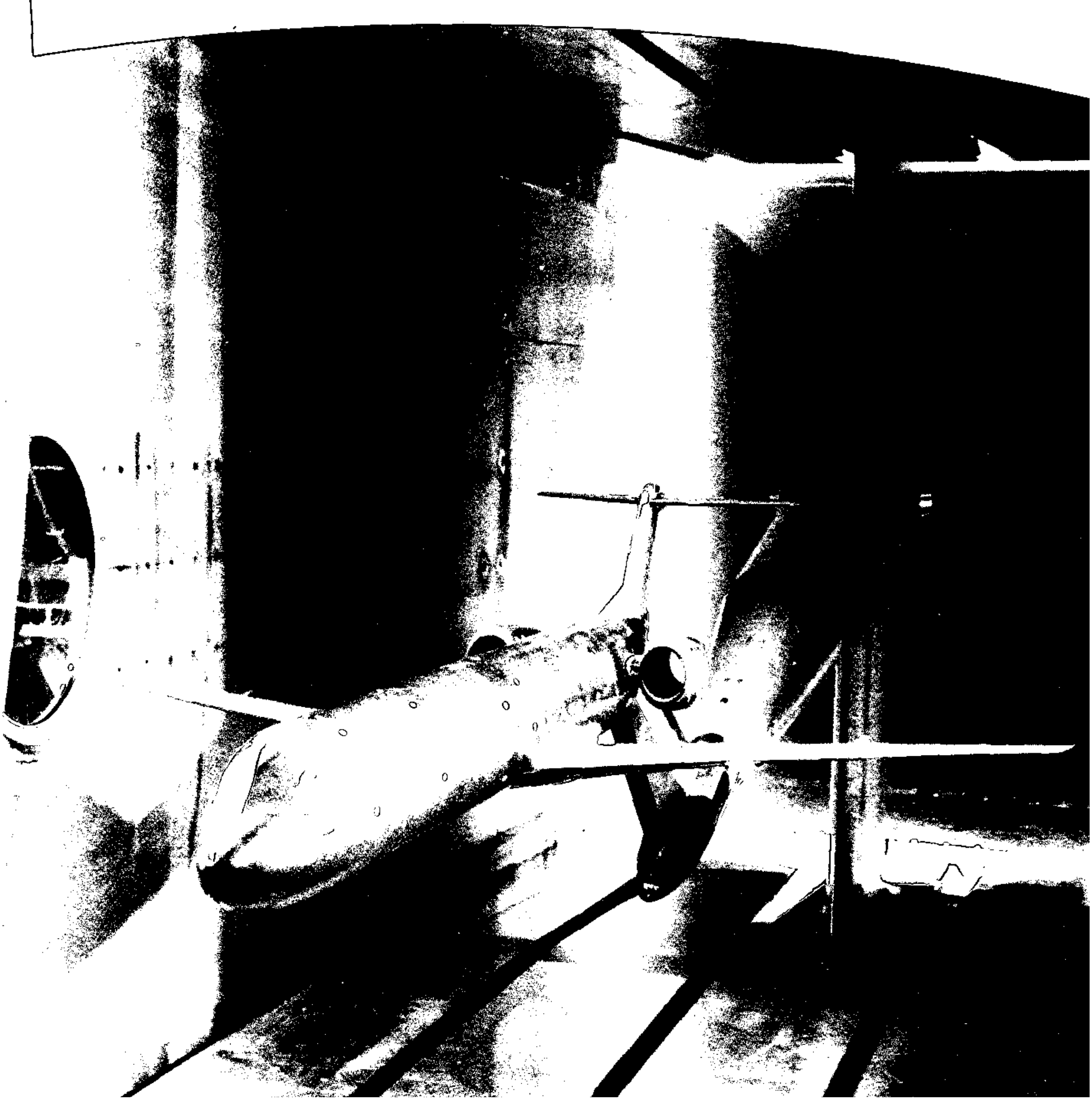
Annual Report 1993

Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR



Annual Report 1993

Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

1 ## The Board of the Foundation NLR *)

