual system has been prepared. The development of the software was started; the software configuration predesign was completed. A new computer system was ordered.
The NSF is developed in phases, the first phase, called Basic NSF, is planned to be completed by the end of 1994. Developments in following phases include making possible low-level flight simulation, mission rehearsal and helicopter simulation.

Helicopter Simulation

Validation of a mathematical helicopter model to be used in the National Simulation Facility was continued. Results were compared with data obtained through international co-operation on mathematical modelling. A lot of attention was paid to limiting the demand of computer power such that real-time calculation can be achieved, to allow pilot-in-the-loop simulation.

NARSIM

The development of the NLR ATC Research Simulator (NARSIM) was continued. The performance of the host computer has been improved, and the ATC workstations have been extended with programmable touch input devices (TID's) and tracker balls for human factors research. Rate sensing software has been developed to improve the functionality of the three-button mouse.

AAI

In NLR's Avionics-ATC integration project (AAI), the connection between the ATC Simulator (NARSIM) and the Research Flight Simulator (RFS) was extended. Experiments were carried out with both facilities to test this connection for data transfer in both directions and for voice communication.

ART (Avionics Research Testbed)

To allow fitting two EFIS displays in NLR's Fairchild Metro II research aircraft to be used as an Avionics Research Testbed, major modifications to the cockpit are required. Some preliminary modifications were prepared. In addition to this, a GPS receiver was added to the instrumentation.
The preparations for installing the navigation display of the programmable EFIS were completed. The VHF-bidirectional data link between aircraft and ground station was tested. It will be used for the flight testing of new air traffic management concepts.

Facilities for Measurement and Processing of Flight Test Data

The technological development in the field of sensors is closely followed. A new accelerometer and a gyroscope have been evaluated. The development of a 5-hole sensor for high dynamic directional airspeed measurements has progressed to the status of wind tunnel tests. In-flight tests will be performed in 1993.

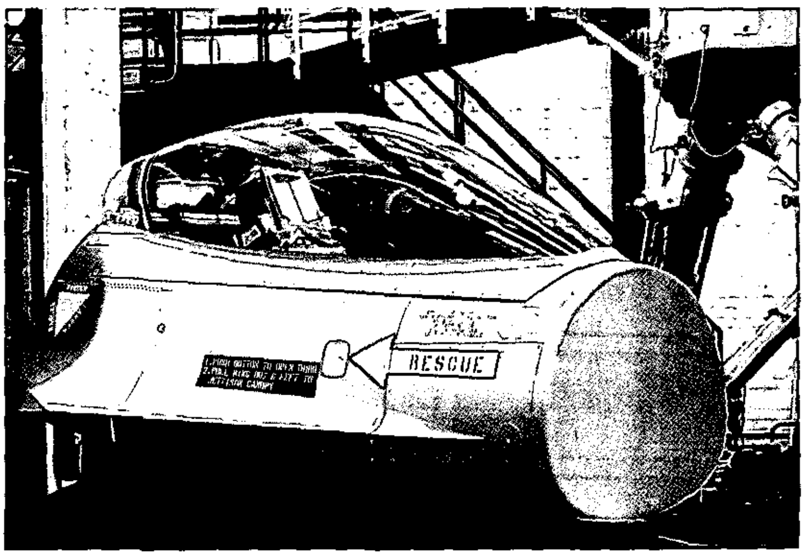
A new measurement system for use on board helicopters during helicopter/ ship qualification testing was developed.

The software for the computer for the processing of flight test data has been optimized, now taking full advantage of its 32-bits operating mode. The specifications for a new data processing system were studied.

Calibration and Test Equipment

An avionics and integration test facility providing programmable IRIG PCM, ARINC 429 and MIL-STD 1553 data streams was acquired. It will be used for testing flight test instrumentation packages in the laboratory.

The pressure calibration facility passed the yearly audit by the Netherlands Calibration Organization NKO. The quality assurance system described in the new quality manual was implemented and internally audited. Technical developments included improvement of the angle calibration set up and the preparation of a major overhaul of both software and hardware of the electrical filter calibration facility.



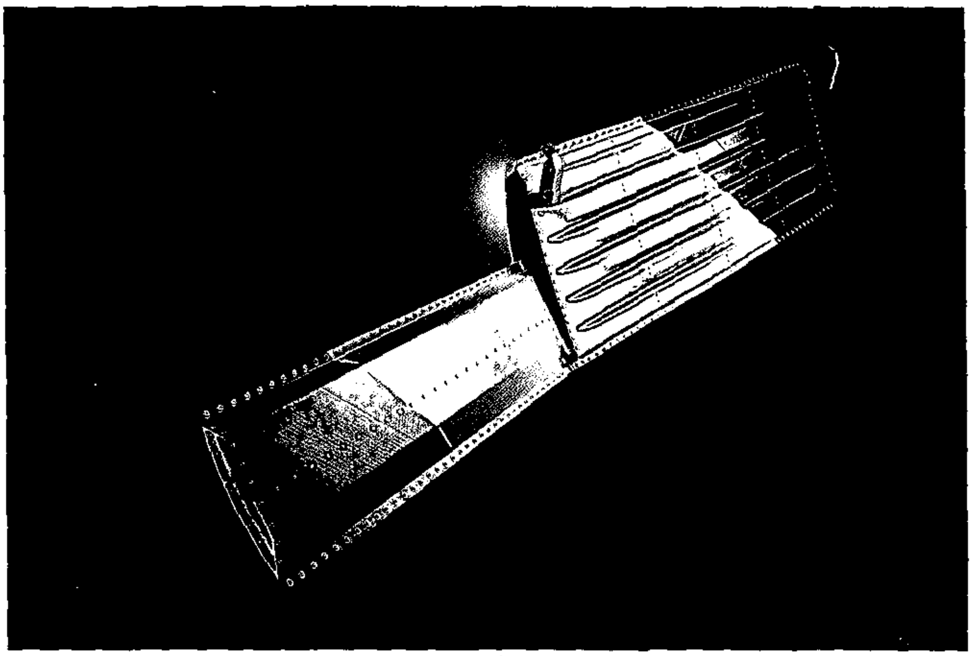
F-16 cockpit in MLU configuration to be mounted on the moving base of the National Simulation Facility (NSF)

3.3 Structures and Materials

Summary

The programme of research and development in structures and materials was marked by a steady growth of collaborative projects in the field of pre-competitive research and by a further integration with industrial activities where technology development is concerned.
Another noticeable development is the gradual increase of interdisciplinary relationships. The relatively strong position in research areas such as load and usage monitoring and damage tolerance methodology led to an increasing volume of contract research for both national and foreign customers.

Under contract to RLD and the US Federal Aviation Administration (FAA), NLR takes part in the FAA Aging Aircraft Research Programme. NLR has gathered European load data from existing sources and has defined procedures to re-analyze these data and achieve a common format. In addition, NLR performs an advisory role in a planned project of flight load measurements in large transport aircraft as well as commuter aircraft within the United States.
Also the structural safety associated with the damage tolerance of lap joints in ageing aircraft is addressed. The results of tests on specimens representative of Fokker aircraft fuselages and on specimens used by the FAA will provide a better understanding of multiple site damage (MSD) and they may lead to design recommendations.



Prototype thermoplastic Main Undercarriage Door set for the Fokker 50, successfully fabricated and tested by Fokker special Products and NLR. A weight savings of about 30 per cent has been achieved with respect to an optimized aluminium door. In addition, improved service performance is expected.

A test facility for fuselage panel structures under simulated differential pressure and fuselage bending was designed, and its development is now in progress. Under a BRITE/EURAM collaborative programme, second generation aluminium-lithium alloys were studied; the combination of fatigue and corrosion properties does not make these alloys attractive alternatives to conventional aluminium alloys.

In the framework of a national aeronautical technology development programme, a method for the prediction of noise transmission through a fuselage wall was further developed, to enable the method to rank different structural wall concepts for design studies.

Optimization studies in structural design are now focused on the preliminary design phase. A preliminary design program, called ADAS (Aircraft Design and Analysis System), is being further developed in co-operation with the originator, the Faculty of Aerospace Engineering of the Delft University of Technology. In a GARTEUR co-operative programme, different approaches to multilevel optimization were investigated. Selected methods will be implemented in the ADAS package.
The crashworthiness of composite helicopter structural parts was investigated. The application of hybrid composite structures incorporating different types of fibres was successful.

Fibre metal laminates like Arall and Glare have fatigue properties superior to monolithic aluminium. However, the blunt notch strength and residual strength properties are only little better, if at all. Under contract to NIVR, NLR undertakes the development of accurate prediction methods for these properties. Also, under the Brite/Euram programme ACOUFAT, the acoustic fatigue characteristics of fibre metal laminates were investigated.

Under the auspices of the Independent European Programme Group (IEPG), an experimental and analytical investigation of fatigue and creep crack growth in gas turbine disc materials was begun. Major aspects of NLR's contribution are the monitoring of short crack growth at high temperature, the use of a complex load sequence, "Hot Turbistan", representative for actual disc usage and the development of elastic-plastic modelling of fatigue and creep crack growth.

On an ad hoc basis, failure analyses were performed to assist in investigations of civil and military aircraft accidents and incidents. Corrosion and fatigue played significant roles in many cases. In most instances, design and/or maintenance deficiencies were identified and remedial actions proposed.

Aircraft Loads

The application of so-called Power Spectral Density (PSD) Criteria for the determination of Gust Design Loads is difficult in cases where the aircraft response is non-linear, for example when gust load alleviation systems with limited authority are fitted. NLR developed a technique, indicated as "Discrete PSD-Method", whereby a discrete gust profile is generated which induces aircraft loads compatible with those defined on a pure PSD basis. This technique has been further developed to be used in case of non-linear aircraft response.

Under contract to RLD and FAA, NLR takes part in the FAA Aging Aircraft Loads Programme. NLR has gathered European load data from existing sources and has defined procedures to re-analyze these data according to a common format. In addition, NLR acts in an advisory role with regard to the instrumentation and data processing for planned flight load measurements in large transport aircraft and commuter aircraft within the United States.

Under contract to the Indonesian aircraft industry IPTN, NLR has participated in the definition, acquisition and development of a nine-channel flight load monitoring system. This system is currently installed in three operational CN-235 aircraft. The system is intended on the one hand to verify the design load spectra of the aircraft and on the other hand to obtain statistical information on the loading environment in the Indonesian Archipelago.

The Fatigue Load Monitoring programmme of F-16 aircraft of the Royal Netherlands Air Force has been continued. Four aircraft within each squadron are equipped with a four-channel recorder, measuring wing root bending moment, speed, altitude and centre of gravity acceleration or engine RPM.
A programme has been started to reduce the operational fatigue life consumption by making judicious use of store configurations.

In addition, NLR is carrying out load and usage monitoring programmes for other aircraft and helicopters, for the RNLAF and the Royal Netherlands Navy, and for foreign Air Forces.

Dynamic Analysis of Structures

In the framework of a national aircraft technology programme (VTP), a method for the prediction of noise transmission through a fuselage wall was further developed. The dynamic behaviour of the exterior fuselage structure in combination with cabin panelling and the cavity in between was being modelled, to enable the method to rank different structural wall concepts for design studies. Also, the description of damping in the analysis method is being improved. Moreover, methods to increase the damping, like applying tuned dampers or special adhesive layers are investigated.

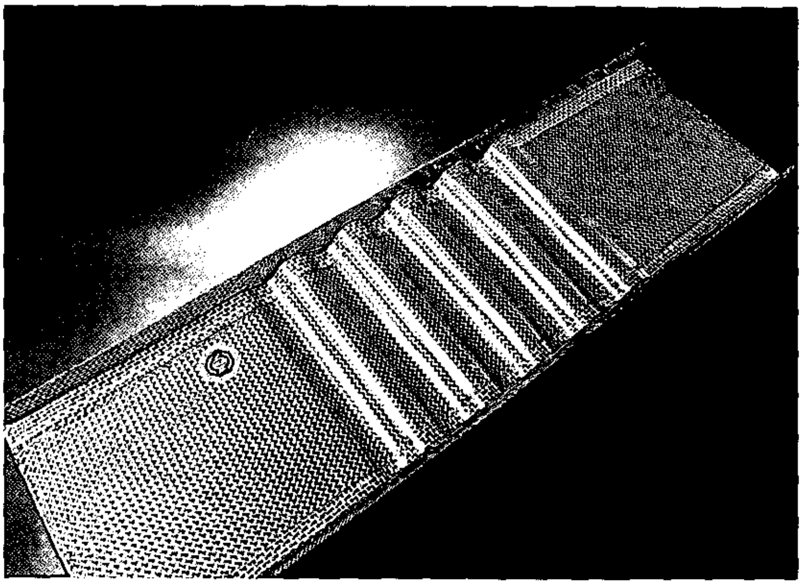
Strength and Stiffness of Structures

Under contract to NIVR, a feasibility study is performed on the application of optimization methods at different stages of the structural design process. The panel optimization code "PANOPT" was developed and has been successfully applied for design studies on composite panels in the framework of the VTP.
The optimization studies are now focused on the preliminary design phase. A preliminary design program, called ADAS, is being further developed in co-operation with the originator, the Faculty of Aerospace of the Delft University of

Technology. The finite element code B2000 used by NLR is added to take into account the structural aspects. In a GARTEUR co-operative programme, different approaches to multilevel optimization were investigated. Selected methods will be implemented in the ADAS preliminary design program.

The investigation under contract to NIVR of the postbuckling behaviour of composite panels is being finalised. The postbuckling behaviour of undamaged panels is predicted correctly by the PANOPT program as well as by the general purpose codes STAGS and B2000. However, final panel failure and damage behaviour in an impact damaged panel will be a subject of a follow-on project starting in 1993.

Methods are developed to analyze and optimize spar web concepts.



Sine wave spar web configurations have demonstrated a favourable and predictable energy absorption behaviour in crash situations. Manufacture by the traditional autoclave process starting from a hand-laid-up prepreg stack proved difficult, while resin transfer moulding produced a better product at lower cost.

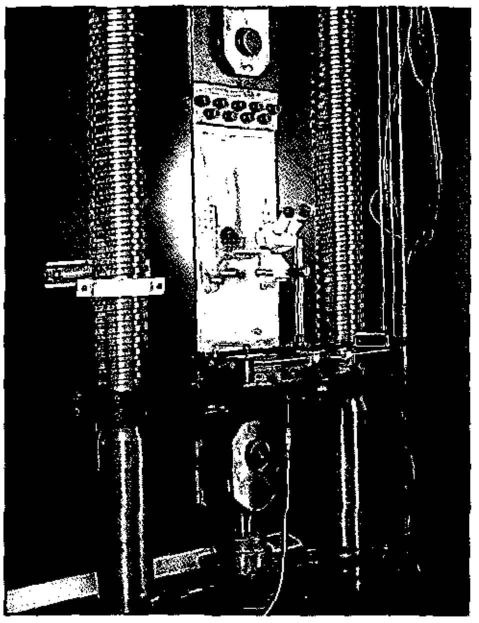
As a new activity, the crashworthiness of composite helicopter structural parts was investigated. A box-type composite structure has been designed, analysed and tested both statically and dynamically. The application of hybrid composite structures incorporating different types of fibres was successful.

Damage Tolerance of Materials and Structures

The structural safety associated with the damage tolerance of lap joints in aging aircraft is addressed in a programme under contract to the RLD, co-sponsored by the FAA. Crack initiation and crack growth at multiple sites in a lap joint under bi-axial loading are investigated in specimens representative of Fokker aircraft fuselages. Also, test specimens used by the FAA in uniaxial tests are subjected to biaxial loading. These tests will provide a better understanding of multiple site damage (MSD) and they may lead to design recommendations.

The crack growth rate in metal structures is largely determined by the strain condition near the crack tip. NIVR has granted a contract to investigate this effect in detail. This investigation must lead to models that can be applied in feasible engineering methods for crack growth prediction.

The durability test on the stabilizer and fin of the Fokker 100 was continued. It now includes loads caused by torsional fin vibrations due to stabilizer excitation by thrust reverser operation.



The development of multiple site cracking in a fuselage lap joint was studied, under an FAA contract, in 14-inch-wide specimens. Doubler strips are provided to create a non-uniform rivet load distribution representative of a fuselage structure featuring tear straps.

The aluminium alloy/aramide fibre laminate ARALL has fatigue properties far superior to monolithic aluminium. However, the blunt notch strength and residual strength properties are only little better, if at all. This necessitates the development of accurate prediction methods for these properties. As part of an NIVR programme, NLR made an experimental investigation of the residual strength of doublers with a crack at the thickness transition. Also, both experimental measurements and finite element calculations were done to determine the stress and deformation states at the edges of holes (blunt notches).

The BRITE/EURAM programme ACOUFAT (Acoustic fatigue and related damage tolerance of advanced composites and metallic structures) was completed. Shaker tests to simulate acoustic loading were performed on GLARE coupon-type specimens, showing that GLARE has a slightly better acoustic fatigue behaviour than Aluminium 2024.

For a number of years, a considerable effort has been directed to the study of the influence of defects on the compressive strength of composite laminates. In 1992 one investigation was aimed at determining the effects of defects on biaxially loaded carbon-epoxy laminates, and another was begun with the goal of predicting the post-impact-damage compression strength using the modelling concept of replacing the actual damage by a more simple but equivalent damage shape.

In a BRITE/EURAM programme, NLR concentrated on the development of surface layers that protect against impact damage in composites, and under the auspices of IEPG TA21 a study was made of the improvement in damage tolerance when replacing ±45° prepreg layers by fabric prepregs. Finally, as part of a GARTEUR programme, a mini-specimen was designed for the examination of the intrinsic compression properties on a microscale inside a Scanning Electron Microscope (SEM).

Under the auspices of IEPG, TA31, an experimental and analytical investigation of fatigue and creep crack growth in gas turbine disc materials was begun. Major aspects of NLR's contribution are the monitoring of short crack growth at high temperature, using an optical system; the use of a complex load sequence, "Hot TURBISTAN", representative for actual disc usage and the development of elastic-plastic modelling of fatigue and creep crack growth.

Materials Characterization

The evaluation of damage tolerant aluminium-lithium alloys in a BRITE/EURAM programme was completed. In this programme the latest versions of the sheet alloys 2091-T84 and 8090-T81 were compared with the industry standard alloy

2024-T3, with respect to fracture toughness, fatigue crack growth and corrosion properties. In agreement with previous results, it was found that these alloys are not direct replacements for 2024-T3, as is also the case for the 6013-T6 alloy.

As part of a GARTEUR programme, the fatigue crack growth properties of the damage tolerant aluminium-lithium plate alloy 8090-T8171 were investigated. This alloy compared well with 2024-T351 plate, under both constant amplitude and flight simulation loading, although the ductility of the centre of the 8090 plate was low, and there was some tendency for out-of-plane fatigue crack deviation.

The aluminium alloy/glass fibre laminate concept GLARE has a configuration with biaxially laid up glass fibre layers that has been specially developed for potential use in pressure cabins. Riveted lap joint specimens of this GLARE configuration were fatigue tested under biaxial loading in comparison with similar specimens made from ARALL and monolithic 2024 aluminium.

The mechanical properties of thermoplastic composites depend partly on the degree of matrix crystallinity; measurements showed that the crystallinity decreases when cooling rates exceed 30 °C per minute but the influence on the composite fracture toughness and shear strength was found to be slight.

As part of the IEPG TA-21 project, the effect of temperature cure conditions on both the rate of the chemical reactions and the viscosity profile were investigated. The objective is to derive models describing the effects of temperature and curing tune in order to optimize the cure cycle for a given product.

An acceptance criterion was formulated for pre-heating of uncured composite plies during the laminating process, as this will simplify the production of complicated composite parts. An investigation was done to determine whether such heat applications are tolerable from a materials point of view.

To assist the RNLAF in selecting paint systems for the F-16, corrosion tests were performed on various aircraft paint, primer and pre-treatment combinations. There was no evident superiority for any one of the systems considered here with respect to corrosion protection and paint adhesion.

Failure Analysis

Under contract to the RNLAF and the RLD, structural and material investigations were performed on engine or engine-related components after accidents and incidents which took place in 1992. Corrosion and fatigue played a significant role in many cases. In the process of building up expertise on failure analysis of advanced composites, NLR takes part in an activity of GARTEUR on fractography of fibre reinforced epoxies.

In order to carry out failure analyses on advanced fibre composites in the future, NLR takes part in a GARTEUR activity on composites fractography.

High Temperature Materials

Under contract to the RNLAF, high-temperature braze repairs on afterburner section components were evaluated. Braze repairs are to replace currently applied labour-intensive weld repairs.

In co-operation with Techspace Aero, ceramic coatings were tested in NLR's burner rig at temperatures of about 1000 °C.