2

	Appointed by:
J. van Houwelingen *Chairman*	Ministers of Transport, of Defence, of Economic Affairs and of Education and Science
Ir. H.N. Wolleswinkel	Minister of Transport, for the Netherlands Department of Civil Aviation (RLD)
Gen.maj. drs. D. Altena	Minister of Defence, for the Royal Netherlands Air Force (RNLAF)
3	
Drs. E.A. van Hoek	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
Dr. R.J. van Duinen	Fokker Royal Netherlands Aircraft Factories
Ir. K.H. Ledeboer	KLM Royal Dutch Airlines
4	
Ir. C.M.N. Belderbos	Netherlands Organization for Applied Scientific Research (TNO)
Drs. G.M.V. van Aardenne	Netherlands Agency for Aerospace Programs (NIVR)
Prof.dr.ir. J.L. van Ingen	Delft University of Technology, Faculty of Aerospace Engineering
5 Jhr.mr. J.W.E. Storm van 's Gravesande	Board of the Foundation NLR

6

The Board of Directors of NLR *)

7

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

*) On 31 December 1993

1 Introduction

1993 has been a positive year for NLR, although the volume of contract work was somewhat below the figure for 1992. NLR's own research programme, sponsored by the Dutch government, was more extensive. As a result both the turnover and the staff were slightly above 1992 figures.

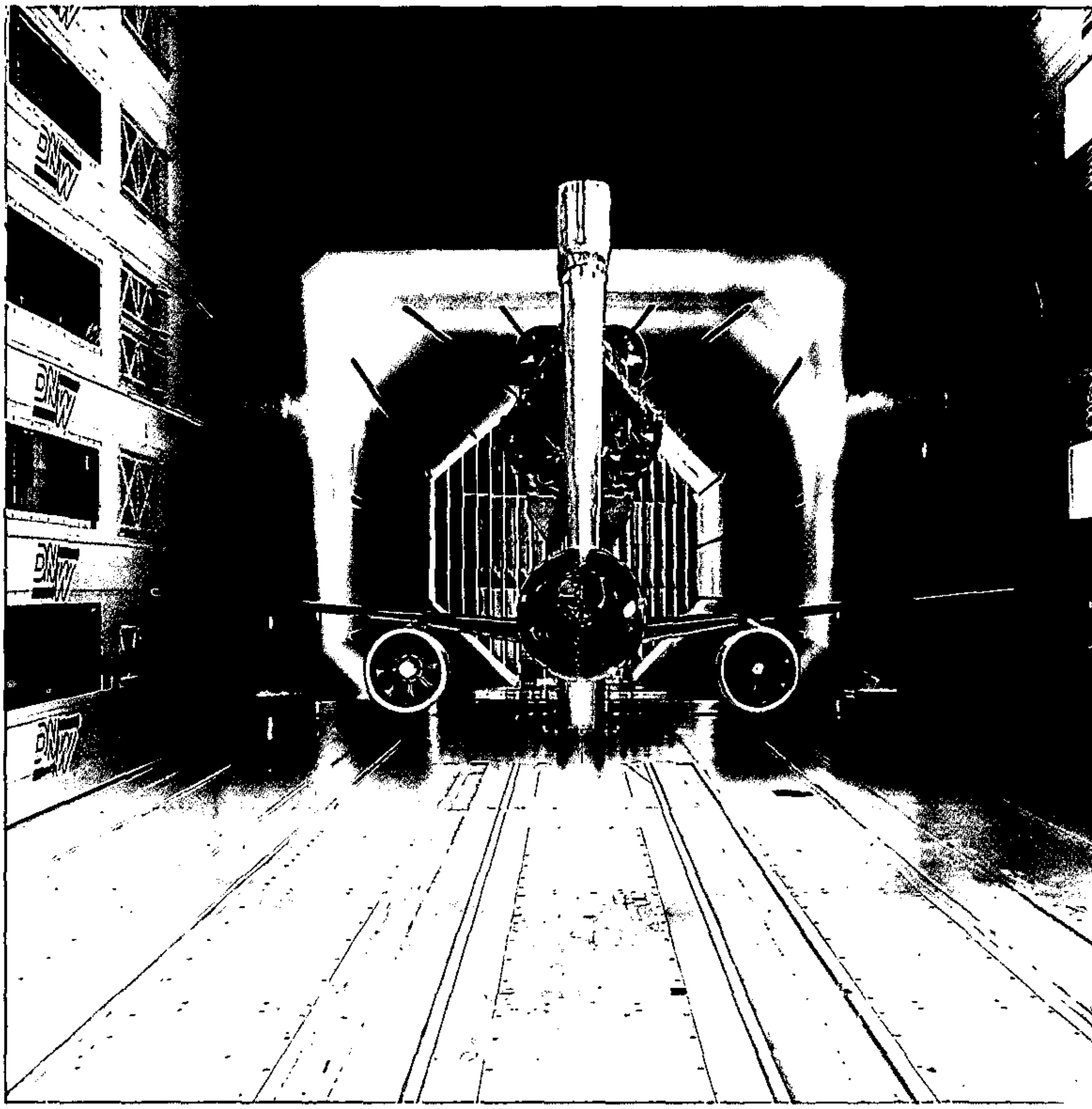
For both the airlines and the aircraft industry, 1993 was another difficult year. There was some improvement compared to 1992, but the profits of most airlines remained far too low and many of them still suffered losses. The market for the aircraft industry was even worse, with cancellations, delayed deliveries and only very few orders for new aircraft. As a consequence, aircraft industries are only cautiously pursuing development programmes for civil aircraft. This has a negative effect on the need for services from the research institutes and particularly on the workload of the large test facilities of these institutes. Although there is a continuously growing demand for air transport, it is expected to take another two or three years for the financial situation of the airline industry to improve such that airlines come into a position to order new aircraft that are more efficient and have less impact on the environment.

As in 1992, there was a growing demand for NLR research from aircraft operators and civil aviation authorities. In particular the Royal Netherlands Air Force, facing new tasks and preparing for the operation of a variety of aircraft and helicopters, asked for more support from NLR. Also the volume of NLR's activities in areas such as air traffic control/air traffic management, aviation safety and environmental impact, executed within both national and international programmes, has been extended.

In 1993 important steps have been taken on the way to a closer co-operation in aerospace research and development in Europe. The seven European research establishments made the necessary preparations for what is called an association agreement, while the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) and NLR agreed upon a further extension of their existing co-operation through a partnership agreement. Progress in European co-operation in aerospace research will largely depend on further integration of the European industry and on financial support from the EC.

The increasing contributions to NLR's own research programme and to an aircraft technology programme for Fokker indicate the commitment of the Dutch government to continue its support for the country's activities in aerospace. This will strengthen NLR's position as a leading aerospace research establishment.

J. van Houwelingen, *Chairman*



BRITE/EURAM DUPRIN (Ducted Propulsion Integration) test in the closed 6 m x 6 m test section of the German-Dutch Wind Tunnel

2 General Survey

2.1 Mission and Means

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

Quality systems according to ISO 9001 are the basis for guaranteed quality, and a tight project control system has been established, for timely delivery of services, within budget.

With sites in Amsterdam and in the Noordoostpolder, NLR operates several wind tunnels, laboratory aircraft and research flight simulators. NLR also has facilities for research in the areas of Air Traffic Control, structures and materials, space technology and remote sensing. NLR's extensive computer network includes a 5.5 GFlops NEC SX-3/22 supercomputer, tools for software development and advanced software for computational fluid dynamics and for calculations of aircraft and spacecraft structures.

NLR participates, on an equal base together with DLR, in 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 in the construction and operation of the European Transonic Windtunnel (ETW) in Cologne. NLR holds 7% of the shares of the company ETW GmbH.