For gas turbine hot section blades, life extension is economically preferable to replacement. Microstructural degradation is a major factor in service life consumption. Accordingly, investigations were performed on carbide precipitation in the cast nickel alloy IN-738, with a view to estimating when to apply rejuvenating heat treatments.

Facilities and Equipment

A test facility for fuselage panel structures under simulated differential pressure and fuselage bending was designed, and its development is now in progress.

The new digital image analysis system was subjected to acceptance tests. Some modifications were made, and the system is now being implemented.

The ASCOR (Automated Stress COrrosion Ring) test was developed for stress corrosion testing of aluminium alloys. The test is completely automated and enables stress corrosion crack initiation lives to be determined without visual inspection, while fulfilling the specifications of ASTM Standard G44.

The minute thickness step at the end of a fingertip doubler constitutes a fatigue-sensitive location in a fibre-metal laminate structure with otherwise superior damage tolerance. Thermoelastic stress measurements were used to support the analysis of experimentally observed damage development.

3.4 Space

Summary

Under contract to Fokker Space & Systems (FSS) and NIVR, NLR participates in the development of the Italian-Dutch X-ray satellite SAX. The participation of NLR consists of the development of the application software for the Attitude and Orbit Control System (AOCS), the integration and testing of the software in a functional model (FUMO) of the on-board computer for the AOCS and the development of a Test and Simulation Assembly (TSA) for these tests.
The SAX-TSA was tested and delivered early 1992. It was then integrated and tested with the FUMO and its basic software (BSW), made by the Italian firm Alenia. FUMO and BSW were integrated with the Basic Attitude Control software during the second half of 1992. The integration and testing of the software will be completed in 1993.

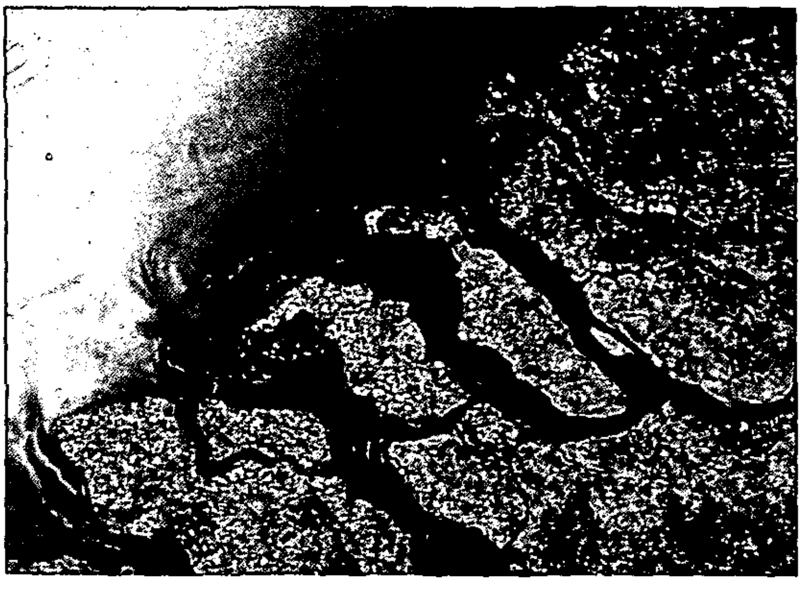
In the framework of ESA's In-orbit Technology Demonstration Programme, an experiment will be carried out with a two-phase heat transport system, on board

of a Space Shuttle, in October 1993. The experiment consists of a closed system, partially filled with ammonia, which transports heat by means of evaporation and condensation. The flow itself is driven by capillary forces. The experiment is a joint effort of NLR as main contractor, SABCA (Belgium), Bradford Engineering (BE), FSS and Stork. The experiment will verify the correct functioning of the capillary pump, developed by SABCA, the quality sensor, developed by NLR and BE, the condenser, developed by FSS and the three-way valve, developed by BE.

On 9 April 1992 the Wet Satellite Model (WSM) was launched by the sounding rocket MASER-5. The WSM experiment was performed to study the behaviour of liquid in a partially filled container under micro-g conditions and to measure satellite movements with a simple strapdown system, consisting of nine accelerometers. Under contract to ESA, a pre-feasibility study was performed to investigate the possibilities of a similar but larger satellite, the Slosh Test Orbital facility (STOF) to be launched from a platform in a Space Shuttle.

During the past few years NLR has participated in an ESA study on the infrastructure which will be needed to support future users of the Columbus Space Station during the preparation and execution of their experiments. Under contract to NIVR, NLR concentrated on the requirements for a Dutch Utilisation Centre (DUC). A pilot project was defined and demonstrated at the International Space Year conference at Munich (Germany). An ESA/NIVR project has been started to develop in co-operation with ICT a software testbed for a smart telescience camera based on a high performance video acquisition system.

Under contract to NIVR and in co-operation with FSS, Stork Product Engineering and ICT Automatisering, a study is performed on 'Automation and Robotics for Microgravity Applications DEmonstrator' (ARMADE). The purpose of this study is the development and demonstration of technologies for internal automation and robotics to be used in microgravity facilities.
A development model for payload control systems is being realized to enable proper design of control systems, essential for the automation of microgravity-based experiment payloads. This so-called Payload Control Development Model will comprise comprehensive engineering guidelines in the form of reference models, standard procedures to support design consistency and traceability, as well as appropriate computer-based tools.



Synthetic Aperture Radar image from the ERS-1 satellite showing a part of Zeeland in the Netherlands

As in previous years, NLR acted as National Point of Contact (NPOC) for the distribution of Landsat, ERS-1 and NOAA remote sensing data for EURIMAGE and, on behalf of SPOT-Image, for the distribution of SPOT data within the Netherlands. NLR's own research on remote sensing was concentrated on monitoring techniques, geographical information systems and the processing of ERS-1 SAR data, in particular on the reduction of radar speckle by the combination of multitemporal images. Several flights were performed with the optical sensor CAESAR on board of NLR's Metro II research aircraft.

SAX

NLR continued its participation in the development of the Italian-Dutch X-ray satellite SAX under contract to Fokker Space & Systems (FSS) and the Netherlands Agency for Aerospace Programs (NIVR). FSS is subcontractor for the Attitude and Orbit Control System (AOCS) of this satellite, and the participation of the NLR consists of:
- the development of the application software for the AOCS;
- the integration and testing of the software in a functional model (FUMO) of the on-board computer for the AOCS;
- the development of a Test and Simulation Assembly (TSA) for these tests.

The application software for the AOCS consists of two parts: the Basic Attitude Control (BAC) modules and the Extended Attitude Control (EAC) modules. The BAC modules perform the primary attitude control functions required for the safety of the satellite, the EAC modules take care of the attitude control during the observations. The BAC modules were completed (see also Chapter 3.6).

The Test and Simulation Assembly consists of a Front End connected to and placed in the vicinity of the satellite, and a test computer. The Front End and the test computer are connected by an Ethernet line. The test computer simulates the satellite rotations due to the actuator commands from the AOCS, and sends back the resulting sensor signals to the FUMO via the Front End. Actuators and sensors are simulated during the first stages of the satellite integration, but are, replaced by the real hardware components later.

The SAX-TSA was tested and delivered early 1992. It was then integrated and tested with the FUMO and its basic software (BSW), made by the Italian firm Alenia. FUMO and BSW were integrated with the Basic Attitude Control software during the second half of 1992. The integration tests will be completed in February 1993. Integration and testing of the EAC software will be completed in the middle of 1993.

A second and nearly identical TSA was made under contract to Alenia, to be used during the integration of the SAX-satellite in Italy. The TSA software was adapted to the test system of Alenia. The TSA was delivered in May 1992.

For the European Space Agency (ESA), a separate study was begun to design and develop a modular concept of the TSA, based on VME or VXI standards.

Two-Phase Experiment

In the framework of ESA's In-orbit Technology Demonstration Programme, an experiment will be carried out with a two-phase heat transport system on board of a Space Shuttle, in a so called "Get Away Special" container. The experiment consists of a closed system, partially filled with ammonia, which transports heat by means of evaporation and condensation. The flow itself is driven by capillary forces. The experiment is a joint effort of main contractor NLR with SABCA of Belgium, Bradford Engineering (BE), FSS and Stork. The experiment will verify the correct functioning of the capillary pump developed by SABCA, the quality sensor

developed by NLR and BE, the condenser developed by FSS and the three-way valve developed by BE. The main tasks of the NLR are: thermal modelling, mission planning, providing control electronics and software, performing system tests and project management.
In 1992 the various components were made and calibrated. Special attention was given to the selection of a flow meter for low velocities. Integration will take place at Bradford and at SABCA, after which final tests will be performed at NLR. The Shuttle flight will take place in November 1993. The work is performed partly under contract to ESA and NIVR and partly under NLR's basic research programme.

Micro-Gravity Research

On 9 April 1992 the Wet Satellite Model (WSM) was launched by the sounding rocket MASER-5. The WSM experiment was performed both to study the behaviour of liquid in a partially filled container under micro-g conditions and to measure satellite movements with a simple strapdown system consisting of nine accelerometers. The processing of the results is in progress. Two aspects are being studied: the reconstruction of the motion of the WSM from the measured accelerations, and the analysis of algorithms for the fluid dynamics, using numerical simulations.

Under contract to ESA, a pre-feasibility study was performed to investigate the possibilities of a similar but larger satellite, the Slosh Test Orbital facility (STOF) to be launched from a platform in a Space Shuttle.

The study on diagnostic instrumentation techniques for microgravity experiments was continued. A proposal was made to Comprimo for a method to investigate protein crystallisation in space. For the Fluid Science Laboratory in Columbus, a study was made on speckle interferometry for the observation of fluid surfaces, with special attention to laser diodes as a light source.

Related to the development of instruments for the Columbus Precursor flights in Spacelab, the study on an optical analysis facility was continued under contract to NIVR. It will be used in Dornier's facility for "Bioscreening with Robotics".
Supporting activities have been executed in the preparation of a "Bubble, Drops and Particle Unit (BDPU)" in Spacelab by Alenia. Support is also given to a phase-A study by Alenia for the Fluid Science Laboratory in Columbus. In this study, NLR in co-operation with FSS investigates the reference instrument, the diagnostic methods and the control method by tele-operation or internal robotics.

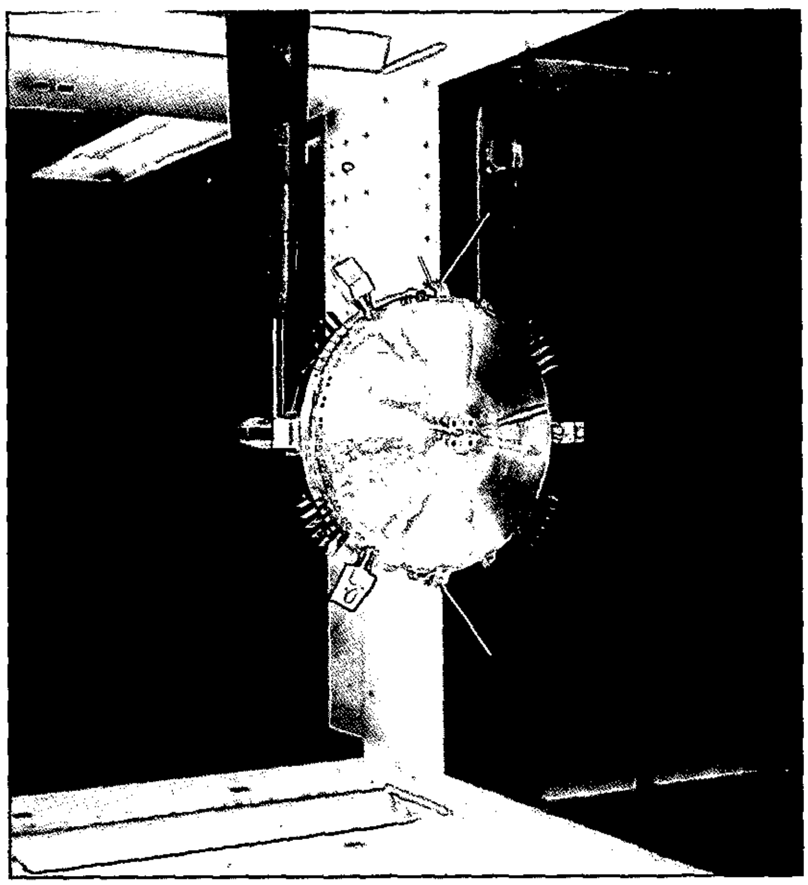
Telescience and Utilisation

Under contract to NIVR, the concept of telescience, remote control by telecommunications of scientific experiments, has been introduced to increase the efficiency of experiment development and execution in microgravity. To prepare for new technology developments, various Dutch experiments and telescience pilot experiments have been reviewed. An ESA/NIVR project has been started in co-operation with ICT of Deventer to develop a software testbed for a smart telescience camera based on a high performance video acquisition system.

During the past few years NLR has participated in a study of ESA on the infrastructure that will be needed to support future users of the Columbus Space Station during the preparation and execution of their experiments. NLR, under contract to NIVR, concentrated on the requirements for a Dutch Utilisation Centre (DUC). A pilot project was defined, based on an instrument for high performance capillary electrophoresis. Demonstrations with the DUC Pilot were given at the International Space Year Conference at Munich, Germany.

A proposal was made to ESA to utilize the user support organization concept in the activities with the Crew Work Station testbed, to be performed in 1993 under contract to ESA and NIVR.

The Dutch Utilisation Centre (DUC) will be used for the first time during the second German Spacelab flight D-2. Six experiments in the Anthrorack will be controlled by the Principal Investigator from the DUC at NLR's laboratory in the Noordoostpolder. The flight will take place in March 1993.



Model on scale 1:3.5 of Huygens probe descent module to be used in *the joint* ESA/NASA Cassini *mission* to Saturn, tested in NLR's Low Speed Tunnel (LST)

Space Robotics

In the past few years a computer program REALDYN has been developed for the simulation of flexible space manipulators, based on *a recursive Nth-order algorithm. This program was validated in 1992 with several multi-body systems,* such as the Hermes manipulator arm HERA, in co-operation with ESTEC, FSS and RAFAEL The program was also used to study the disturbances of micro-gravity experiments due to robot movements.

Under contract to NIVR and in co-operation with FSS, SPE and ICT, a study is being performed on an 'Automation and Robotics for Microgravity Applications DEmonstrator' (ARMADE). *The purpose of this study is the development and* demonstration of technologies for internal automation and robotics to be used in microgravity facilities.
A development model for payload control systems is being realized to enable proper design of control systems, which is essential for the automation of microgravity-based experiment payloads. This so-called Payload Control Development Model will include comprehensive engineering guidelines in the form of reference models, standard procedures to support design consistency *and traceability, as well as appropriate computer-based tools.*

Remote Sensing

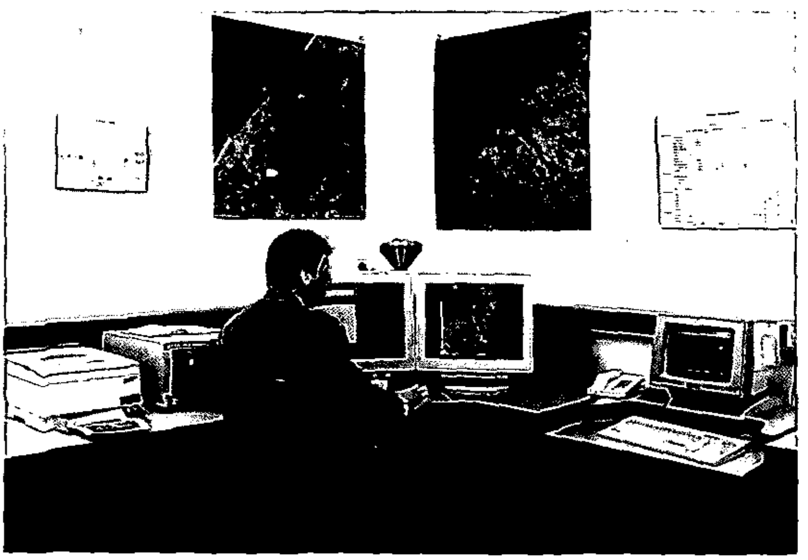
Under contract to NIVR, a mathematical description was formulated for monitoring. Monitoring, the detection of variations of objects on the earth's surface can for instance be used for the detection of deforestation. Under contract to the BCRS, a feasibility study was made of an operational forest-monitoring system for the Food and Agriculture Organization (FAO) of the United Nations. This study resulted in a proposal for a system for Forest Assessment and Monitoring Environment (FAME). FAME consists of two functional elements: RESPAS, for preprocessing of SPOT, Landsat, NOAA and ERS-1 data to standard products, and local systems, based on Geographical Information Systems (GIS), that use product of RESPAS to support local forest management.

In 1991 a study was made of the changes of the Jamuna river in Bangladesh, in order to detect the most suitable position for a bridge across the river. Under contract to Delft Hydraulics, the set of remote sensing data about the river flow was extended to the past 20 years, in order to investigate the processes that influence the changes of the river. Protection of the river embankments in the right places might prevent the river from overflowing in future.

Under contract to the BCRS, flights were performed with the optical sensor CAESAR on board of NLR's Metro II research aircraft, above the dunes of Oost-Voorne to study the possibility of monitoring the protective vegetation of the dunes, by means of remote sensing data. Flights with CAESAR were also made above the Loosdrechtse Plassen, the Amsterdam-Rijnkanaal and the Vecht river in order to investigate the quality of the water and the mutual interaction of these inland waters.

NLR's own research on remote sensing was concentrated on monitoring techniques, geographical information systems and the processing of ERS-1 SAR data, in particular on the reduction of radar speckle by the combination of multitemporal images. NLR has been appointed as the national centre for the reception of the Fast Delivery data of the ERS-1 Synthetic Aperture Radar.

As in previous years, NLR also acted as National Point of Contact (NPOC) for the distribution of Landsat, ERS-1 and NOAA remote sensing data for EURIMAGE and, on behalf of SPOT-Image, for the distribution of SPOT data within the Netherlands.



Remote Sensing Data Processing System (RESEDA) of NLR

Facilities and Equipment

Several improvements were made to the two-phase ammonia loop, in use for the selection and calibration of components for the TPX Two-Phase experiment. Special attention was given to the thermal modelling of the condenser and the development of a flow meter for low flow velocities.
Test procedures were developed for the Test and Simulation Assembly (TSA) and the Attitude Check Out Equipment (ACOE), with emphasis on the configuration control. Modifications were made to the FE-communication software, MACS-clock and RTM-UCE interface.

For the optical laboratory, a diode laser system was procured, for use in interferometry observations. A PC program was selected and purchased for the development and analysis of optical systems.

The development in co-operation with ICT of a user interface for the new Remote Sensing Data Processing System (Reseda) was almost completed. The software of Reseda was extended with a draw function, an image loop function and interactive classification.

A commercial robot system was selected for installation in the Space Division's robotics laboratory. The selection was based on simulations with the CAE program ROBCAD. The system will be used for hardware simulation of robotic operations on board spacecraft.

3.5 Informatics

Summary

Mathematical models and methods have been developed for a variety of applications in such areas as fluid dynamics, robotics, risk assessment, acoustics and earth observation.

The national project ISNaS, for computational fluid dynamics on the basis of the Navier-Stokes equations, has been concluded. The main activities concerned the development of a graphics-oriented user environment, the definition of public domain tools for data, software and document management, the development of a post-processing system for the analysis of flow simulation results and the design and production of a flow solver according to the ISO quality standard for process and product control. The multi-block flow solver (Euler version) has been verified for the multi-element airfoil application. The laminar version has been designed and produced; the turbulent version is being designed.

Integration testing of the software for the mission preparation function of the F-16 mission preparation system MSS/C was started. Test releases were made available to the prime contractor General Dynamics (from March 1993: Lockheed Fort Worth). The information preparation system of MSS/C was made operational for map scanning and handling of digital geographical and terrain data.

Under contract to RLD, the aircraft model of the basic ATC training simulator (made by Ferranti) was substituted by an extended model.

Under contract to Eurocontrol, the development of the Radar Sub System (RSS) of the SMART system (Simulator for Multi radar Analysis for Realistic Traffic) was started.

Measuring the effects of High Intensity Radiated Fields in a helicopter

In the field of airborne electronics, main research and development items were: integrated navigation systems (in the project TRIANGLe), performance assessment of the NAVSTAR Global Positioning System, the development of a Phased Array Airborne Synthetic Aperture Radar for remote sensing applications (PHARUS) and investigations into High Intensity Radiated Fields for supporting the establishment of certification requirements for airborne electronic equipment.
To support ATC studies NLR developed a Data Link Processor Unit which provides for digital communication between airborne avionics systems and ground based air traffic control centres. In 1992 a major software update, providing for enhanced functionality including the transfer of weather reports on pilot's request, neared completion.

NLR has headed an international consortium that has developed a demonstrator system supporting experiments with near-real-time rectified image transmissions, real-time compression schemes and encryption. The system has been implemented in the European Space Operations Centre's operational Meteosat dissemination system.

NLR has contributed to the microgravity sounding rocket programme of ESA by designing and delivering the subsystems for digital control and data acquisition and processing of an experiment module designed by FSS.
Data acquisition equipment designed by NLR for the European Transonic Wind Tunnel (ETW) was successfully installed.

The second phase of the project NICE, NLR's Infrastructure for Computer Aided Electronics Engineering (CAE), has been completed, adding analog and digital simulation for the automated design process as well as designing of wiring. The Avionics Test Facility and the Automated Calibration System have been extended.
The general availability of UNIX in NLR's computer network, from the NEC SX-3 supercomputer to workstations, made it possible to release a software repository function, which is based on commercially available and public domain software. Activities in the fields of High Performance Computing and Networking (HPCN) have started and are expected to grow.

ISNaS

The main activities related to ISNaS, the national project for the development of an information system for flow calculations based on the Navier-Stokes equations, concerned the user environment, data management, software management, document management and post processing. A graphics-oriented user environment was developed that enables users to start and control programs from a terminal or workstation in the computer network without knowing on which computer the files of data or programs are located. Commercially available software for data management was evaluated, and a simple tool was implemented. For the configuration management of software, a repository tool was implemented. This tool was also applied for document management. A post-processing system for the analysis of flow simulation results was developed. The project ISNaS was concluded by a presentation, a demonstration and a final written report to representatives of the government, industry and research institutes. Follow-on activities will be aimed at High Performance Computing for Computational Fluid Dynamics (CFD).

A pilot single-block Euler code has been validated. For this a C-type grid has been generated that in future can also be used for multigrid applications. The Euler version of the multi-block production flow solver has been verified for the multi-element airfoil application. A better performance has been obtained by improved vectorization. The laminar version has been designed and implemented. A turbulence model has been selected for the turbulent version, which is in the design stage.

Mathematical Models and Methods

As a follow-on of the development of a controller for the wind tunnel HST, research was started on closed loop identification of systems with variable time delay and on the applicability of adaptive predicting controllers.

A mathematical model has been developed for the representation of dynamical systems described by behaviourial inequalities. It has been determined when these representations can be called minimal. The first application of the model will be the control of constrained motion of space robots.

The applicability of neural networks for robot path planning has been investigated.

In support of the development of a method for the assessment of risk due to aircraft accidents in the vicinity of airports, a stochastic/statistical model has been specified.

The validation of the boundary element method for the determination of acoustic effects of vibrating solar arrays has started, in co-operation with Fokker Space & Systems. For the analysis of sound transmission through panels of cabin walls, a coupled boundary/finite-element model has been defined.

A mathematical model has been defined for a monitoring concept to be used in earth observation.

Tools

The availability of UNIX in components of NLR's computer network, from supercomputer to workstations, has enabled commercial and public domain software to be applied for the software repository function. The first release of a repository tool was made available for ISNaS and for a selection of other projects, for operational evaluation.

System Integration

Integration testing of the software for the mission preparation function of the Mission Support System MSS/C was started. The integration of over 40 software components was performed on an incremental basis. At the end of the year, the entire functionality was in the test phase, as well as the external interfaces. The first test releases were transferred to the prime contractor of MSS/C, General Dynamics (from March 1993: Lockheed Fort Worth Company). The information preparation system was put into operation. The production of map scanning was completed, and digital geographical and terrain data were fed into the system. Optical disk sets with data on the selected test area were produced to support the testing of the mission preparation function.

Under contract to the Netherlands Department of Civil Aviation (RLD), the aircraft model of its basic ATC training simulator (made by Ferranti) was substituted by an extended model. The feasibility of the new aircraft model had already been demonstrated. In order to prepare future integration of more sophisticated aircraft models, the way of interfacing was analyzed and documented. The modified simulator software was tested and transferred to RLD for operational use.

Under contract to Eurocontrol, the development of the Radar Sub System (RSS) of the SMART-system (Simulator for Multi radar Analysis for Realistic Traffic) was started. The German company Orthogon was contracted for the Trajectory Sub System (TSS) and the graphical user interface library. NLR's tasks are the development of RSS and the system integration. The designing of RSS has been supported by the CASE-tool Teamwork. The implementation is in the object oriented programming language C++. Testing was started.

Electronic Systems for Airborne Applications/Avionics

In the framework of the "Nationaal Technologie Programma (NTP)", the Ministry of Defence awarded NLR a contract to design, develop and flight-test an integrated navigation system based on the following three navigation sensors:

- Terrain Referenced Navigation (TRN);
- Inertial Navigation System (INS);
- Global Positioning System (GPS).

A Kalman-type integration algorithm was developed, validated and implemented in an on-board flight-qualified computer. The integration algorithm was coded in the Ada programming language. The algorithm integrates the individual solutions originating from the navigation sensors, taking into account the individual covariance matrices and figures of merit. The project, called TRIANGLe: TRN, INS and GPS Locationer, was completed. Flight tests have shown the system meets the objectives: high navigation accuracy and high robustness to external disturbances: jamming of GPS and degradation of TRN performances by flying over flat terrain.

The successful result of the TRIANGLe programme encouraged the formulation – in co-operation with DASA – of a follow-on programme RAPIN: Reliable, Autonomous, Precision, Integrated Navigation. The attention in this programme is focused on enhanced navigation accuracy and enhanced systems integrity.

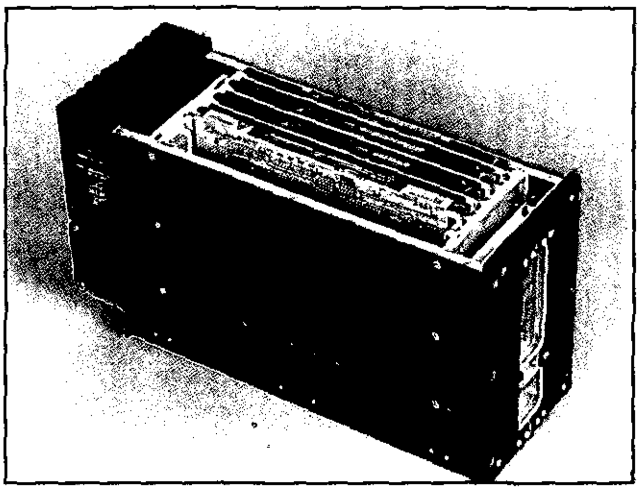
The Navstar GPS satellite navigation system is entering its operational phase. In the next ten years a number of other navigation systems will be phased out. A Working Group has been formed in NATO to deal with this matter: WG/5, "On GPS and other advanced navigation systems". A member of the NLR staff was elected as chairman of this Working Group, which provides for, among other things, exchange of information on navigation systems and devices, STANAGS (Standardization Agreements) on GPS signal characteristics, and Differential Military GPS.

Under contract to the Royal Netherlands Navy, NLR developed and built a prototype shipboard adaptive antenna for the Navstar GPS system, which potentially is able to reduce the influence of jammers.

DLPU

Following the successful development of one prototype and the delivery of twelve copies of the Data Link Processor Unit (DLPU) by NLR in 1989, Eurocontrol has awarded NLR a contract for upgrading the software of the DLPU. Eurocontrol conducts experiments with the DLPUs, which transfer data from avionics systems such as Air Data Computer, Flight Management Computer and Navigation

Systems on board aircraft to ground stations at the request of ground-based operators. NLR will integrate software that has been developed by the Technical University of Braunschweig (TUB) with the existing software of the DLPU. This will provide new functionality, such as the transfer of the latest weather reports to a cockpit printer, at pilot's request. The selected integration strategy will enable future software developments by the TUB to be easily migrated to the DLPU.
The enhancement of the DLPUs including their re-certification, based on RTCA document DO-178A by the Civil Aviation Authority is completed early 1993.



Data Link Processing Unit developed by NLR

F-16 Mid Life Update

NLR takes part in the multinational (NL, B, DK, NO, USA) programme for the Mid Life Update of the F-16, by contributing to the design of the new avionics suite, at Lockheed's Fort Worth premises, and by executing evaluations, at NLR's facilities. Contracts for this participation were awarded to NLR by Lockheed Fort Worth (formerly General Dynamics Fort Worth).

PHARUS

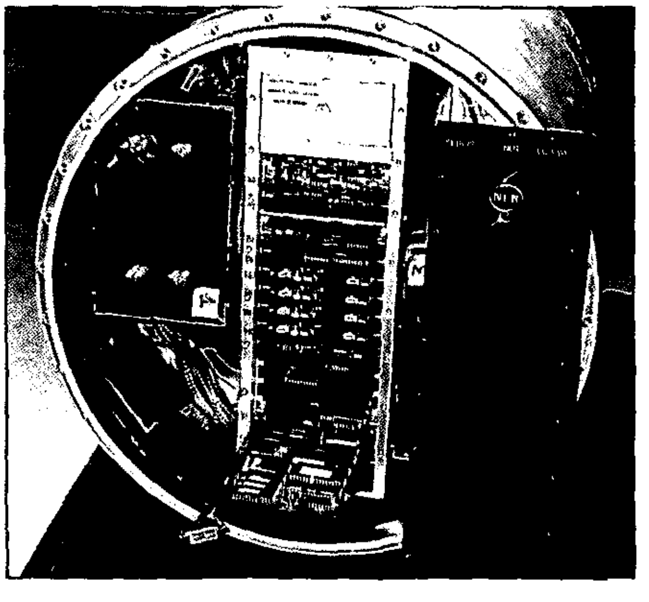
The PHARUS project consists of the definition, design and construction of a polarimetric synthetic aperture radar to be flown on a research aircraft of NLR. The project is a co-operation of NLR, the Physics and Electronics Laboratory TNO and the Delft University of Technology. NLR's contribution is the design of the electronics for digitization, preprocessing and recording of the radar signals, the design of the external container for the radar, the measurement of the trajectory and the aircraft operation.
In the electronics the radar signals are digitized at 100 million samples/sec; preprocessing operates on 40-bit wide data with processing speeds in the order of 50 MHz. A major design change has been introduced to incorporate a recording system capable of 100 Mbit/sec.

Electronic Systems for Space Applications

Under contract to ESOC, the main part of the project MERID (Meteosat Real Time Image Dissemination) was executed. NLR is leader of this international project, with MATRA-Espace (France), VCS (Germany), and ITC and BSO (the Netherlands) as participating industries. The MERID system is based on the Meteodis (Meteosat Dissemination) demonstration system developed by NLR in a previous project, where the possibility of applying compression and encryption in the Meteosat dissemination link was proven. In the MERID project, the demonstration system is extended to show the use of the selected compression method implemented in an operational real-time dissemination structure. This implementation enables the dissemination of the weather images to start as soon as parts of the raw data have been processed by ESOC. In this way, the meteorological users have early access to the images, which increases their value for operational use. At the same time, data dissemination gaps resulting from the data compression method are filled with other product data. The integration of the demonstration method with the operational Meteosat dissemination system in Darmstadt has been completed. Preliminary performance tests have shown that the MERID system enables dissemination of all Meteosat image data (three spectral channels) within about a quarter of an hour, leaving nearly half of the dissemination capacity available for the dissemination of other products.

New data compression algorithms were evaluated with respect to their applicability for remote sensing applications. In particular the effect of the use of wavelet compression on Meteosat image data and the use of vector quantisation for the compression of raw ERS-1 radar data were studied.

The sounding-rocket programme of ESA requires modules for biological experiments. Fokker Space & Systems (FSS) has designed the Cells In Space (CIS) module, for which NLR as a subcontractor to FSS has developed the electronic subsystems. CIS-3 was successfully launched early 1992. Preparations for the development of CIS-4 were started. Since CIS-4 requires a significant increase of the experiment capacity, preparatory investigations for a highly modular facility have been performed under the NIVR Space Technology programme, to limit the size of the on-board facility controller. A prototype of a Smart Thermal Interface Plate (STIP) has been developed to demonstrate the applicability of this modular concept.



Cells In Space (CIS) module, for research on living cells in microgravity, with electronic control systems developed by NLR

Multimedia Applications

The Columbus Attached Laboratory, Europe's contribution to the International Space Station, will be equipped with optical mass memory units, for storage of system software and maintenance documentation. NLR, together with Signaal Special Products, has developed a concept for a space-qualified CD-ROM drive,

based on a MIL-standard device. The design includes all necessary adaptions to meet the specific environmental and interfacing requirements of the Columbus module. The system is extendable to CD-Rewriteable and CD-Interactive.
NLR and BSO/CAT have developed a multimedia database, aimed at the microgravity user community. This database will be distributed on CD-ROM and contains textual, graphics, audio and video information on flown microgravity experiments, missions, launchers and related organizations. It demonstrates the feasibility of advanced multimedia technology to enhance information services in the space research area.

Ground Stations

The Artemis operational remote sensing system NLR developed for the Food and Agricultural Organisation (FAO) of the United Nations has been extended. The generation of operational products (thematic maps) was further automated, and the generation of sub-maps for external users in Africa was added. Maintenance of the Artemis system was carried out using a remote log-in facility from NLR.

The development of a low-cost station for the Meteosat and NOAA satellites has been studied based on the Meteosat receiver which is installed at NLR. This receiver was coupled to the NLR computer network to make the received data available for general research in the area of image processing.

Signal Conditioning, Wind Tunnel Instrumentation

In December 1992 the European Transonic Wind Tunnel (ETW) has taken delivery of a large amount of signal conditioning and data acquisition equipment for its cryogenic wind tunnel. This equipment had been developed and manufactured under a contract ETW awarded to NLR just one year earlier. The contract included delivery of Universal Signal Conditioning Units, Inclinometer Conditioning Units, Multi Channel Conditioning Units, RMS Conditioning Units, Calibration Generators, Data Acquisition Interfaces, Patch Panels and Cabling. In close cooperation with subcontractor Van Rietschoten en Houwens of Zaandam, the equipment was designed, manufactured, tested and calibrated, within a tight time schedule.

Under contract to the German-Dutch Wind Tunnel (DNW), NLR started the design and development of a new generation conditioning unit, its primary characteristics being remote control of parameter settings and remote control of maintenance. The conditioner will incorporate a transputer which also takes care of internal data processing (filtering) and external communication.

Computer Aided Design of Electronics

The second phase of the introduction of NICE, NLR's Infrastructure for Computer Aided Electronics Engineering (CAE) has been completed. The installation of a local area network, the backbone of NICE, has been finalised. The Viewlogic CAE application software has been extended with facilities for the simulation of analog and digital electronic circuits and with interfaces to existing CAE tools, including a tool for the automated design of complex cabinet wiring. A modern system for Computer Aided Design of complex Printed Circuit Boards (Ultiboard) has been procured and integrated in NICE.

Automating measurements and tests

The measurement process for the calibration of standards for electronic quantities was automated. For the generation of procedures an automated system (AKS) was used. The Avionics Test Facility (ATF) has been adapted to allow software development and test of the Data Link Processing Unit (DLPU) Model C. Among other things, ARINC channels have been introduced.

Environmental Conditions

In a co-operation with Germany, Sweden, UK and France, a model was established of the electromagnetic environment an aircraft may encounter during flight, the so-called HIRF environment (High Intensity Radiated Fields). This model will form the basis for certification requirements of new aircraft. The increasing dependability of aircraft on complex avionic systems, notably in fly-by-wire, has urged the civil aviation authorities to increase the level of the so-called susceptibility tests. New specifications have been set up already, which has induced NLR to plan expanding the capabilities of its ECM test laboratory. Powerful generators will be acquired to be used to generate high fields strengths.
As electronic equipment in aircraft may encounter lower field strengths than the aircraft itself – the hull may provide for attenuation – tests were carried out on an RNLAF helicopter to determine this attenuation. The results of these tests may be used in the establishment of requirements for avionics in new helicopters.

Visualization

The development of a common visualisation tools system, in the framework of GARTEUR AD (AG-16), has progressed. A common Particle Tracer has been finalised and its validation was started. The functional design of the Eurovis system has been further developed, and the user interface has been enhanced.

Satellite Attitude Control

As mentioned in Chapter 3.5, Space, NLR develops attitude control software for the Italian-Dutch scientific satellite SAX. Software modules, optimised with respect to the available memory, have been coded, tested and verified in a simulated satellite environment. Subsequently, parts of the software were delivered for integration tests with the real Attitude Control Computer and its Basic Software. These integration tests have been successfully completed and the software has been delivered to Alenia Spazio in Italy for integration with the satellite subsystems.

Networks

NLR participates in the ESPRIT project Pagein. The purpose of this project is to establish, to exploit and to evaluate a pilot European high speed network for aerospace research. The network will serve as a test bed for new forms of trans-european collaboration, and requires supercomputers, databases and multimedia visualization stations to be integrated, despite their geographical distribution.
NLR is responsible for the visualisation part, and participates in networking and validation strategies. In 1992 application and network requirements have been established.

High Performance Computing and Networking (HPCN)

NLR has begun participating in national and international HPCN initiatives. At the national level, discussions on the establishment of a national programme for HPCN have started with industries, research institutes and universities. Application areas will be Computational Fluid Dynamics and multiparticle systems.
At an international level, a GARTEUR Working Group on Informatics (WGI) was established, with HPCN as one of the main subjects. NLR was a founding member, along with DLR, ONERA and DRA. The institutes CIRA, FFA, INTA and several aerospace industries are expected to join the Working Group in 1993. Exchange of information about knowledge and facilities and about the question how to evaluate industry needs against the background of technical possibilities has started. There is general agreement that medium or massively parallel systems will not replace today's vector machines before 1996. NLR's modern and expandable supercomputing and network facilities can easily bridge this time frame.

Computer Facilities

NLR's central computer facilities consist of an NEC SX-3 supercomputer, Control Data CYBER 962 and 4000 mainframe computers/servers, workstations and other terminal equipment, connected via a communication network mainly based on TCP/IP.
This communication network is connected to other facilities of NLR, to computer equipment of major customers and to international networks.
The use of the computer facilities, especially of the supercomputer, showed considerable growth. The amount of data stored showed a similar growth. Attention was therefore paid to the enhancement of processing capacity and data storage.
Parallel processing on the supercomputer was introduced, and enhancement has been studied and discussed with NEC. Expansions of the main memory, extended solid memory and disc memory have also been discussed. Expansions of these memories from 0.5 to 1 Gbyte, from 1 to 4 Gbyte and from 20 to 60 Gbyte, respectively, are planned.
An investigation of mainframe/server capacity revealed a need for expansion. This led to the decision to install a CDC 4000 database server and a CDC 4000 file server, together with a Storage Tek tape robot. This tape robot has a storage capacity of 1500 Gbyte and enables the user to retrieve the information transparently, without time consuming tape handling by operators. Besides file serving and archiving, the tape robot also will be used for back-up purposes for computer equipment connected to the network. The tape robot was installed.

Environmental Testing

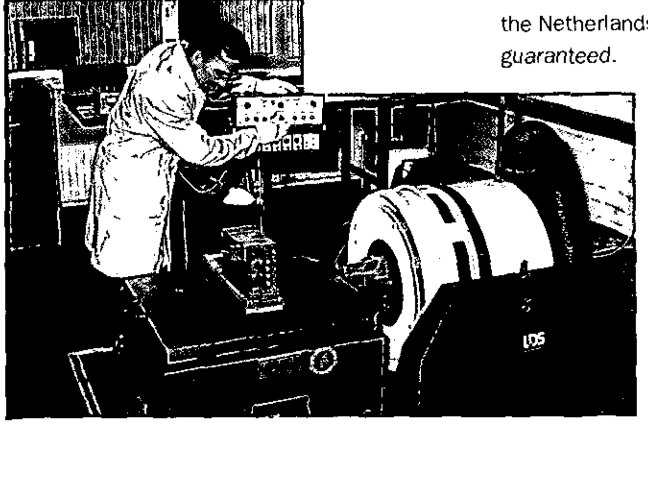
As in previous years, a lecture was held on susceptibility testing at a PATO course on EMC (PATO: Post Academic Technical Education).

Under contract to both military and civil, both national and international customers, EMI measurements were carried out on various equipment. Such EMI measurements determine the level of generated interference, and establish the susceptibility for interference.