2.2 Activities in 1993

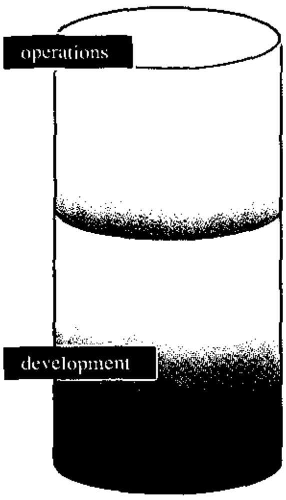
In 1993 NLR's turnover was 144 million guilders compared to 141 million in 1992. The income from contracts was 101 million guilders compared to 102 million in 1992.

In 1993 about 60% of the total of NLR's activities were related to the development, and 40% to the operation of aircraft and spacecraft; 85% of NLR's activities were related to aeronautics and 15% to space. Civil and military research amounted to 70% and 30%, respectively.

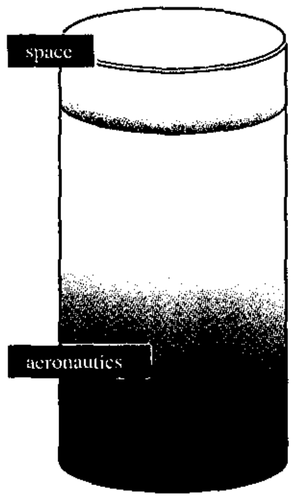
The total operating costs of NLR, amounting to 144 million guilders, included personnel costs of 94 million and direct costs for customers of 13 million guilders.

Services Provided under National Contracts

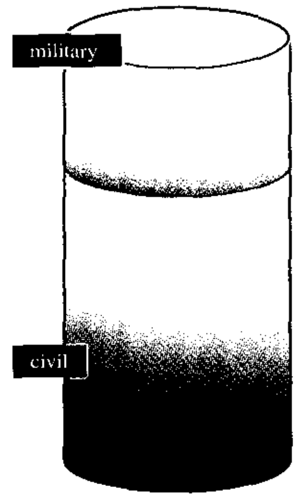
Contracts from Dutch customers amounted to 83 million guilders. These contracts included work for the Netherlands Agency for Aerospace Programs (NIVR), under its programme for aeronautics and space research and technology and for the development of Fokker aircraft. A number of research programmes were executed under contract to the Royal Netherlands Air Force, the Royal Netherlands Navy, the Netherlands Department of Civil Aviation (RLD), the Netherlands Agency for 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 Windtunnel (ETW) and several government services and private companies.



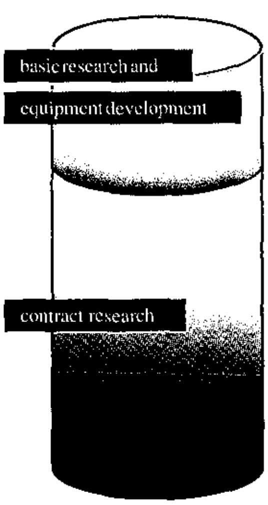
Division of the work into development and operations support



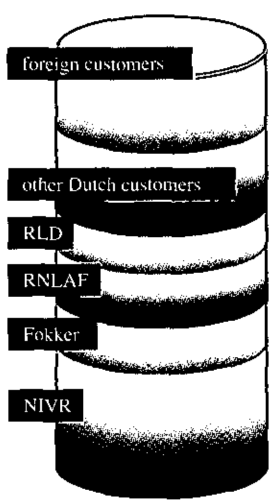
Division of the work into aeronautics and spaceflight support



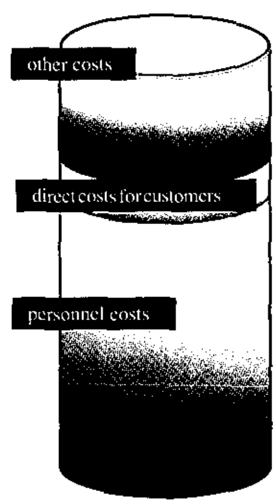
Division of the work into civil and military support



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 developments 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 present and future ATC systems was also done under contract to the Netherlands Agency for Air Traffic Control, KLM Royal Dutch Airlines and Amsterdam Airport Schiphol.