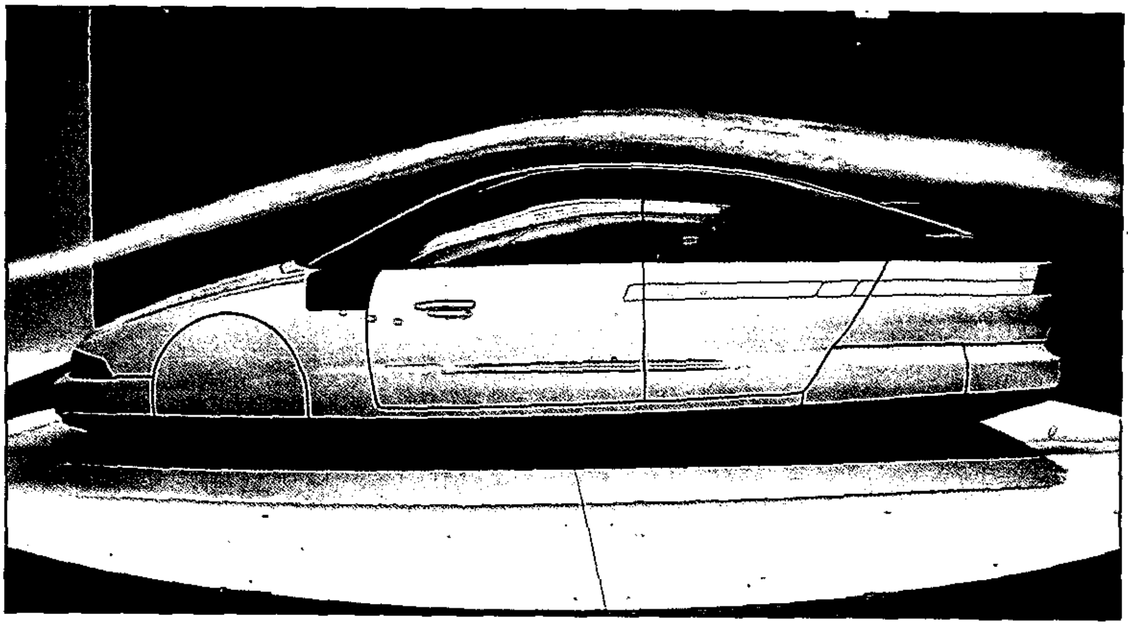
NLR has acquired and installed a new shock and vibration system, because of the fast growing importance of environmental testing and the growing number of stringent laws and specifications. The system consists of the following parts: a vibration control system delivered by LMS (Leuven Measurement Systems), a shaker with matched high power amplifier delivered by LDS (Ling Dynamic Systems) and a slip table delivered by Kimball. Shock and vibration tests can be performed with loads up to 122 kg and accelerations up to 100 g in a frequency range from 5 to 3000 Hz.

Quality Assurance

The calibration laboratory for electromagnetic quantities was certified again by the Netherlands calibration organisation NKO. Traceability of measurements is guaranteed.



Shock and Vibration System for environmental testing



Non-aeronautical testing: a wind
tunnel model of Nedcar in the LST

4.1 Research on High-lift Devices

Introduction

For low wing drag, aircraft wings should have areas as small as possible, causing wing loading to be high. Wing loading is limited, however, by requirements to aircraft speeds at take-off and landing. To achieve sufficiently low speeds, high-lift devices have to be applied then. Usually, wings are equipped with flaps (see figure 1). The development of more effective high-lift devices may help in improving cruise economy. In addition, research on wings with flaps may help in improving flight safety during take-off and landing. During the past few years, experimental and theoretical high-lift research has been carried out by NLR, partly in international co-operation.

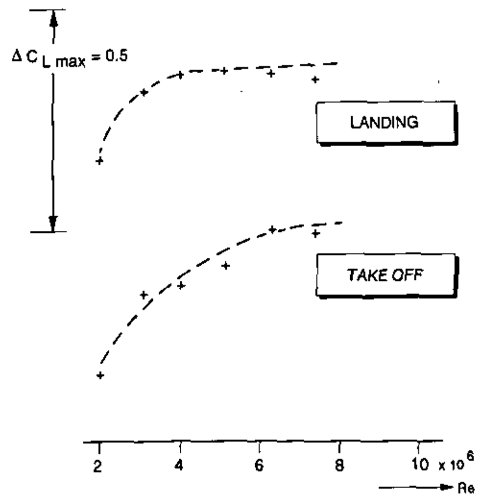


Fig. 3 – Effect of Reynolds number, Re, on the maximum lift coefficient $C_{L_{max}}$, of an airfoil section with flap and slat, at free-stream Mach number $M_\infty = 0.22$

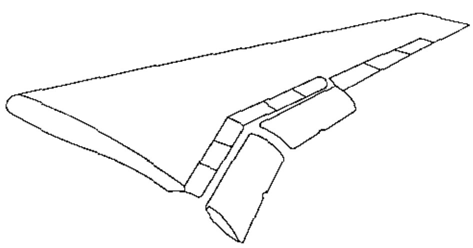
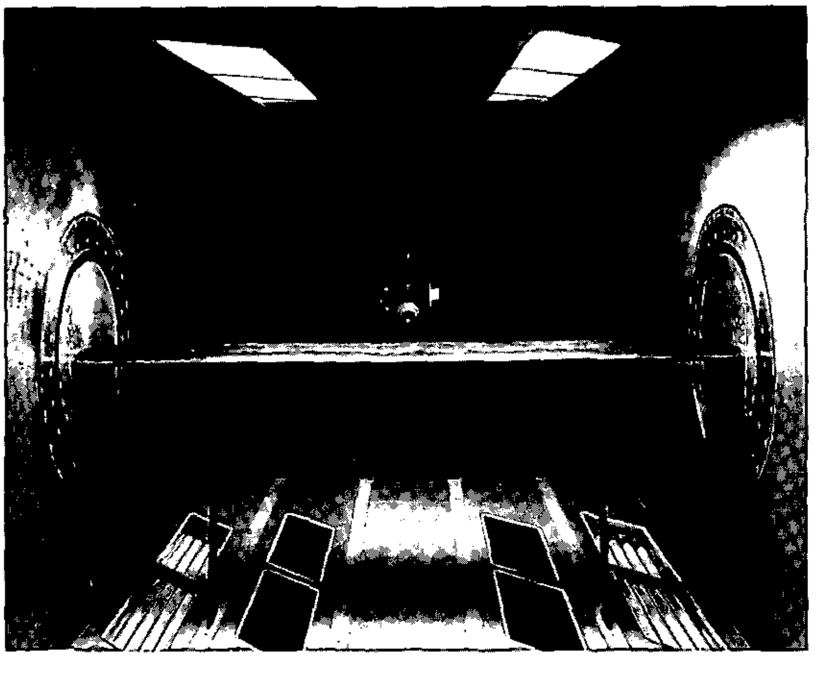


Fig. 1 – Sketch of wing with flaps extended

Fig. 2 – Two-dimensional test set-up in the HST



Experimental Research on Two-Dimensional Flow

For practical reasons, experimental investigations to determine optimum flap shapes and positions are usually carried out in two-dimensional test set-ups. A cylindrically scaled model of a wing section with flaps and/or slats is then mounted between two opposite wind tunnel walls. In the tests, the position of the flaps and slats relative to the main wing can often be adjusted, to find the optimum position. To ensure a two-dimensional flow at all high-lift test conditions, NLR applies boundary layer control by blowing air along the tunnel walls where the model is mounted. Testing is carried out both in NLR's low speed wind tunnel (LST) and in its transonic wind tunnel (HST). A two-dimensional test set-up in the HST is shown in figure 2.

As the stagnation pressure in the HST can be changed, the Reynolds number can be varied independently from the Mach number during testing. Both numbers are important parameters for the flow around wings with flaps. In model tests, the Reynolds number normally remains substantially below the flight value. An extensive investigation on the effects of Reynolds and Mach number variations on the properties of high-lift devices has been executed in the HST a few years ago, as a part of a GARTEUR co-operation project. Figure 3 shows the behaviour of the maximum lift of an Airbus wing section with a slat at the nose and a flap at the trailing edge, as a function of the Reynolds number varying between two and seven million. A substantial effect appears, notably for Reynolds numbers below four or six million.

In the French F1 wind tunnel, measurements have been carried out with a larger model of the same configuration, with Reynolds numbers up to seventeen million, which is close to normal flight values during take-off and landing. No large changes in maximum lift were found to occur for Reynolds numbers above six million.

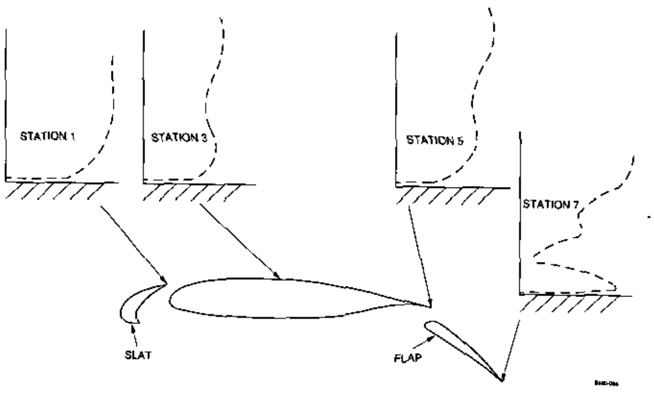


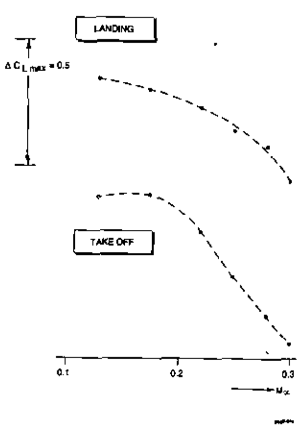
Fig. 4 – Measured boundary-layer velocity profiles on an airfoil section with flap and slat (for $M_{\infty} = 0.22$, Re = 1.9 million and $\alpha = 20^{o}$)

The GARTEUR investigation included more detailed flow measurements. Figure 4 presents results of boundary layer measurements executed in the LST tunnel on the high-lift model also tested in the HST. The results show that the wake of the slat merges with the main wing boundary layer half-way the wing. Subsequently, the combined wing and slat wakes merge with the flap boundary layer near the flap trailing edge. It is clear from the velocity profile graphs in figure 4 that the viscous flow above the flap is not a thin shear layer, but comprises a substantial part of the flow. High-lift configurations generally have discontinuities in their geometry. These discontinuities lead to local flow separations, notably in the slat cove and in the wing cove for the flap. On all wing elements, the transition from laminar to turbulent of the boundary layer flow may play a role that is strongly dependent on the Reynolds number.

The effect of variations of the free-stream Mach number on the maximum lift has been determined for the same high-lift configuration. The results of the tests made in the HST at a constant Reynolds number of four million with various Mach numbers are plotted in figure 5, showing a highly significant effect for Mach numbers above 0.22. The maximum lift decreases considerably at larger Mach numbers. The results demonstrate that, notwithstanding the low flight speeds during take-off and landing, it is important to carry out high-lift tests in the wind tunnel at the correct Mach numbers. The significant compressibility effects are due to the high suction pressures, which occur especially on the slat upper surface. The suction pressures may become so high that local flow velocities exceed the speed of sound. In these conditions the maximum attainable lift may be limited by the presence of a shock wave on the slat. Analysis of the test data has led to the conclusion that the effects of compressibility on.the maximum lift must be explained here by a series of coupled phenomena. The shock wave on the slat leads to an increased growth of the boundary layer on the slat and consequently to a thicker wake behind the slat. The thicker slat wake merges with the main wing boundary layer, which thereby becomes more prone to separation. Consequently, the presence of the shock wave on the slat appears to result in early flow separation near the trailing edge of the main wing.

The conclusion of the investigation performed, is that for modern efficient high-lift configurations the free-stream Mach number is an important parameter. The effect of Mach number variations should be investigated in wind tunnel tests. The two-dimensional test set-up in the HST, where Mach and Reynolds numbers can be varied independently in a relevant range, seems a very suitable facility for this purpose. For detail measurements and for preliminary investigations, the two-dimensional test set-up in de LST tunnel is more suitable.

Fig. 5 – Effect of the free-stream Mach number, M_{∞}, on the maximum lift coefficient, $C_{L_{max}}$, of an airfoil section with flap and slat, for Re = 4 million



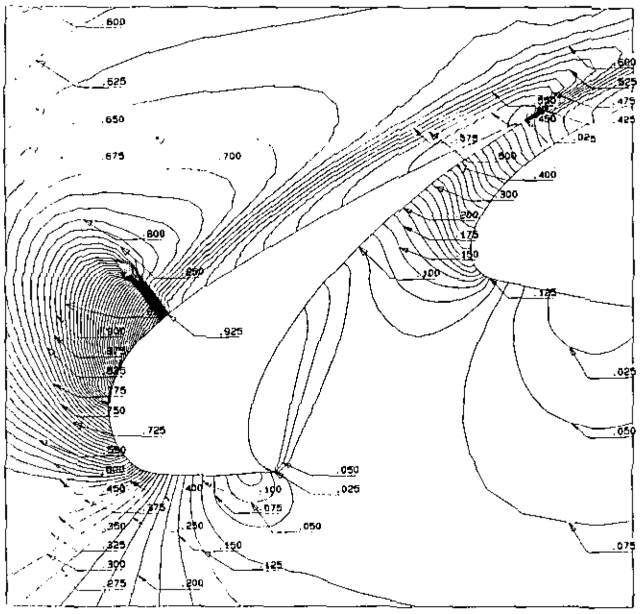
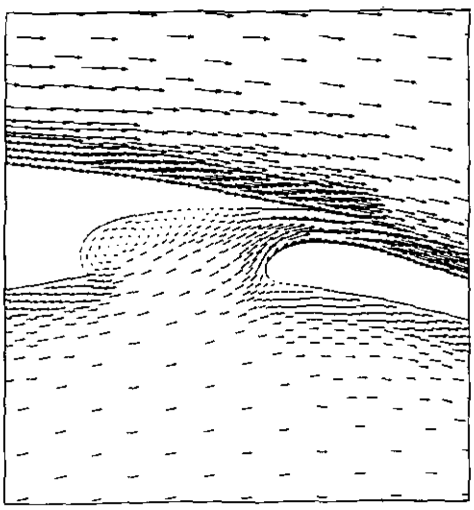


Fig. 6 – Lines of constant local Mach number, M, in the flow around the slat, calculated with an Euler code

Theoretical Research, Two-Dimensional Flow

To compute the influence of the free-stream Mach number, a calculation method is needed which treats compressibility and shock waves satisfactorily. For the calculation of the flow around a slat, the separation region in the slat cove cannot be neglected. Calculations have been carried out at NLR with a method based on the compressible Euler equations. Although this is an inviscid flow method, separation regions near sharp edges, such as at the slat hook, appear to be reasonably well simulated. Figure 6 presents the results of such a calculation for the wing section with slat and flap discussed in the preceding paragraph. The free-stream Mach number is 0.30 and the incidence is close to the value for maximum lift. The figure shows computed lines of constant local Mach number in the flow around the slat. The presence of a shock wave on the slat upper surface is clearly visible. The calculation results confirm the importance of compressibility effects and the occurrence of a shock wave of considerable strength, notwithstanding the low free-stream Mach number.

Fig. 7 – Velocity vector plot of the flow between the flap and the main wing, calculated with an Euler code



The computed flow field between the main wing and the flap is shown in figure 7. The local separation region in the wing cove appears to be well represented in the calculations, at least qualitatively. A similar local separation region has been computed in the slat cove, but is less clearly visible in figure 6 than in this velocity vector plot. The numerical calculations have been performed with an Euler code using a so-called unstructured grid. The application of unstructured grids for complicated high-lift configurations is important for easy application of the calculation method in industry environments.
In the near future, the Euler code will be extended with extra terms in the equations, to represent also viscous effects. This calculation method, which solves the Reynolds-averaged Navier-Stokes equations, is expected to become a valuable tool for the prediction of Reynolds and Mach number effects. It will support the aircraft industry in the development of efficient high-lift devices.

Three-Dimensional Effects

In the more distant future, the calculation method will be extended to three-dimensional flows around swept wings with part-span flaps. Measurements on models of complete aircraft with flaps extended for verification of the design are carried out in the German-Dutch Wind Tunnel (DNW) and, usually on half-span models, in the HST. The effects of wing sweep and finite span are very large in some conditions. For instance, it is known that the characteristics of the separation region in the slat cove may change essentially due to sweep. Research on this subject takes place at NLR in co-operation with the Indonesian aeronautical laboratory LAGG and aircraft industry IPTN and with Boeing of the United States. Measurements will be carried out in the Indonesian low-speed wind tunnel ILST on a half-span model of a fuselage with a wing equipped with a flap and a slat, at zero and 25° wing sweep. Detailed measurements will be made in the flow around the slat. As a preparation for these tests, potential flow calculations with a panel method have been executed at NLR for both the swept and the unswept wing (see figure 8).

Effects of Icing and Rain

When aircraft are operating in adverse weather conditions, the effectiveness of the high-lift devices can be seriously affected by deposit remainings on the surface. The contamination of the wing by frost is one of the potential problems. The subject has received increasing attention lately. The effect of frost is to create roughness on the wing surface. This can be simulated in wind tunnel tests by applying carborundum grains of aerodynamically equivalent dimensions on the surface. Two-dimensional measurements have been carried out under contract to Fokker Aircraft Industry in the LST on a flapped wing section with and without surface roughness. The influences of the extent of the roughened area and of the roughness size were investigated. Figure 9 presents the effect of roughness on the entire upper surface on the maximum lift as a function of the roughness size relative to the wing chord. A comparison is made between the effect for the wing section with only the flap extended and with flap and slat extended. Owing to investigations like these, the knowledge about the characteristics of high-lift wings in poor weather conditions is increasing, to the benefit of flight safety during take-off and landing.

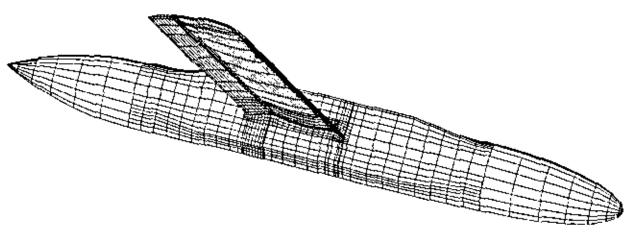


Fig. 8 – Panel method calculations to support an experimental investigation on the effect of sweep on a wing with flap and slat

Concluding Remarks

Up to now, the optimization of high-lift devices has received less attention than the optimization of the wing at cruise conditions. This is due mainly to the flow problems in high-lift conditions being so complex that no adequate research tools were available. However, improved experimental and theoretical tools have recently been developed or will soon become available. This should make possible the optimization of flaps and slats, at least for two-dimensional flow conditions. Further research is still needed for three-dimensional flows, to improve insight into the effects of sweep and finite flap spans.

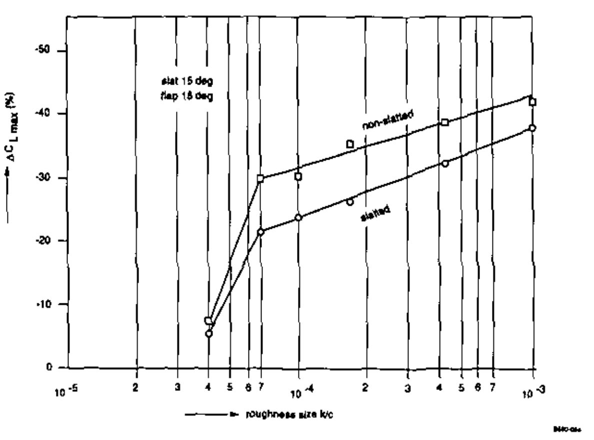


Fig. 9 – Effect of the size of surface roughness simulating frost, on the maximum lift loss for an airfoil section with slat retracted and extended

4.2 Aircraft Load Monitoring

Metal aircraft structures have limited fatigue lives. During the design of a structure, a design load spectrum is defined, based on the expected operational usage with regard to flight lengths, flight profiles, take-off weights etc, and on estimations of the loads associated with this usage. These estimations are based on statistical data on gust intensities at various altitudes, manoeuvre frequencies, sinking velocities at touchdown, etc. Adequate fatigue performance of the structure to withstand this Design Load Spectrum during the "Design Service Life" is demonstrated by analysis and, *possibly full scale, fatigue tests.*

Yet, in actual service, fatigue cracks occur unexpectedly early in fully proven aircraft structures. Quite often, it turns out that these cracks are due to the actual load experience in service being different from, and more severe than, the design assumption.

Such a difference can have two causes: the loads associated *with a specific usage are different from the design assumption*, or the actual aircraft usage is different. With regard to the latter cause, it should be realized that one type of aircraft may be used by different operators in quite different ways. This applies to military aircraft with multi-role capability but *also to civil transport aircraft:* one operator may use a particular aircraft type for flights of only twenty minutes, whereas another operator may use it with an average flight duration of two hours, leading to very different load experiences per flight hour.

Over the past few decades, reliable and relatively inexpensive data recorders of various types and sizes have become available, and it has become possible to monitor actual loads in aircraft service. As the above suggests, service *load monitoring may have two different* objectives; it may be design-oriented or operator-oriented.

The objective of design-oriented load monitoring is to obtain improved (statistical) data on the loading associated with a given type of operation. These data may used to verify the *validity of assumed design load spectra, and to* establish design load spectra for future aircraft. The objective of operator-oriented load monitoring is to determine differences in load experience due to variations in operational usage. *Operators flying their aircraft in a* relatively mild role may consider alleviating their inspection schedules, whereas operators flying severe missions may have to apply shorter inspection intervals. Operator-oriented service load monitoring is usually called fatigue life monitoring. NLR has been actively involved in a variety of *both design-oriented and operations-oriented* service load monitoring projects. Below, some of these recently or currently active load monitoring programmes are briefly described.

Tail Load Measurements in a Fokker 100 Aircraft.

For a long time, in-service load measurements in transport aircraft were largely restricted to the measurement of vertical acceleration at or near the aircraft centre of *gravity. This quantity is a reasonably good* measure for the loading of the wing but gives hardly any information about the loads on the tail structure. In order to obtain statistical information about actual tail loads in service and to check the validity of current procedures for defining design tail load spectra, NLR is carrying out tail load measurements during operational flights on a Fokker 100 aircraft. Horizontal tail bending loads are measured by means of strain gauges and the recorded load signals are searched for peaks and valleys, *which are stored in their original sequence in* the solid state memory of a microprocessor-based "Spectrapot 4" data recorder (see Fig. 1). These recorded tail load data are complemented with aircraft and flight parameters obtained from the Aircraft Condition Monitoring System (ACMS). This load monitoring system is *easy to install, and does not interfere with* other aircraft systems.

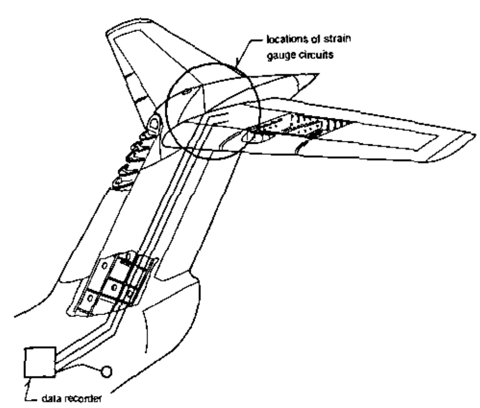


Fig. 1 – Lay-out of the monitoring instrumentation in the tail of the Fokker 100

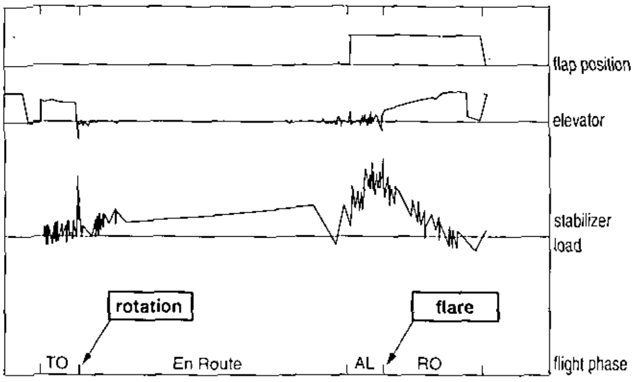
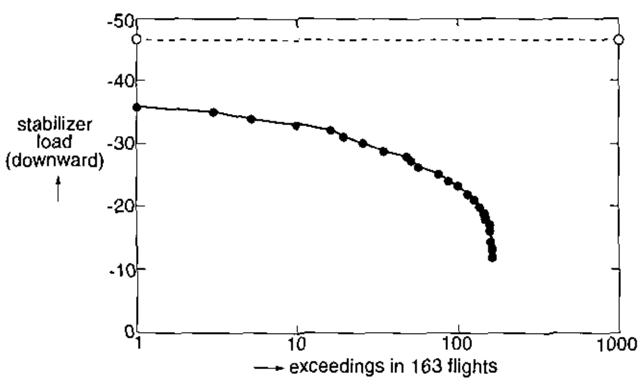


Fig. 2 – Load history of Fokker 100 stabilizer (TO: take off, AL: approach and landing, RO: roll out)

Figure 2 shows a reconstructed load trace for the stabilizer bending moment during one flight, together with the elevator position and the flap position. Typically, the stabilizer bending moment contains two "load cycles" per flight: starting at approximately zero load, the bending moment reaches a peak (downward tail load) during the rotation at take-off. At the end of the en-route phase, the tail load reaches a minimum just before flap extension in the approach/landing phase. A second load peak occurs just before touchdown, when the pronounced downward balancing tail load, associated with the flap-out condition, combines with the flare. As an example of the type of load statistics that are obtained from these measurements, figure 3 shows the distribution function of the magnitude of the tail load at rotation, obtained from a batch of 163 recorded flights.

This project, which has already provided valuable information about in-service tail loads, will be continued until a data base of about 2000 flights has been obtained.

Fig. 3 – Stabilizer load during rotation, as a function of the number of exceedings in 163 flights



Service Load Measurements in CN-235 Aircraft

The CN-235 is a twin-engine regional commercial transport and military freighter, developed jointly by the aircraft industries CASA of Spain and IPTN of Indonesia. Under contract to IPTN, NLR co-operates in the specification, acquisition and installation of a service load monitoring system which will be installed in three CN-235s of different operators. This project has two objectives: the verification of the design fatigue load spectra of the aircraft and the gathering of load statistics pertaining to the tropical environment of the Indonesian Archipelago. The following quantities are measured: vertical acceleration, speed, altitude, bank angle, bending moments in wing, vertical tail and horizontal tail (by means of strain gauges), and cabin pressure differential. A number of these measured quantities, indicated as

CN-235 transport aircraft

"master" signals, are searched for peaks and valleys. These are stored, together with a time tag and the values of one or more "slave" signals at the instants of master signal peaks. Some other parameters are recorded every minute (see Table 1). Data conditioning, reduction and storage takes place in a Swift Mass Micro Box system (see Fig. 4), equipped with a solid-state memory capable of storing over one hundred hours of reduced load data. Several programmes have been developed to analyze recorded data for specific purposes. In one programme, aircraft mission profile statistics are determined; in another programme, the bending moment spectra are determined for wing and tail; and in a third programme, gust statistics for the Indonesian tropical environment are derived by the reduction of acceleration data. The measurement programme will continue for several years.

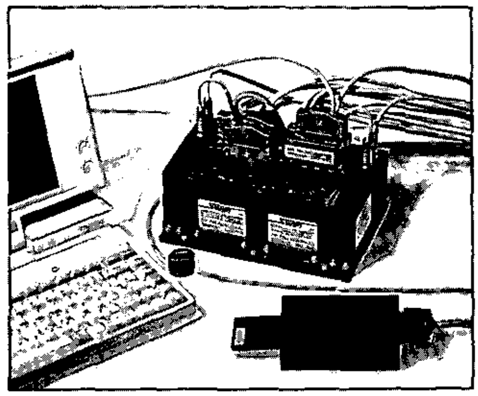


Fig. 4 – Load monitoring equipment used in the CN-235 aircraft: a Mass Micro Box data recorder

Table 1 - Signals recorded in monitoring system in CN-235 aircraft

SIGNAL	SYMBOL	RECORDED	SLAVED SIGNALS
Vertical Acceleration	N_z	peaks/valleys, time tags	H, V, Φ, BM_{wing}
Speed	V	at 1 minute intervals	
Altitude	H	at 1 minute intervals	
Bank Angle	Φ	slaved to N_z	
Wing Bending Moment	BM_{wing}	peaks/valleys, time tags	
Horizontal Tail Bending Moment	BM_{Htail}	peaks/valleys, time tags	BM_{Vtail}
Vertical Tail Bending Moment	BM_{Vtail}	peaks/valleys, time tags	BM_{Htail}
Cabin Pressure Differential	ΔP_{cabin}	peaks/valleys, time tags	

The measurement programmes described above are typical examples of design oriented monitoring. In addition, NLR is currently carrying out fatigue life monitoring projects for several military aircraft types. In the following, the most extensive NLR-project in this area is briefly described.

Fatigue Life Monitoring of RNLAF F-16 Aircraft

The General Dynamics F-16 is the principal first-line combat aircraft of the Royal Netherlands Air Force (RNLAF). The aircraft are distributed over nine squadrons, stationed at five different air bases. The overall load experience of the RNLAF's F-16s is severe compared with other air forces. In addition, there is a difference in load experience between different squadrons. This difference is partly due to differences in mission type mixture. Also, the loading associated with a specific mission type appears to differ per air base because of different distances to shooting ranges and air-to-air exercise areas, etc.

In order to monitor changes in aircraft usage and associated load experience, three aircraft of each squadron have been equipped with a 4-channel "Spectrapot" data recorder. Four quantities are measured, namely wing root bending moment BM (using strain gauges), speed, altitude and entre of gravity vertical acceleration or engine RPM. Recorded data are complemented with flight data such as Date, take-off configuration, mission type etc. The recorded BM history is the prime monitoring parameter, as the loading of a very large part of the fatigue-critical structure is proportional to the wing root bending moment. Figure 5 shows recorded BM histories pertaining to three different mission types. NLR has developed a methodology to quantify the severity of a recorded load history in terms of "potential

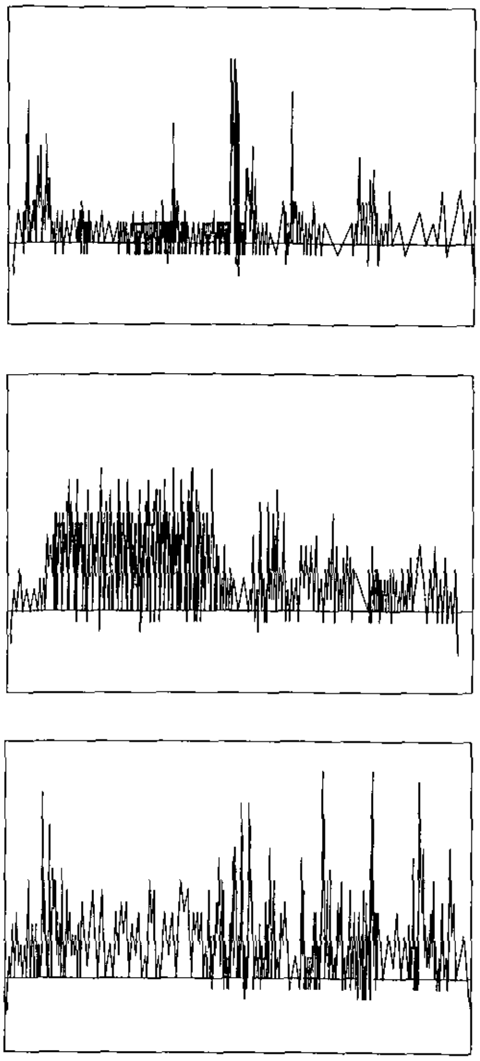


Fig. 5 – Bending moment histories
for three different mission types

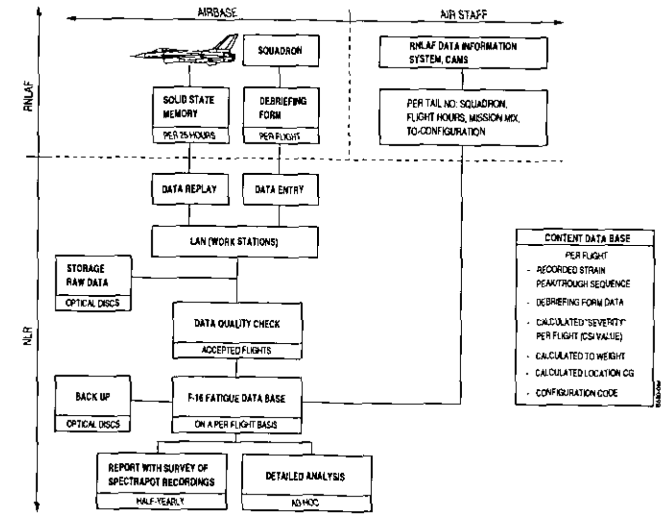


Fig. 6 – The flow of data in the F-16 load monitoring programme of the Royal Netherlands Air Force supported by NLR

fatigue crack growth". This method, called the Crack Severity Index (CSI) concept, estimates the crack growth associated with a recorded spectrum, taking into account load interaction effects such as crack growth retardation due to overloads.
The recorded data are used both to establish average severities per mission type and per squadron (in terms of their CSI values) and to monitor possible changes in these severities. The load experience of any individual aircraft may be calculated using these CSI-values per mission type, taking into consideration the mission mixture flown by that particular aircraft. Recordings of the mission types of all flights of each aircraft are provided through the RNLAF's data information system CAMS. Figure 6 presents an overview of the data flow in the F-16 load monitoring system.

Observation of increased load severity may on the one hand be used in a passive way, that means the increased usage severity is accepted as a fact of life and the inspection periods and retirement lives are reduced accordingly. On the other hand, such an observation may be used in an active manner. Then, the cause of the increase is traced back, using the additional parameters recorded. For example, from the recordings of speed and altitude, changes in mission profile can be deduced; also, it may turn out that aircraft configurations have changed, etc. On the basis of these findings, actions can be considered to reduce the service loading experience.
Recently the RNLAF and NLR have initiated a project to reduce the service fatigue life consumption by a judicious selection of aircraft store configurations. It turns out, for example, that the fatigue damage due to specific manoeuvres can be reduced by changing the locations of external fuel tanks from the centre line to the wing. Also, the carrying of stores like missiles on outboard wing stations has a favourable effect.

NLR is carrying out similar fatigue life monitoring projects for other aircraft types, including helicopters.
There is no doubt, that the current trend to keep military aircraft considerably longer in service than originally expected will further increase the emphasis put on adequate monitoring of in-service fatigue load experience. Service fatigue load monitoring has become possible at relatively low cost, using simple recording devices that do not interfere with existing aircraft systems. A wider application of service load monitoring in transport aircraft is therefore feasible. This may contribute to the economy and safety of civil aviation.

4.3 *Air Traffic Management*

Introduction

The airspace capacity demand in the North American and European regions is so great that the present Air Traffic Control (ATC) systems can hardly cope with traffic loads during peak hours. Air traffic authorities, research institutes and industry are working to improve this situation, trying to reduce delays while keeping the same or an even better level of safety, and taking into account a possible doubling of the traffic flow in the coming ten years.
Improvements are expected to come from both short term actions (such as the decision of Eurocontrol to create a Central Flow Management Unit in Brussels) and long term, strategic research and development. The common feeling is that further automation and harmonisation on an international scale is needed, the air traffic controller remaining in the loop.
Air traffic controllers guide aircraft in a safe, efficient way to their destinations. Today's ATC systems consists of radar systems for observation and interrogation of aircraft, radar data and flight plan processing systems, and control suites with displays and communication equipment.

The national authorities in Europe are in the process of directing their national ATC modernisation plans towards a single European ATC system (the European ATC Harmonisation and Implementation Plan (EATCHIP, organized by Eurocontrol on behalf of the European Civil Aviation Conference)). Several European authorities and institutes including NLR have come to terms in the PHARE co-operation (Program of Harmonised Air Traffic Management Research within Eurocontrol). PHARE is now acting as a central point for the definition of European research and development programmes. The Commission of the European Communities (CEC), also being aware of the ATC congestion, is providing funds for ATC improvements via several of its Directorates. In the CEC context, PHARE members and Eurocontrol define the various programme proposals together with industry, airlines and airport authorities.

NLR is heavily involved in the research and development for new ATC systems. Several departments of the NLR Flight Division, with support from NLR's Informatics Division, are working on the aircraft part of the ATC system, with NLR's Research Flight Simulator and research aircraft as important tools. Investigations are made on an Experimental Flight Management System and on the Microwave Landing System, procedural research and human factors research is carried out as well as research on Aeronautical Telecommunications Networks. This section is confined to NLR's work on the ground part of the ATC system.

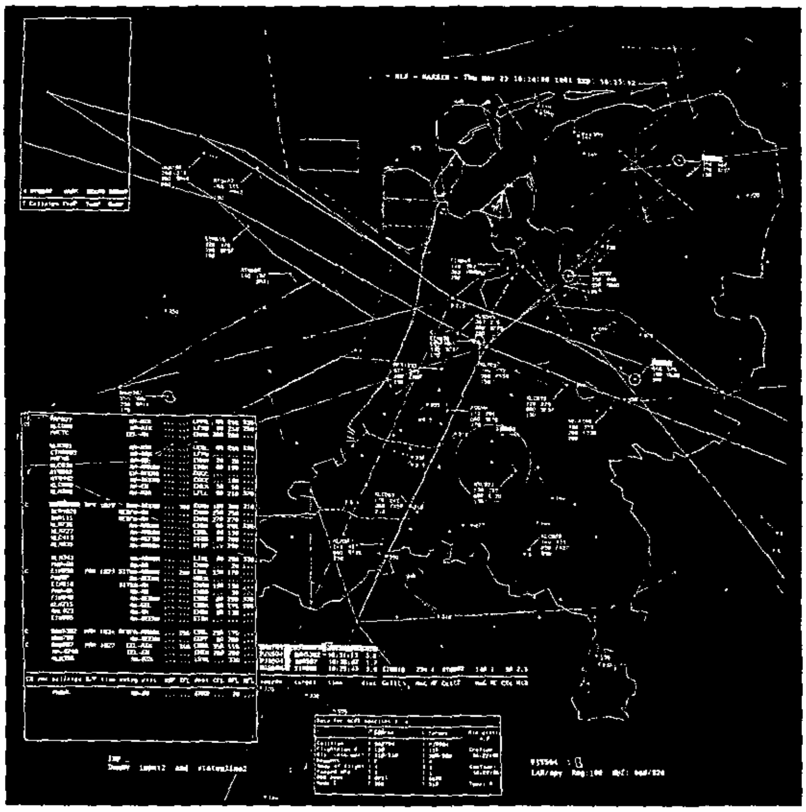
Research Facilities

NLR is both using and extending its NLR Air Traffic Research Simulator (NARSIM). NARSIM is used to support ATM research and prototype development with its ground, ground/air and aircraft simulation components and two Air Traffic Controller Working Positions. Four Blipdrivers may control up to 40 aircraft, and links of NARSIM to NLR's Metro II Research Aircraft and NLR's Research Flight Simulator have been realised. Further developments are going on for improved Ground/Air Datalink Simulation. The software is being adapted to UNIX X-Windows and Client Server Architecture. For the NARSIM basic simulation system and its multi-user distributed software applications, a larger computer system, an HP887, has been acquired in 1992. The first of a series of three large-scale experiments, using NARSIM with participating Blipdrivers and Air Traffic Controllers, has been prepared for the CEC SWIFT programme, to investigate European Specifications for Working positions In Future air Traffic control.

Application and Prototype Developments

Area Conflict Detection and Flight Path Monitoring

The Netherlands Air Traffic Control Service (in Dutch: LVB - Luchtverkeersbeveiliging) has contracted Raytheon for supplying the Amsterdam Advanced Air Traffic Control System (AAA). AAA will be equipped with Area Conflict Detection (ACOD) and Short Term Conflict Alert (STCA) prototyped and evaluated by NLR on NARSIM in co-operation with LVB.
ACOD has resulted from several years of research and development starting with the Spijkerboor Conflict Detection program. In the Netherlands, five airways merge at the Spijkerboor beacon. The requirements of LVB for safeguarding these airways, using software tools to assist the air traffic controller, were translated into prototype conflict detection software. The ACOD program is a further development of the existing Spijkerboor program, taking into account the entire Netherlands Flight Information Region (FIR).



Plan view display of the Executive Controller of NARSIM showing an Area Conflict (orange) and a Short Term Conflict (red)

Short Term Conflict Alert

The Short Term Conflict Alert (STCA) tool has been developed by NLR in co-operation with LVB several years ago. STCA supports the air traffic controller by detecting conflicts between aircraft from data supplied by the radar data processing system. STCA functions as a safety net for short term periods, a few minutes ahead. STCA observes pairs of aircraft, checking for conflicts in the vertical direction first. If a possible conflict is detected, the horizontal STCA detection is started. The present STCA module is based on mono-radar input, and has been designed to estimate aircraft positions in case of bad or missing radar data. The results of evaluations of the STCA in the past and a recent extension to include holding aircraft in stacks, are now being used in the specification for the STCA of the future AAA.

ACOD has been designed to support also Direct Routing, where aircraft deviate from airways in order to shorten the distance to travel.
ACOD starts its conflict search for all pairs of aircraft as soon as a flight is identified to cross the Netherlands FIR. ACOD is re-executed every minute, after every new trajectory prediction, and after every track update in case of a conflict. Conflict means in ACOD that certain parametrized separation criteria are expected to be infringed. ACOD starts with a search for conflicts in the vertical direction; if any is found, it continues in the horizontal plane. Conflicts are signalled to the air traffic controller, using specially developed and evaluated symbology and pop-up menus for further conflict information. ACOD functions are based on a geometrical conflict search algorithm combined with parameter settings from air traffic controller evaluation sessions. A Flight Path Monitor function, originally developed by the LVB, has been modified and added to ACOD in order to signal any deviation of an aircraft from its Flight Plan. The main end product of the ACOD program: evaluated specifications for AAA, is now ready for the AAA project, and the final large-scale evaluation of the parameter settings will be completed in 1993.