Services Provided to Foreign Customers

Research and research support carried out under contract to foreign customers amounted to 18 million guilders. Major customers were the European Space Agency (ESA), the Commission of the European Communities (CEC), Eurocontrol and Lockheed. The contracts for Lockheed included research 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 21 million guilders on its basic aerospace 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 NLR's research facilities amounted to 23 million guilders, for the greater part used for 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 13 million guilders was used for capital investments, of which the extension of the SX-3 supercomputer, the development of the NSF, and new instrumentation for the DNW were the most important ones.

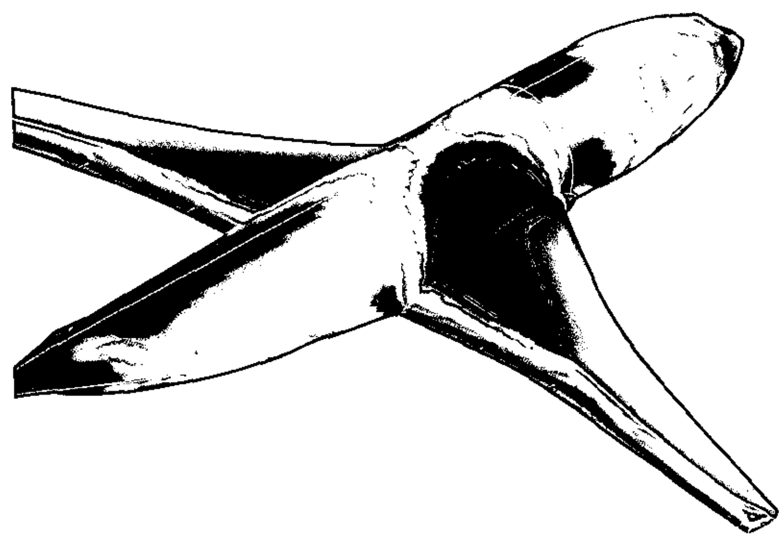
National and International Co-operation

In several projects, NLR co-operates with research institutes and universities in the Netherlands. NLR and the Delft University of Technology (DUT) jointly operate a Citation II aircraft, which is used as a research aircraft. Five 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.

The co-operation between NLR and the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) was extended. Preparations have been made for a DLR-NLR Partnership Agreement aiming at the joint operation and mutual use of research facilities and the joint execution of research projects. As a result of this agreement, the two low speed wind tunnels of NLR and DLR will be operated by the German Dutch Wind Tunnel (DNW).

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. In 1993 the seven aeronautical research institutes of the EC-countries took the initiative for a closer co-operation within an "Association of European Aeronautical Research Establishments". The main activities of the Association will be to execute joint research programmes and to execute a joint approach towards the planning, use and management of large facilities.



Visualization of Euler wing/body calculation carried out in the framework of a Garteur *collaboration*

In 1993 the European Transonic Windtunnel (ETW), located near Cologne, Germany, was in the phase of commissioning and calibration. Initial operation will start mid-1994.

Following the design and construction of the Indonesian Low Speed Wind Tunnel (ILST), collaborative activities of the research institutes LAGG of Serpong and NLR together with industry (Fokker, Indonesian Aircraft Industries IPTN) and universities (TUD, ITB Bandung) were continued under an interim Aerospace Programme for Education, Research and Technology (APERT). It was decided to extend the programme with one year (1994) to allow for sufficient time to finish the preparations for a follow-on programme. The co-operation is co-ordinated by NLR and by the Agency for the Assessment and Application of Technology (BPPT) of Indonesia.

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 the NASA Ames Research Center. Preparations were started for extensions of the co-operation in the areas of structures (ageing aircraft) and computational fluid dynamics.