In the PHARE context, NLR is contracted to build a Conflict Probe and a Flight Path Monitor for the PHARE Advanced Tools programme, shich should demonstrate the capabilities of advanced Air Traffic Management tools.

Research on Air-Ground Integration for Air Traffic Control

NLR and the US National Aeronautics and Space Administration (NASA) are collaborating in research into air-ground integration for Air Traffic Control. The basis for this research is provided by the Center/TRACON Automation System (CTAS), under development at the NASA Ames Research Center. Early 1992, a copy of CTAS was installed at NLR, adapted to Dutch airspace and linked to NARSIM. The CTAS research at NLR is financially supported by Amsterdam Airport Schiphol.

The baseline CTAS is an integrated set of automation tools that assist air traffic controllers in efficient management and control of arrival traffic. It comprises three complementary tools: the Traffic Management Advisor (TMA), the Descent Advisor (DA) and the Final Approach Spacing Tool (FAST).

The TMA generates schedules of optimal landing sequences and landing times for arrival aircraft. These schedules are broadcast to all sectors equipped with DA or FAST. The DA assists centre controllers in controlling arrival traffic to the feeder gates in accordance with the schedules from the TMA. It gives advisories for cruise and descent speeds, as well as for the locations of the top of descents. FAST assists approach controllers in sequencing and spacing aircraft onto the final approach path. It gives speed and heading advisories which allow the aircraft to meet the arrival times as scheduled by the TMA. Both the DA and FAST broadcast estimated times of arrival, needed for scheduling, to the TMA.

To enable research on the integration of airborne and ground-basid systems, NLR has added several functions to the baseline CTAS and NARSIM. The objective of this type of research is to investigate different concepts of integration, in order to determine potential benefits, in terms of capacity and efficiency improvement, while maintaining the current level of safety.

Currently, with CTAS linked to the NARSIM facility, fully automated simulations are performed, with arrival traffic for Schiphol Airport. Communications between the ground (CTAS) and the aircraft (NARSIM) are performed by a multi-purpose data link, supporting simulation of SSR mode S, satellite data link and conventional radio-telephony communication. Variable pilot response times are simulated.

The extensions and modifications to the baseline CTAS include improved trajectory planning (trajectory synthesis, conflict prediction and resolution), trajectory monitoring and clearance management.

The various automation concepts that are investigated include:

- autonomous aircraft (no ATC 'interference');
- ATC arrival planning only (no conflict detection and resolution);
- arrival planning and (conflict free) trajectory planning;
- the above concept plus trajectory monitoring.

The above concepts are compared with a baseline concept of CTAS-assisted conventional ATC.

Future research with CTAS linked to the NARSIM facility will focus on aspects of man-machine integration: the presentation of information to air traffic controllers, their processing of the available information and their communication of negotiations and decisions with aircraft.

Tracker Server development for Eurocontrol

The Advanced Radar Tracker and Server (ARTAS) project of Eurocontrol is aimed at the development of a European operational tracker. It is based on a theory developed by NLR, and several years of prototype study on contract basis. ARTAS will be the Eurocontrol Tracker Server for the years 1996 and later. Three ARTAS units are to be developed within three years from mid-1993. ARTAS will use multi-radar observations and tracking techniques developed mainly by NLR. The Multi-hypothesis probabilistic tracking with the Mode Of Flight modelling of aircraft and the prototype JUMPDIF tracker NLR developed for the LVB were the main reasons for Thomson-CSF to co-operate with NLR and for Eurocontrol to select Thomson/NLR in competition with the largest ATC suppliers of the world. NLR is subcontractor to Thomson-CSF in the ARTAS project and main responsible for the ARTAS tracker development. NLR expects to obtain a strong input from the operational ATC side for the theoretical and prototype work done at NLR. The ARTAS contract negotiations are expected to be completed in the summer of 1993.

Theoretical Research and Development

The automated systems and functions described above all need to be optimized and evaluated with respect to capacity, efficiency and safety.

NLR is developing the theoretical basis for safety-based advanced Air Traffic Management (ATM) systems. Using NLR funding, ATM mathematical models and theory are being developed, translated into numerical applications and, in certain cases prototyped for customers such as the Dutch LVB (ATC The Netherlands). Keywords in this area are Optimal Control, Decision Theory and ATM Validation by Layered Safety Concepts and Collision Risk Modelling.

5 Internal and External Relations

NLR received many visitors over the past year. NLR participated in Airshows and other events and organized many excursions to NLR.

Visitors from the Netherlands

- Cdr. drs. H.J.D. Wanders and lt.col. J. Zwart from the Directorate of Materiel of the Royal Netherlands Air Force.
- Gen.maj.drs. D. Altena and col.ir. W.J. Kauw, who visited the Structures and Materials Division.
- Mr. L. van de Muyzenberg, advisor to the Chairman of the Foundation NLR.
- Col. F.J.M. Vogelpoel, Commander of Twenthe Airbase.
- Mr. Th.C. van Gelder, Director of the National Aerospace Medical Centre of Soesterberg.
- Mr. M. van Dorigo, from the Ministry of Economic Affairs.
- Mrs. J.R.H. May-Weggen, Minister of Transport and Public Works.
- Mr. J. Fledderus, Director General of Materiel of the Ministry of Defence.
- Mrs. mr. T. van Beek, Deputy Secretary of State from the Ministry of Transport and Public Works, who showed interest in our Remote Sensing activities.

Foreign Visitors

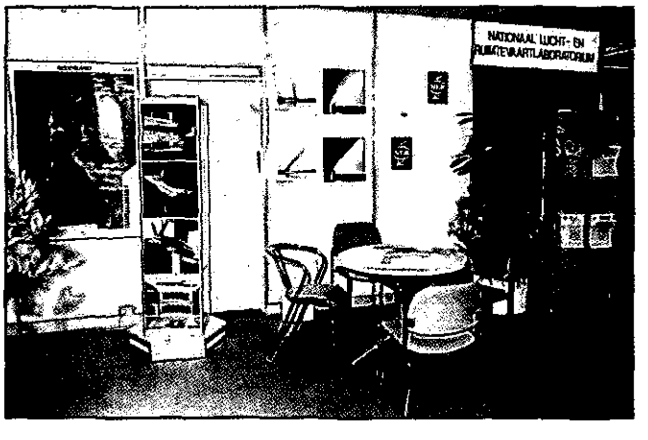
- Dr. Seeler and dr. Weise from Deutsche Airbus.
- Ing. Kojtech Nejedly from the Research and Test Institute of the (former) Tsjechoslowakia.
- US Lt.col. Sismorr and US Lt.col. Croshe of the ODC (Office of Defence Co-operation) from the American Embassy.
- Prof. Zhang Xuebin from SBW in Sheryang.
- Mr. K. Blixt (Assistent Undersecretary of State of Defence) and mr. J. Dinell (Head of the Naval Materiel Section) from Sweden.
- Members of the Joint Research Centre (JRC) of the EC.
- A delegation from B.P.P.T., Jakarta, Indonesia, in Holland on an assignment by Minister B.J. Habibie.
- Members of the China Aerodynamic Research and Development Centre.
- Mr. M. Demetz from General Dynamics.
- Dr. Masahiko Nagayasu from the National Aerospace Laboratory, Tokyo, Japan.

Excursions

- Students from the "Bel Air" flying school.
- Students in their finals for Aerodynamics from the Delft University of Technology.
- Employees of KORI (Korean Aerospace Institute).
- Members of "Mohres leren", students of the faculty of Mechanical Engineering of the University of Twente.
- Members of the Senior Convent from the FME.
- Employees of Fokker, Product Division.
- Participants of the SERA-course (Session Européenne des Responsables - 'Armement) from the Independent European Programme Group (IEPG).
- Members of the AGARD (Advisory Group for Aerospace Research and Development) Staff from Paris.
- The Eastern Europe Committee '92" from the mathematics students association "Christiaan Huygens", Delft University of Technology.
- Technical chemists from Akzo Zout- en Basischemie.
- European students participating in "Space-4 Conference" at the Delft University of Technology.

Exhibitions

- From 25 February until 1 March the 6th "Asian Aerospace" was held at Singapore. NLR participated in the stand of the Netherlands Aerospace Group, which was combined with the stand of Fokker. The show was well organised, had lots of participants and attracted many visitors.
- The ITEC'92 (International Training Conference and Exhibition) was held in the Trade Fair and Congress Centre" in Luxembourg. In the NISP (Netherlands Industrial Simulator Platform) stand, NLR showed pictures of the National Simulation Facility (NSF) it is building and of its ATC research facilities.
- NLR participated in the trade exhibition "The Instrument" (held every second year) organised by the Netherlands Line Organisation and Federation for Industrial Electronic Automation, Laboratory Technology and Medical Technology in Utrecht. NLR showed its activities related to Electro Magnetic Interference (EMI) tests.
- From 6 to 13 September the "Farnborough International Airshow '92" was held in England. For the fifth time NLR participated in the NAG stand.
- During the "Open Day" of the Royal Netherlands Air Force, organised at Gilze Rijen Airbase, NLR was one of the exhibitors in one of the shelters.
- To celebrate the 75th anniversary of the Air Division of the Royal Netherlands Navy, an exhibition was organised at De Kooy naval air base. NLR showed pictures of its helicopter-ship qualification tests.
- NLR also participated in the exhibition held during the "European Rotorcraft Forum" at Avignon, France.
- During the NIL Research Day in the Hague, NLR contributed to the exhibition by means of pictures.



NLR participated in the stand of the Netherlands Aerospace Group at the Farnborough International Airshow

Events

- Well-attended New Year receptions were held in the Amsterdam and Noordoostpolder sites.
- Members of the Works Council had their annual lunch with members of the NLR Board.
- De Amsterdam district council "Stadsdeelraad Zuid" held a meeting at NLR Amsterdam to present the future plans for the Schinkel area.
- At a meeting at NLR Amsterdam, presentations on noise zoning were held for officials from municipalities invited by the Department of Civil Aviation.
- The German Dutch Wind Tunnel organised a workshop "Aeroacoustics in cars".

6 Scientific Committee NLR-NIVR

The Scientific Committee advised NLR on:

- the results of the work NLR carried out under the programme for basic research and development of facilities of NLR;
- the preliminary Work Plan for 1993;
- the results of the work carried out by NLR in 1991 under the 'General Research Programme with a view to aircraft development in the near future' of NIVR;
- the reports NLR submitted to the Committee to be considered for suitability as scientific publications.

The annual report of the Scientific Committee contains the following concluding remarks:
'The year 1992 was the year of the negotiations between Fokker and DASA on a far-reaching co-operation. Partly because of these negotiations, a 'Position Paper on the Dutch infrastructure for aircraft development' was written. The Scientific Committee expresses its approval of the Work Plan of NLR for 1993, while observing that this Work Plan leaves out of account the consequences of a possible acceptance of the proposals formulated in the Position Paper. It would be desirable that clarity about the fulfilment of the wishes stated in the Position Paper arrive within not too long a period.

The Committee has repeatedly noted the decrease of the volume of the Basic Research. This type of research enables a research institute to continue playing a leading role in the long term nationally and internationally. The Scientific Committee is therefore very pleased to have learnt that the possibilities of NLR carrying out basic research have been extended. This extension will certainly contribute to strengthening the position of NLR in a situation where the national aircraft industry is incorporated in a larger entity, and the European borders are fading.

The volume of the contracts carried out in 1992 and expected for 1993 is impressive, the more so because they do not seem to go at the expense of the basic research. The sharp decrease of defence-related contracts has created a new situation for the European research institutes, which will at some time lead to more competition among them. The consequences of this development will show up at NLR also. Still, given the situation of its sister institutes, NLR is doing very well both nationally and internationally. This is confirmed by the positive judgement on the large number of NLR reports submitted to the Scientific Committee to be considered for suitability for publication.

The Work Plan 1993 shows that NLR is increasing the efforts with respect to safety and environment. The Scientific Committee supports this, since it is of the opinion that these aspects are becoming of ever larger importance, not only during operations, but also in the production phase of aircraft.

In the improvement and extension of its facilities, NLR pursues an energetic policy, the most important example being the modernization of the HST. The Scientific Committee takes pleasure in the HST being fully operational in the beginning of 1993.'

Scientific Committee

Prof.dr.ir. P.J. Zandbergen, *chairman*
Prof.ir. C.J. Hoogendoorn
Prof.ir. P. Jongenburger
Prof.dr. T. de Jong
Prof.dr.ir. J.A. Steketee
Ir. P.G. Vermeulen, *secretary*

Subcommittee for Aerodynamics

Prof.dr.ir. J.A. Steketee, *chairman*
Prof.dr.ir. P.G. Bakker
Dr.ir. R. Coene
Prof.dr.ir. J.L. van Ingen
Prof.dr.ir. P.T.M. Nieuwstadt
Prof.ir. E. Obert
Prof.ir. E. Torenbeek
Ir. N. Voogt
Prof.dr.ir. P. Wesseling
Prof.dr.ir. L. van Wijngaarden

Subcommittee for Space Technology

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

Subcommittee for Structures and Materials

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Prof.dr. Joh. Arbocz
Ir. F. Holwerda
Prof.dr.ir. Th. de Jong
Prof.ir. P. Jongenburger
Maj.ir. J.W.E.N. Kaelen
Dr. P.V. Kandachar
Ir. A.N. Kraan
Prof.dr. A. Rothwell
Prof.dr.ir. J. Schijve
Prof.dr.ir. H. Tijdeman
Prof.dr. J.H. de Wit
Prof.dr.ir. S. van der Zwaag

Subcommittee for Applied Mathematics and Information Technology

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Prof.ir. D. Bosman
Drs. P.J.W. ten Hagen
Prof.dr.ir. G.Y. Nieuwland
Prof.dr. G.J. Olsder
Prof.dr.ir. J. Schalkwijk
Prof.dr.ir. C.R. Traas
Prof.dr.ir. P. Wesseling

Subcommittee for Flying Qualities and Flight Operations

Prof. J.H.D. Blom, *chairman*
KTZSD ir. K. Bakker
Ir. H. Benedictus
Prof. J.H.D. Blom
LTZ(T) ir. W.G. de Boer
J. Hofstra
Ir. R.J.A.W. Hosman
Ir. H.J. Kamphuis
Maj. E.R.A. van Kleef
Prof.dr.ir. J.A. Mulder
Prof.ir. E. Obert
Lt.Kol.Vl. b.d. A.P. Okkerman
Ir. P. van Otterloo
Ir. H. Tigchelaar

7 International Co-operation

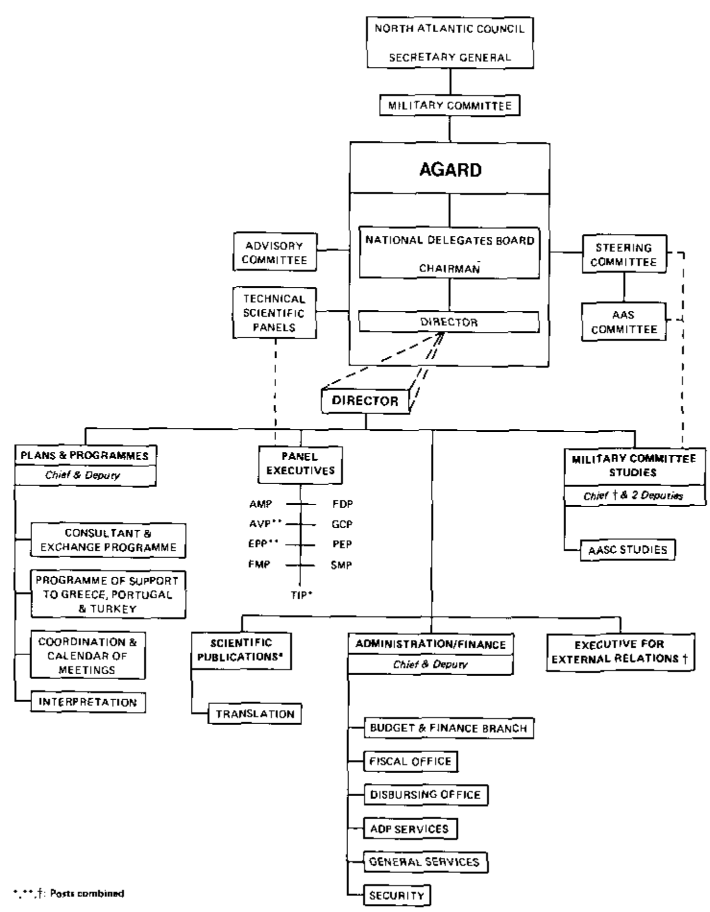
7.1 AGARD

Mission

According to its Charter, the mission of AGARD, the Advisory Group for Aerospace Research and Development, is to bring together the leading personalities of the NATO member nations in the fields of sciences and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the military Committee in the field of aerospace research and development;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving co-operation among member nations in aerospace research and development;
- Exchanging scientific/technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

Organization diagram of the Advisory Group for Aerospace research and Development (AGARD)



Organization

AGARD is organized around three main elements:

- The National Delegates Board, the governing body, assisted by a Steering Committee and an Advisory Committee;
- The AGARD staff, the executive body of the Agency;
- The Scientific and Technical Panels and the Aerospace Applications Studies Committee, which together constitute the expert bodies of the Agency.

These main elements carry out the AGARD mission through a number of differentiated and specialized activities, including:

- Panel programmes of conferences, symposia and specialists' meetings, and meetings of sub-committees and working groups;
- Consultant and Exchange programmes under which individual consultants are provided to NATO member nations, Lecture Series are organized and personnel exchanges and contacts arranged;
- A programme of Military Committee Studies, consisting of aerospace applications and technology studies initiated at the request of the NATO military committee;
- A publication programme resulting from the above activities or initiated by them;
- A programme of support to the Southern Flank nations (Greece, Portugal and Turkey).

Summary of Main Activities in 1992

Panel meetings/symposia

AGARD symposia are technical meetings concerned with subjects of relatively general interest within specific fields. In 1992 nineteen symposia have been organized, none of them in the Netherlands.

Lecture Series

AGARD organizes a limited number of Lecture Series each year, and each series is given for two days, usually in three NATO member nations, as requested by the nations. In 1992 six Lecture Series have been organized, two of them in the Netherlands.

Special Courses

A team of experts presents lectures in one, and rarely in two or three, nations on a specific topic. In 1992 six Special Courses have been organized, none of them in the Netherlands.

Support programmes

The following numbers of support programmes were active in 1992:

Greece: 20
Portugal: 27
Turkey: 26

The Netherlands actively participated as supporting nation in seven programmes.

Consultants programme

In 1992 a total of 96 consultants mission have been carried out.

Military Committee Studies Programme

The Steering Committee, with advice from the Aerospace Applications Studies Committee, normally recommends two topics from the Military Committee Memorandum as Aerospace Applications Studies each year.
In 1992 two studies commenced, AAS-37 and AAS-38.

National Delegates Board Meetings

Twice a year the National Delegates Board comes together for a meeting. A Spring meeting is always planned in France, normally in Paris, whereas an Autumn meeting takes place in one of NATO's other member nations. The Autumn 1992 National Delegates Board meeting took place in The Hague.

Netherlands Delegation to AGARD

The Netherlands Delegation consists of:

- three national delegates (two provided by NLR);
- one national co-ordinator (NLR);
- twenty-three panel members (ten provided by NLR).

7.2 The German-Dutch Wind Tunnel

Since 1980, NLR, on an equal base together with the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR), operates the German-Dutch Wind Tunnel (DNW), located on the Noordoostpolder site of NLR.
The German-Dutch Wind Tunnel (DNW) was well occupied for contract testing. A great deal of effort was spent in a programme for modernization and extension of test systems and auxiliary equipment.