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 Prof.dr.ir. P.J. Zandbergen, Chairman of the Scientific Committee NLR/NIVR, and by the members of the Board of Directors. The Scientific Committee, consisting of experts from the aerospace community (industry, universities), advises the Board on the long term programme of basic research and on results of research carried out, described in NLR reports and in the annual report of NLR's basic research programme.

In 1993 the Board adopted new Statutes for the Foundation NLR, which were approved by those Ministers who are entitled to appoint a member on the Board. Under the new Statutes the Post Office, the Royal Netherlands Aeronautical Association as well as the National Aerospace Medical Centre no longer have a seat on the Board, whereas a new seat was created for the Delft University of Technology, who appointed Prof.dr.ir. J.L. van Ingen, Dean of the Faculty of Aerospace Technology per 1 September 1993. Another seat was created for a member to be appointed by the Board, following a nomination by the Works Council. This appointment, of Ms. prof.dr. A.J.M. Roobeek, took effect per 1 January 1994.

The laboratory is headed by the directors mentioned on page 3.

On 31 December 1993 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*

As of 1 January 1993, NLR's Electrical Power Station Department, formerly under the General Services, was incorporated into the Aerodynamic Facilities Department.

The organization of the laboratory is shown on page 14.

At the end of 1993 NLR employed a staff of 923, of whom 355 were university graduates. Of the total, 837 were employed on a permanent basis, and 86 had temporary appointments. About 55 per cent of the staff are posted in Amsterdam, 45 per cent in the Noordoostpolder. A breakdown of the permanent staff is given on page 15.

Technical Director
Prof.ir. F.J. Abbink DT

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

Financial Director
J.A. Verberne R.A. DF

Associate Director — Drs. A. de Graaff DO

Support Staff — Ing. F.J. Sterk DD

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

Co-ordinators:

- **Defence Projects** — Ir.J.M.A. van den Heuvel (CPD)
- **Aircraft Development Projects** — Ing. P. Kluit (CPO)
- **Space Projects** — Drs. J.C. Venema (CPR)
- ***Aircraft Operations* Projects & Basic Research and Equipment Development** — Ir. J.A.J. van Engelen (CPG & CEW)
- ***Quality* Assurance NLR** — H. Blokker (CKZ)

Secretary — E. Folkers DJ

- **Legal** DJ
- **Filing** DB
- **Security** DB

Co-ord. AGARD / GARTEUR — Ir. L. Sombroek DA

Co-ord. Indonesia — J.P. Klok DI

Personnel — Drs. H. de Heer DZ

Company Welfare Work — Ms. M.Th.F.J. Simons DM; Ms. C. Diekema DM

Engineering and *Technical* Services
Ir. G. Brink — T

- **Technical Projects** — Ir. C.C. Groothoff — TP
- **Technical Design** — A. van den Berg — TO
- **Workshops** — Ir. H.Th.J.A. Lafleur — TW

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

- **Aerodynamic *Facilities*** — Ir. F. Jaarsma, Ir. H.A. Dambrink — AF
- ***Experimental* Aerodynamics** — Ir. A. Elsenaar — AX
- **Theoretical Aerodynamics** — Dr. B. Oskam — AT
- **Unsteady Aerodynamics & Aeroelasticity** — Prof. ir. R.J. Zwaan — AE
- **Aeroacoustics** — Dr. H.H. Brouwer — AK

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

- ***Flight Testing* and Helicopters** — Drs. N. van Driel *a.i.*, Ir. L.T. Renirie *a.i.* — VV
- **Air TrafficControl and Avionics** — Ir. H.J.. Berghuis van Woortman — VG
- **Flying Qualities and *Flight Simulation*** — Ir. W.P. de Boer — VS
- **Operations Research** — Ir. G.J. Alders — VO
- ***Aircraft* Instrumentation** — Ir. R. Krijn — VA