The Board of DNW at the end of 1992

Dr.rer.publ. J. Blum, *Chairman*	DLR
J. van Houwelingen, *Vice-chairman*	NLR
Drs. G.M.V. van Aardenne	Netherlands Agency for Aerospace Programs (NIVR)
Dipl.-Ing. K.-H. Heilmann	Ministry of Defence of the Federal Republic of Germany (BMVg)
Dr.-Ing. H. Hertrich	Ministry for Research and Technology of the Federal Republic of Germany (BMFT)
Dr.-Ing. O. Lawaczeck	DLR
Dr.ir. B.M. Spee	NLR
Ir. H.N. Wolleswinkel	Ministry of Transport and Public Works of the Netherlands (RLD)

Secretary: Dipl.Volksw. A. Dick (DNW)

Advisory Committee

The Advisory Committee, providing support to the Board, and representing the aerospace industry and research establishments, consisted of:

Dipl.-Ing. O. Friedrich, *Chairman*	Deutsche Aerospace Military Aircraft
Dipl.-Ing. B. Haftmann	Deutsche Aerospace Airbus
Prof.dr. ir. J.L. van Ingen	Delft University of Technology
Prof.ir. E. Obert	Fokker Aircraft
Dipl.-Ing. J. Roeder	Airbus Industrie
Prof.ir. J.W. Slooff	NLR
Dr.-Ing. B. Sträter	Deutsche Aerospace Dornier
Prof.Dr.-Ing. F. Thomas	DLR
Ir. F. Holwerda	Fokker Aircraft

Secretary: Ir.J.C.A. van Ditshuizen (DNW)

The Board and the Advisory Committee had a joint meeting.

DNW Board

	Appointed by NLR	Appointed by DLR	
V&W nominated by V&W[1])	**NLR** nominated by NLR Board	**DLR** nominated by DLR Board	**BMFT** nominated by BMFT[2])

Executive Committee

	Vice-chairman	Chairman	
EZ nominated by EZ[3])	**NLR** nominated by NLR Board	**DLR** nominated by DLR Board	**BMVg** nominated by BMVg[4])

Advisory Committee

Secretary

Director

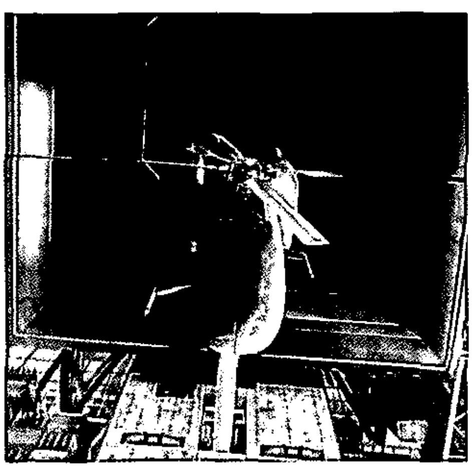
Deputy Director

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

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

The Board of Directors of the DNW

Prof.Dr.-Ing. H.U. Meier (DLR), *Director*
Ir. H. Runge (NLR), *Deputy Director*



BRITE/EURAM Helinoise experiment in the open jet of the DNW

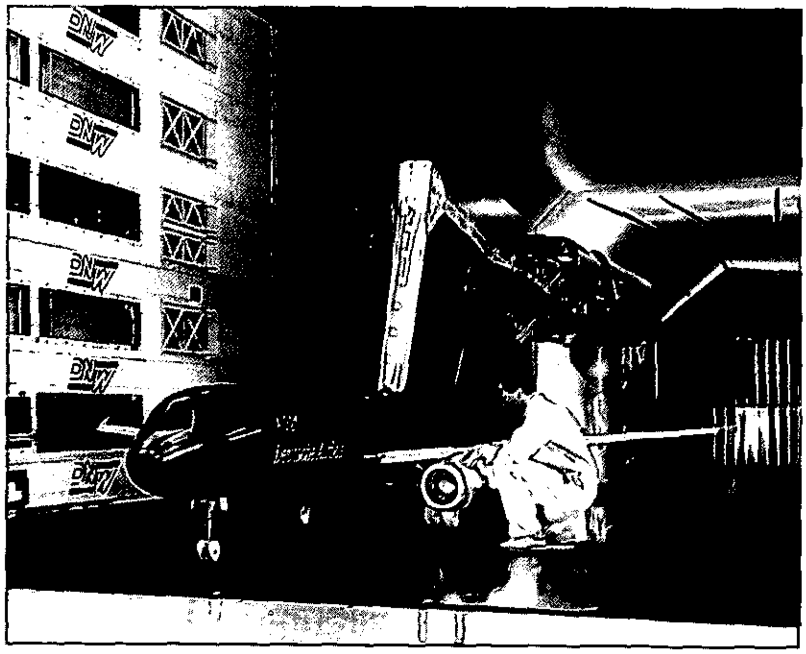
In 1992 contract testing increased with respect to the previous year. The activities included research under three BRITE/EURAM programmes of the Commission of the European Communities: DUPRIN, GEMINI and HELINOISE. Work for the programme DUPRIN (Ducted propfan integration investigation) continued in 1993, whereas the activities for the other two programmes were concluded.

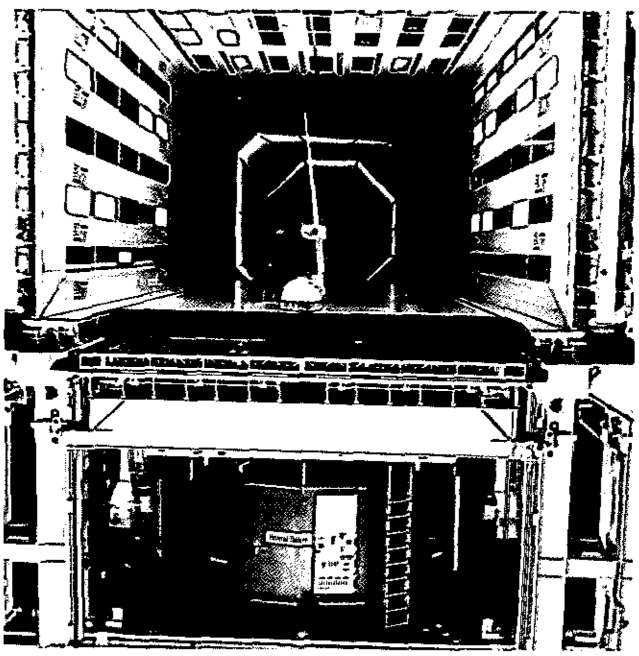
Several Airbus configurations were tested for Aérospatiale and Deutsche Airbus, some in co-operation with engine manufacturers. The testing of the large model of the huge Airbus Special Transport was concluded. Engine integration studies were carried out as well. A propulsion study for a new thrust reverser concept of Hurel Dubois used DNW's engine test stand and moving belt ground plane. A large scale half-model test was carried out for CASA.
Several helicopter rotor tests were carried out, both in the open jet and closed test sections.

A performance and stability verification test of a full-scale missile was carried out for MBB Deutsche Aerospace.

Many contracts for testing cars and lorries were received. A new user-friendly platform for car testing is under construction, enabling rolling wheel and moving ground simulation to be combined with external force measurements.

Ground proximity test with an Airbus A321 model above the moving belt ground plane





Scale 1:3,5 semi-span model of CASA in the test section, above the external balance

MAN van for cross-wind tests in the DNW

7.3 The European Transonic Wind Tunnel

NLR is a 7% shareholder in the European Transonic Windtunnel GmbH, established in 1988. In December 1992 the mechanical completion of this cryogenic wind tunnel facilty was reached, within the originally foreseen budget and planning, which can be considered as an a major achievement. For the Netherlands participation in the construction costs (6%) a substantial industrial return, through contracts let to Netherlands companies, was realised.
The Supervisory Board adopted a first version of the ETW Business Plan, to be finalized in the coming year.
In October Queen Elisabeth II of the United Kingdom visited ETW.

At the end of 1992 the membership of the Supervisory Board was as follows:

France	IGA G. Dorey	(ONERA)	
	IGA A. Dubresson	(DGAC)	
	IGA J. Cheret	(DRET/SDCE)	
Germany	Dr.-Ing. H. Hertrich	(BMFT)	
	Dr.rer.publ. J. Blum	(DLR)	
	Dr.-Ing. O. Lawaczeck	(DLR)	
United Kingdom	Dr. G.T. Coleman	(DTI)	*Chairman*
	R.E. Jones	(DRA)	
The Netherlands	Ir. H. Wolleswinkel	(V&W)	
	J. van Houwelingen	(NLR)	
	Dr.ir. B.M. Spee	(NLR)	

At the end of 1992 the membership of Board of Directors was as follows:

Ir. X. Bouis (Fr)	Director General
Dr. A. Freytag (G)	Director Finance and Administration
Mr. G. Offringa (NL)	Director Engineering

In 1992 Mr. G.L. Harris (UK), Director General, left ETW. He was succeeded by Ir. X. Bouis (F), former Director Technical.

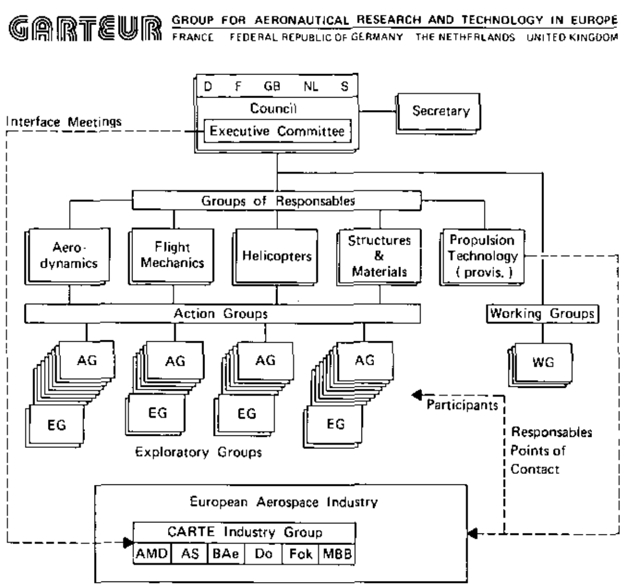
7.4 GARTEUR

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

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

GARTEUR co-operation is concentrated on applied aeronautical research. The potential research areas and subjects are identified by Groups of Responsables and investigated for collaboration feasibility by Exploratory Groups. When the subject is feasible an Action Group is established in which normally all GARTEUR countries participate.

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



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

The organizational diagram shows three levels: Council/Executive Committee, Groups of Responsables and Action Groups. Via CARTE (Group for Collaboration on Aeronautical Research and Technology in Europe) GARTEUR has an interface with the European Aerospace Industry.

Composition of the GARTEUR Council and Executive Committee

France

IGA J. Bouchet	(DRET)	
IGA M. Benichou	(ONERA)	
ICA J.M. Duc	(ONERA)	*)
ICA Y. Gleizes	(STPA)	
ICA E. Lisack	(DGAC/DPAC)	

Federal Republic of Germany

Dr.-Ing. H. Hertrich	(BMFT)	
Dipl.-Ing. Heilmann	(BMVg)	
Prof. F. Thomas	(DLR)	
Dr. K.O. Pfeiffer	(DLR)	*)

United Kingdom

Dr. R.H. Warren	(DRA)	
Mr. M. Earwicker	(DRA)	
Mr. P.G. Wilby	(DRA)	*)
Dr. G.T. Coleman	(DTI)	

Sweden

	Mr. L.B. Persson	(FFA)	
	Mr. A. Gustafsson	(FFA)	*)
	Mr. Ch. Heinegard	(Nutek)	
	Mr. L.T. Olsson	(FMV-F)	

The Netherlands

	Mr. J. van Houwelingen	(NLR)	
	Prof.ir. F.J. Abbink	(NLR)	*)
	Ir. L. Sombroek	(NLR)	

*) member of the Executive Committee

During 1992 dr. Hertrich holds the chairmanship of the Council. Dr. Pfeiffer holds the chairmanship of the Executive Council for the years 1992 and 1993. The Secretary of GARTEUR for the period 1992-1993 is mr. G. Gruber (DLR).

For 1993 the chairmanship of GARTEUR is fulfilled by IGA Bouchet.

NLR Participation

NLR participates in all five Groups of Responsables.
At the end of 1992 twenty-four Action Groups were active; NLR participates in twenty-two Action Groups.

7.5 Co-operation with Indonesia

Background

In 1980 a co-operation was started between NLR and the Agency for the Assessment and Application of Technology in Indonesia, primarily to realize the foundation of an aerodynamic laboratory (LAGG) in Serpong, near Jakarta, to support the fast developing aircraft industries in Indonesia.
The first project, the design and construction of the Indonesian Low Speed Wind Tunnel (ILST) was completed in 1987.
The support by NLR was part of the Technical Assistance Projects TTA-79 and TTA-79, Phase II 'Integral Support for Aeronautical Research and Development' (ISARD).
The Delft University of Technology (DUT) and Fokker, together with their Indonesian counterparts, the Institute of Technology Bandung (ITB) and the Indonesian Aircraft Industries (IPTN), also took part in the projects; ISARD was successfully completed in September 1991.
As all participants and both Governments emphasized their positive attitude concerning continuation of the collaboration in the future, action was taken to appoint a bilateral working group with the main task to draft a plan for long term co-operation. This plan should aim at structural relationships between the partners involved, on the basis of equal partnerships and mutual interests. In the meantime, agreement was reached to start an interim Aerospace Programme for Education, Research and Technology (APERT), to be concluded in 1994.

APERT

In January, APERT activities were started in the Project Bandung, basically covering the collaboration between ITB and DUT, and in the Project Serpong, mainly directed at the collaboration between LAGG and NLR. Detachment of a permanent NLR representative in Serpong is an essential part of this project.

Activities in the Project Joint Research, directed at the preparation and execution of different research projects with participation of all institutions represented in APERT and other related scientific and research institutions in both countries, were also begun.
Overall Coordination and Control was provided by BPPT and NLR. In the course of the year agreements were signed by all parties concerned regarding the programme as a whole and covering the projects Bandung and Serpong in more detail. Agreements on joint research were in preparation.

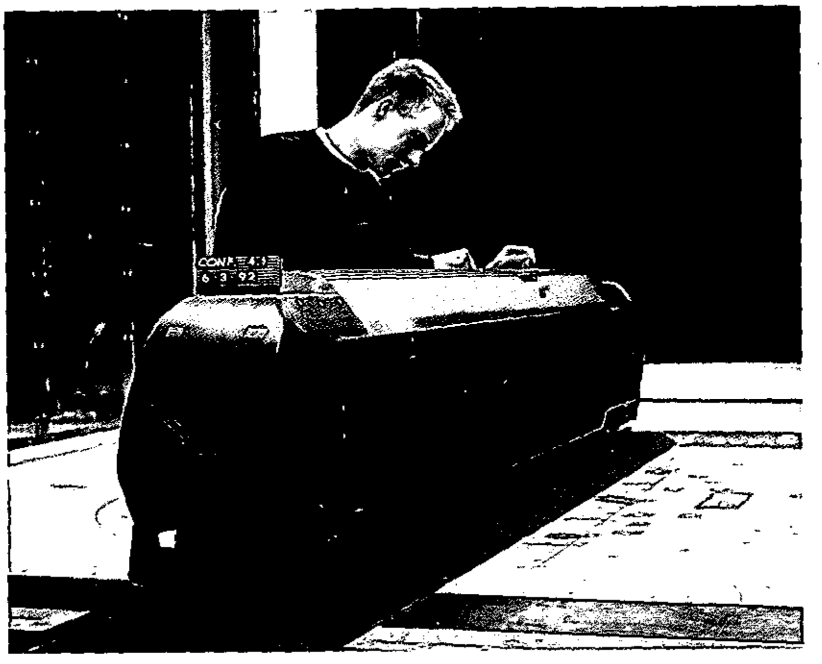
Governmental Support

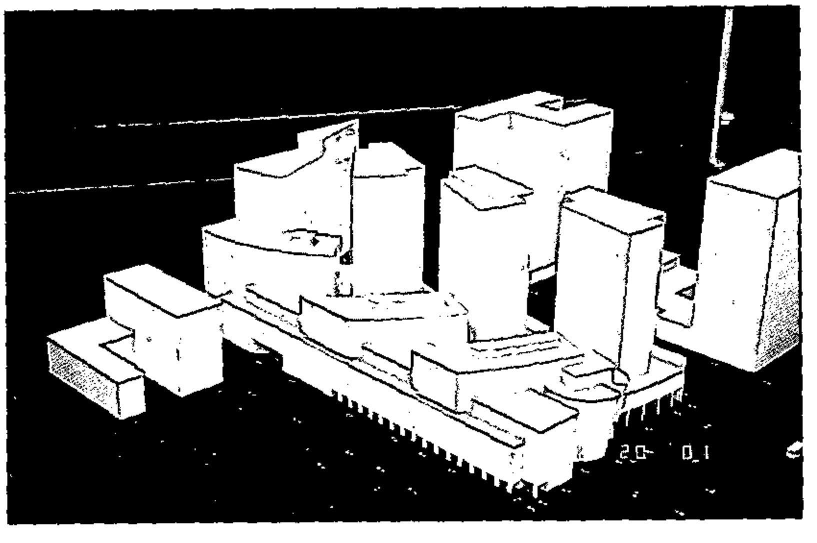
During visits to Indonesia of the Minister of Education and Sciences, dr.ir. J.M.M. Ritzen, and the Minister of foreign trade, mrs.mr. Y.M.C.T. van Rooy, in September and December, respectively, it was made clear that both governments are prepared to support the continuation and enhancement of the co-operation in the field of Aerospace Technology.

Other Activities

Under the umbrella agreement signed on 30 June 1988 by IPTN and NLR, contract work was continued and preparations were made for additional contracts.

Model of Netherlands Railways train in the LST





Scale model of the Beatrixkwartier in The Hague for wind hindrance testing in the LST

Appendices

1 Publications

In 1992, NLR produced a total of 540 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

TP 90238 U
Flight simulator evaluation of the flyability of curved MLS approaches with wide-body aircraft
Erkelens, L.J.J.; Dronkelaar, J.H. van

TP 90242 U
Validation report of the ISNaS single-block Euler Pilot Code
Brandsma, F.J.

TP 90326 U
Telescience pilot experiments using Telepodi
Kuijpers, E.A.

TP 91008 U
NAVSTAR Global Positioning System - Introduction and Status
(Paper presented at the 'NERG Meeting on Satellite Navigation', NLR, Amsterdam, 6 November 1990)
Pietersen, O.B.M.

TP 91016 U
Design of a multisensor tracking system for advanced air traffic control
(Published in: 'Multitarget-Multisensor Tracking. Applications and Advances, Volume II' by Prof. Y. Bar-Shalom, Artech House)
Blom, H.A.P.; Hogendoorn, R.A.; Doorn, B.A. van

TP 91036 U
A study on focusing in telescience using the TELEPODI breadboard
Pinches, G.L.; Kuijpers, E.A.; Spaan, F.

TP 91046 U
New concepts for multi-block grid generation for flows around complex aerodynamic configurations
(Presented at the Third International Conference on Numerical Grid Generation in Computational Fluid Mechanics and Related Fields, Barcelona, Spain, 3 – 7 June 1991)
Spekreijse, S.P.; Boerstoel, J.W.; Vitagliano, P.L.

TP 91051 U
Two-phase heat transport systems for space: Thermal gravitational modelling & scaling predictions versus results of experiments
Delil, A.A.M.

TP 91052 U
Global/local interlaminar stress analysis of a grid-stiffened composite panel
Wiggenraad, J.F.M.; Bauld, N.R. Jr.

TP 91062 U Pt.2
European studies to investigate the feasibility of using 1000 ft vertical separation minima above FL290 - Part II: Precision radar data analysis and collision risk assessment
(Published in Journal of Navigation, Vol 45, No 1 (1991) p.91 – 106)
Harrison, D.; Moek, G.

TP 91072 U
Hybrid state estimation for systems with semi-Markov switching coefficients
(Presented at the 'First European Control Conference', Grenoble, France, 2 – 5 July 1991)
Blom, H.A.P.

TP 91076 U
Pilot opinions on the use of flight management systems
Dorp, A.L.C. van

TP 91085 U
Manufacturing and inspection of artificial delaminations in composite materials
(Prepared for presentation at the 5th European Conference on Non-Destructive Testing, Sarajevo, Yugoslavia)
Heida, J.H.; Beuker, G.; Verdegaal, M.

TP 91092 U
Review of aeronautical fatigue investigations in the Netherlands during the period March 1989 - March 1991
(Presented at the 22nd ICAF Conference, Tokyo, Japan, 20 – 21 May 1991)
Jonge, J.B. de

TP 91093 U
Spacecraft sustained load fracture control
(Presented at the International Conference on

Spacecraft Structures and Mechanical Testing, Noordwijk, The Netherlands, April 1991)
Wanhill, R.J.H

TP 91098 U
Predesign of a simulator for inverse robot kinematics
Groothuizen, R.J.P.

TP 91104 U
Flight simulation and constant amplitude fatigue crack growth in aluminium-lithium sheet and plate
(Presented at the 16th ICAF Symposium, Tokyo, 20 – 21 May 1991)
Wanhill, R.J.H.; Hart, W.G. 't; Schra, L.

TP 91116 U
Load monitoring of F-16A/B aircraft of the RNLAF with a smart electronic device
(Presented at the AGARD Specialists Meeting on Fatigue Management, Bath, United Kingdom, May 1991)
Spiekhout, D.J.

TP 91117 U
An experimental study of the flow over a sharp-edged delta wing at subsonic and transonic speeds
(Presented at the AGARD Fluid Dynamics Panel Symposium on 'Vortex Aerodynamics', Scheveningen, The Netherlands, 1 – 4 October 1990)
Elsenaar, A.; Hoeijmakers, H.W.M.

TP 91119 U
Integration of wall interference assessment and wall adaptation
(Presented at the International Conference on Adaptive Wall Wind Tunnel Research and Wall Interference Correction (ICAW 91), Xian, China, 10 – 14 June 1991)
Smith, J.

TP 91121 U
Modal analysis of solar arrays using boundary integral equations
(Presented at the 7th GAMM-Seminar on Numerical Techniques for Boundary Element Methods, Kiel, Germany, 25 – 27 January 1991)
Heijstek, J.J.; Schippers, H

TP 91134 U
NLR investigation of flutter behaviour of fighter aircraft with external stores
(Presented at the International Aerospace Congress 1991, Melbourne, Australia, 12 – 16 May 1991)
Meijer, J.J.

TP 91154 U
Modelling and numerical simulation of vortex flow in aerodynamics
(Presented at the AGARD Fluid Dynamics Panel Symposium on 'Vortex Flow Aerodynamics', Scheveningen, The Netherlands, 1 – 4 October 1990)
Hoeijmakers, H.W.M.

TP 91155 U
Control law synthesis for large flexible spacecraft
(Presented at the Summer School 1991 on Control of Mechanical Systems, organized by the Dutch Graduate School of Systems and Control, Zeist, The Netherlands, 3 – 7 June 1991)
Woerkom, P.Th.L.M. van

TP 91156 U
Development of new flight procedures for the Microwave Landing System (MLS)
(Presented at the Symposium 'Environmental Issues and Pollution in Aviation', Sipke Wynia, Hogeschool Haarlem, 11 April 1991)
Erkelens, L.J.J.

TP 91166 U
Photogrammetric methods for trajectory measurements
(Presented at the 'SFTE Fourth European Mini Symposium', Rome, Italy, 1991)
Willekens, A.J.L.

TP 91168 U
Experiences with two GPS SPS receivers in Northern Europe
(An abstract of this report was published in 'GPS World', April 1991)
Pietersen, O.B.M.

TP 91169 U
Operator workload as a limiting factor in complex systems
(Published in: 'Automation and Systems Issues in Air Traffic Control', Wise, J.A.; Hopkin, V.D. and Smith, M.L. (Eds.), 1991)
Jorna, P.G.A.M.

TP 91185 U
Free motion of an unsupported tank that is partially filled with liquid
(Poster presentation at the UITAM Symposium

on Microgravity Fluid Mechanics, Bremen, Germany, 2 – 6 September 1991)
Vreeburg, J.P.B.

TP 91188 U
Aerodynamic aspects of offshore structures
(Presented at the Eighth International Conference on Wind Energy, London, Canada, 8 – 12 July 1991)
Willemsen, E.

TP 91191 U
Wind-tunnel experiments on wind effects at tunnel portals
(Presented at the 7th International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels, Brighton, United Kingdom, 27 – 29 November 1991)
Maarsingh, R.A.; Swart, L.

TP 91193 U
Software development practice in a scientific configuration environment
(Presented at the VDM '91 Symposium, Noordwijkerhout, 21 – 25 October 1991)
Jong, S. de; Jong, H. de

TP 91196 U
Life cycle oriented method for development and production of large scale industrial mathematics software
(Paper presented at the Second International Conference on Industrial and Applied Mathematics, Washington D.C., USA, July 8 – 12, 1991)
Loeve, W.

TP 91200 U
Instrumentation for in-flight acoustic measurements in an engine inlet duct of a Fokker 100 aircraft
(Presented at the SFTE 22nd Annual Symposium, St. Louis, Missouri, USA, 5 – 9 August 1991)
Klijn, J.M.; Rademaker, E.R.

TP 91203 U
Accelerated and real-time corrosion testing of aluminium-lithium alloys
(Presented at the 6th Aluminium Lithium Conference, Garmisch-Partenkirchen, Germany, October 1991)
Schra, L.

TP 91206 U
TPX: Two-Phase Experiment for Get Away Special G-557
(Presented at the Thermal Control Technology Session of the 21st Conference on Environmental Systems, San Francisco, 15 – 18 July 1991)
Delil, A.A.M (NLR).; Heemskerk, J.F. (NLR); Supper, W. (ESTEC)

TP 91213 U
On board image processing for telescience support
Kuijpers, E.A.

TP 91216 U
Beyond the frequency limits of time-linearized methods
(Presented at the International Forum on Aeroelasticity and Structural Dynamics, Aachen, 1991)
Hounjet, M.H.L.; Eussen, B.J.G.

TP 91219 U
Investigations preparatory to the wet satellite model experiment
Vreeburg, J.P.B.

TP 91220 U
A break-down of sting interference effects
(Presented at the DGLR/DNW Symposium 'Model Support Corrections in Wind Tunnels', DNW, Marknesse, The Netherlands, 16 May 1991)
Elsenaar, A.; Han, S.O.T.H.

TP 91227 U
Production flight test: Data acquisition, reduction and presentation
(Presented at the European Test and Telemetry Conference '91, Toulouse, France, 25 – 27 June 1991)
Veerman, H.P.J.; Storm van Leeuwen, S.

TP 91229 U
Time-step enlargement for Runge-Kutta integration algorithms by implicit smoothing
Loon, M. van

TP 91237 U
Performance of gasturbine compressor cleaners
(Paper presented at the '37th ASME International Gas Turbine and Aeroengine Congress and Exposition', Köln, Germany, 1 – 4 June 1992)
Kolkman, H.J.

TP 91244 U
Damage tolerance behaviour of aluminium-lithium sheet alloys
(Prepared for the Conference 'Materials Processing and Performance', Melbourne, Australia, September 1991)
Wanhill, R.J.H.

TP 91250 U
CFD efforts in the Netherlands
(Presented at the 4th International Symposium on CFD, Davis, California, 9 – 12 September 1991)
Loeve, W.

TP 91260 U
Review of aerodynamic design in the Netherlands
(Presented at the ICIDES III, 3rd International Conference on Inverse Design concepts and optimization in Engineering Sciences', Washington DC, 23 – 25 October 1991)
Labrujère, Th.E.

TP 91267 U
Modal analysis of solar arrays using hypersingular integral equations
(Presented at a Seminar of 'Nederlands Akoestisch Genootschap', Utrecht, The Netherlands, 23 May 1991)
Schippers, H.; Heijstek, J.J.

TP 91269 U
DEFMEF Predesign document
Jong, S. de

TP 91280 U
Modified dynamics modelling for maneuvering, flexible space manipulators
Woerkom, P.Th.L.M. van

TP 91288 U
The development of flexible software for the Italian/Dutch satellite SAX
Dekker, G.J.; Hameetman, G.J.

TP 91290 U
GARTEUR compression behaviour of advanced CFRP
(Presented at the AGARD Workshop 'Utilization of advanced composites in military aircraft', San Diego, USA, October 1991)
Hart, W.G. 't

TP 91291 U
Wasmiddelen voor gasturbines vallen vies tegen
(Published in: Polytechnisch Tijdschrift, editie Procestechniek)
Kolkman, H.J.

TP 91306 U
Application of an Euler-equation method to a sharp-edged delta-wing configuration with vortex flow
(Presented as AIAA Paper 91-3310 at the AIAA 9th Applied Aerodynamics Conference, Baltimore, USA, 23 – 25 September 1991)
Hoeijmakers, H.W.M.; Berg, J.I. van den

TP 91307 U
On the use of the method of matched asymptotic expansions in propeller aerodynamics and acoustics
(Published in: Journal of Fluid Mechanics)
Brouwer, H.H.

TP 91324 U
Heart rate variability as an index for pilot workload
Jorna, P.G.A.M.

TP 91345 U
A literature survey on the fatigue behaviour of hybrid composites
Oldersma, A.

TP 91346 U
Low cycle fatigue behaviour of titanium disc alloys
(Presented to the AGARD Subcommittee 33 'Engine Disc Cooperative Test Programme')
Looije, C.E.W.

TP 91349 U
The application of phase tracking GPS for flight test trajectory determination
(Presented at the 'First International Symposium Real Time Differential Applications of the Global Positioning System', Braunschweig, Germany, 16–20 September 1991)
Leijgraaf, R. van de; Storm van Leeuwen, S.

TP 91359 U
Development of a method to predict transonic limit cycle oscillation characteristics of fighter aircraft
(Presented at the AGARD Specialists Meeting 'Transonic Unsteady Aerodynamics and Aeroelasticity', San Diego, California, USA)
Meijer, J.J.; Cunningham Jr., A.M.

TP 91363 U
Stable numerical integration of dynamical

systems subject to equality state-space constraints
(Published in Journal of Engineering Mathematics)
Dam, A.A. ten

TP 91366 U
Reasoning with uncertain and incomplete information in Aerospace Applications
J.C. Donker

TP 91384 U
Feasibility of a wind-ellipse criterion in a vortex advisory system for Schiphol Airport
(Presented at the 'FAA International Wake Vortex Symposium', USA, 29 – 31 October 1991)
Polak, F.R.

TP 91387 U
Clebsch variable model for unsteady transonic flow - Application to 20 Airfoils
Westland, J.

TP 91396 U
Evaluation of the flyability of MLS curved approaches for wide-body aircraft.
(Presented at the 'AIAA Guidance, Navigation and Control Conference', New Orleans, 12 – 14 August 1991)
Erkelens, L.J.J.; Dronkelaar, J.H. van

TP 91397 U
A robust quasi-simultaneous interaction method for a full potential flow with a boundary layer with application to wing/body configurations
(Presented at the Fifth Symposium on Numerical and Physical Aspects of Aerodynamical Flows, California State University, Long Beach, California, USA, 13 – 15 January 1992)
Wees, A.J. van der; Muijden, J. van

TP 91399 U
Stress corrosion resistance of damage tolerant aluminium sheet-lithium sheet
Kolkman, H.J.; Schra, L.S.

TP 91401 U
Thermal gravitational modelling and scaling of two-phase heat transport systems for space: an assessment and a comparison of predictions and experimental results
Delil, A.A.M.

TP 91404 U
Panel methods for aerodynamic analysis and design
(Contribution to: AGARD-FDP/VKI Special Course, 'On Engineering Methods in Aerodynamic Analysis and Design of Aircraft', Ankara, Turkey)
Hoeijmakers, H.W.M.

TP 91410 U
NLR inviscid transonic unsteady loads prediction methods in aerolasticity.
(Presented at the 'AGARD specialists meeting on Transonic Unsteady Aerodynamics and Aeroelasticity', San Diego, USA, 9 – 11 October 1991)
Hounjet, M.H.L.

TP 91435 U
Kennistechnologie Begrippenlijst
Donker, J.C.; Nibourg, J.M.

TP 91438 U
The ASCOR test: a simple automated method for stress corrosion testing of aluminium alloys
(Published in Journal of Testing and Evaluation)
Schra, L.; Groep, F.F.

TP 91443 U
Ageing aircraft research in the Netherlands
(Presented at the 1991 International Conference on Ageing Aircraft and Structural Airworthiness, Washington D.C., USA, 19–20 November 1991)
Jonge, J.B. de; Bartelds, G.

TP 91445 U
Technical evaluation report on the AGARD-PEP Specialists' meeting on combat aircraft noise at Bonn, October 1991
(Prepared for the AGARD Sub-committee 33 'Engine Disc Cooperative Test Programme')
Wolf, W.B. de

TP 91453 U
Aerodynamic analysis of slipstream/wing/nacelle interference for preliminary design of aircraft configurations
(Presented at the AGARD Fluid Dynamics Panel Symposium on 'Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles', Fort Worth, Texas, USA, 7 – 10 October 1991)
Beek, C.M. van; Piers, W.J.; Oskam, B.

TP 91460 U

Evaluation of corrosion protecting properties of modern aircraft paint systems
(Presented at the 'Aerospace Corrosion Control Symposium', Amsterdam, 23 – 25 March 1992)
Hart, W.G. 't; Boogers, J.A.M.

TP 91477 U

Thermal gravitation modelling and scaling of two-phase heat transport systems. Similarity considerations and useful equations, predictions versus experimental results
(Presented at the '1st European Symposium on Fluids in Space', Ajaccio, France, 18 – 22 November 1991)
Delil, A.A.M.

TP 91478 U

The photonical, pure grid method
(Published in: Optics and Lasers in Engineering, Elsevier Applied Science Publishers Ltd.)
Sevenhuijsen, P.J.

TP 91485 U

Constrained motion models for insertion/abstraction operation applied to the HERMES robot arm: a feasibility study
Dam, A.A. ten; Couwenberg, M.J.H.

TP 92009 U

Damage severity of monitored fatigue load spectra
(Presented at the 18th ICAS Congress, Beijing, September 1992)
Jonge, J.B. de

TP 92014 U

Transmission of sound through a rotor
(Presented at the 'DGLR/AIAA 14th Aeroacoustic Conference', Aachen, Germany, 11 – 14 May Aachen, Germany)
Schulten, J.B.H.M.

TP 92027 U

Towards distributed control systems for experiments under microgravity
(Presented at the 'IEEE Instrumentation/Measurement Technology Conference IMTC/92', New York, USA, 12-14 May 1992)
Aartman, L.J.; Huijser, R.H. (FSS)

TP 92057 U

Modern aluminium sheet alloys for aerospace applications
(Presented at the '3rd International Conference on Aluminium Alloys', Trondheim, Norway, 22 – 27 June 1992)
Wanhill, R.; Schra, L.; Hart, W.G. 't

TP 92065 U

Conceptual design of a computer-code system for the calculation of flows around transport aircraft
(Publication at the occasion of the retirement of prof.dr. J.A. Steketee, professor of Theoretical Aerodynamics at the Faculty of Aerospace Engineering of the Delft University of Technology, Delft, The Netherlands)
Boerstoel, J.W.

TP 92072 U

Computational methods for aerodynamic design of aircraft components
(Published in Annual Review of Fluid Mechanics Vol. 25, January 1993)
Labrujère, Th.E.; Slooff, J.W.

TP 92119 U

Overview of the FAA/DCA/NLR programs related to ageing aircraft
(Presented at the 'International Workshop on Structural Integrity of Ageing Airplanes', Atlanta, Georgia, USA, 31 March - 3 April 1992)
Ottens, H.H.; Jonge, J.B. de

TP 92121 U

Gravity dependent condensation pressure drop and heat transfer in ammonia two-phase heat transport systems
(Presented at the 'AIAA Session 'Phase Change Heat Transfer', at the 1992 National Heat Transfer Conference', San Diego, California, USA, 9 – 12 August 1992)
Delil, A.A.M.

TP 92143 U

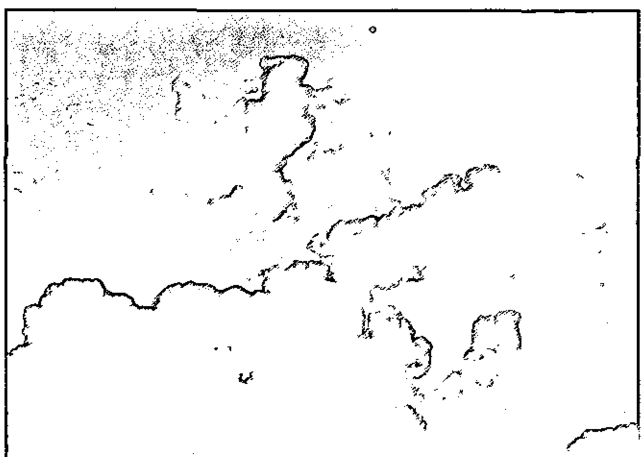
Future development of the NLR Research Flight Simulator
(Presented at the Simulation Symposium of the Aeronautical Students Association 'Sipke Wynia', Haarlem, The Netherlands, 20 March 1992)
Jansen, C.J.

2 Abbreviations

AGARD	Advisory Group for Aerospace Research and Development (NAVO)
AIAA	American Institute of Aeronautics and Astronautics
APERT	Aerospace Programme for Education, Research and Technology
ARALL	ARamide Aluminium Laminate
ATC	Air Traffic Control
BCRS	Beleidscommissie Remote Sensing (Netherlands Remote Sensing Board)
BMFT	Bundesministerium für Forschung und Technologie (Federal Ministry for Research and Technology)
BMVg	Bundesministerium für Verteidigung (Federal Ministry for Defence)
BRITE	Basic Research in Industrial Technologies for Europe
CAE	Computer-Aided Engineering
CAESAR	CCD Airborne Experimental Scanner for Applications in Remote Sensing
CARTE	Collaboration on Aeronautical Research and Technology in Europe
CEC	Commission of the European Communities
CIRA	Centro Italiano Richerche Aerospaziale
DLR	Deutsche Forschungsanstalt für Luft- und Raumfart
DNW	Duits-Nederlandse Windtunnel (German-Dutch Wind Tunnel)
DRA	Defence Research Agency
EC	European Communities
EFIS	Electronic Flight Instrument System
EMI	Electro-Magnetic Interference
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESOC	European Space Operations Centre
ESPRIT	European Strategic Programme for Research and Development in Information Technology
ESTEC	European Space Research and Technology Centre
ETW	European Transonic Wind Tunnel
EURAM	European Research on Advanced Materials
Eurocontrol	European Organization for the Safety of Air Navigation
EZ	Ministerie van Economische Zaken (Ministry of Economic Affairs)
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FEL	Fysisch Elektronisch Laboratorium (TNO) (Physics-Electronics Laboratory)
FFA	Flugtekniska Försöksanstalten (Aeronautical Research Institute of Sweden)
FSS	Fokker Space & Systems
GARTEUR	Group for Aeronautical Research and Technology in Europe
GPS	Global Positioning System
HSA	Hollandse Signaalapparaten B.V.
HST	Hoge-Snelheids Tunnel (High Speed Wind Tunnel)

ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IEPG	Independent European Programme Group
ILST	Indonesische Lage-Snelheids Tunnel (Indonesian Low Speed Tunnel)
INTA	Instituto Nacional de Técnica Aerospacial (Aerospace Research Institute of Spain)
IPTN	*Nusantara Aircraft Industries (Bandung)*
ISARD	Integrated Support for Aeronautical Research and Development
ITB	*Institut Teknologi Bandung (Indonesië)* (Technological Institute of Bandung, Indonesia)
JAR	Joint Airworthiness Regulations
KLM	Koninklijke Luchtvaart Maatschappij N.V. (KLM Royal Dutch Airlines)
KLu	Koninklijke luchtmacht (Royal Netherlands Air Force)
KM	Koninklijke marine (Royal Netherlands Navy)
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
KNVvL	Koninklijke Nederlandse Vereniging voor Luchtvaart (Royal Netherlands Aeronautical Association)
LAGG	*Aero-Gas Dynamics and Vibration Laboratory*
LST	*Lage-Snelheids Tunnel (Low Speed Wind Tunnel)*
MBB	*Messerschmitt-Bölkow-Blohm*
MLS	Microwave Landing System
MRVS	Meet-, Registratie- en Verwerkingssysteem (Measurement, Recording and Data Processing System)
NAG	Netherlands Aerospace Group
NASA	National Aeronautics and Space Administration (USA)
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation System with Time and Ranging
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programs)
NKO	Nederlandse Kalibratie Organisatie (Netherlands Calibration Organization)
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (*National* Aerospace Laboratory NLR)
NLRGC	*Nationaal Lucht- en Ruimtevaartgeneeskundig Centrum* (National Aerospace Medical Centre)
NPOC	National Point of Contact
NSM	Niet-Stationaire Meetmethode (Non-Stationary Measurement Method)
NSF	Nationale Simulatie Faciliteit
ONERA	Office National d'Etudes et de Recherches Aérospatiales (Aerospace Research Institute of France)
RESEDA	Remote-Sensing Dataverwerkingssysteem (Remote Sensing Data Processing System)
RLD	Rijksluchtvaartdienst (Netherlands Department of Civil Aviation)
RTCA	Radio Technical Commission for Aeronautics

SICAS	SSR Improvement and Collision Avoidance System
SPOT	Système Probatoire Observation Terrestre
SSR	Secondary Surveillance Radar
SST	Supersone Snelheids Tunnel (Supersonic Wind Tunnel)
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)
TPD	Technisch Physische Dienst TNO-TU
TPS	Turbine-Powered Simulation
TTA	Technological/Technical Assistance
V&W	Ministerie van Verkeer en Waterstaat (Ministry of Transport and Public Works)
VKI	Von Kármán Institute of Fluid Dynamics
WL	Waterloopkundig Laboratorium (Delft Hydraulics)



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