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

- **Loads** — Ir. J.B. de Jonge — SB
- ***Structures*** — Ir. H.H. Ottens — SC
- **Materials** — Dr. R.J.H. Wanhill — SM
- **Testing Facilities** — Dr.ir. G. Bartelds — SL

Space *Division*
Ir. B.J.P. van der Peet — R

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

***Informatics* Division**
Ir. W. Loeve — I

- **Electronics** — Ir. H.A.T. Timmers — IE
- **Mathematical Models and Methods** — Dr. R.J.P. Groothuizen — IW
- **Numerical Mathematics and *Application* Programming** — Ir. F.J. Heerema — IN
- ***Computing* Centre and Systems Programming** — Ir. U. Posthuma de Boer — IR

General Services
Ir. W.F. Wessels — G

- ***Buildings*** — Ing. H. van der Roest — GC
- **Power Distribution** — A.M.G. Reijntjens — GS
- **Housekeeping** — G. Lipsius — GZ
- **Guarding** — G.M. Zwierink — GX
- **Library and Information Services** — Ir. W.F. Wessels — GB
- **Document Processing** — Ing. D.J. Rozema — GT

Administrative Services
J.A. Verberne R.A. — O

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

Organization diagram of the laboratory, 31 December 1993

Table 1 - NLR staff at the end of 1993 (between brackets the numbers at the end of 1992)

		University graduates		Advanced technical college graduates		Others		Total	
Board of Directors		3	(3)	-	(-)	-	(-)	3	(3)
- Support Staff		15	(12)	9	(8)	4	(4)	28	(24)
		18	(15)	9	(8)	4	(4)	31	(27)
Fluid Dynamics Division	A	3	(3)	1	(1)	3	(3)	7	(7)
- Aerodynamic Facilities [1]	AF	12	(11)	24	(22)	35	(29)	71	(62)
- Experimental Aerodynamics	AX	18	(19)	15	(15)	-	(1)	33	(35)
- Aeroacoustics	AK	7	(7)	3	(3)	-	(-)	10	(10)
- Theoretical Aerodynamics	AT	17	(16)	-	(-)	-	(-)	17	(16)
- Unsteady Aerodynamics & Aeroelasticity	AE	6	(7)	3	(3)	-	(-)	9	(10)
- DNW	AD	3	(4)	13	(14)	17	(17)	33	(35)
		66	(67)	59	(58)	55	(50)	180	(175)
Flight Division	V	2	(2)	1	(1)	1	(1)	4	(4)
- Flight Testing and Helicopters	VV	18	(17)	6	(6)	1	(1)	25	(24)
- Air Traffic Control and Avionics	VG	29	(26)	5	(5)	-	(-)	34	(31)
- Flying Qualities and Flight Simulation	VS	17	(16)	11	(10)	2	(2)	30	(28)
- Operations Research	VO	21	(20)	7	(7)	1	(1)	29	(28)
- Aircraft Instrumentation	VA	15	(15)	32	(32)	7	(6)	54	(53)
		102	(96)	62	(61)	12	(11)	176	(168)
Structures and Materials Division	S	1	(1)	1	(-)	-	(1)	2	(2)
- Loads	SB	7	(8)	3	(4)	-	(-)	10	(12)
- Structures	SC	11	(10)	2	(2)	1	(1)	14	(13)
- Materials	SM	6	(5)	4	(4)	-	(-)	10	(9)
- Testing Facilities	SL	-	(-)	10	(8)	14	(16)	24	(24)
		25	(24)	20	(18)	15	(18)	60	(60)
Space Division	R	2	(2)	-	(-)	1	(1)	3	(3)
- Remote Sensing	RR	6	(6)	4	(4)	-	(-)	10	(10)
- Systems	RS	13	(12)	-	(-)	-	(-)	13	(12)
- Labatories and Thermal Control	RL	5	(5)	7	(7)	1	(1)	13	(13)
		26	(25)	11	(11)	2	(2)	39	(38)
Informatics Division	I	2	(2)	-	(-)	4	(4)	6	(6)
- Electronics	IE	16	(16)	24	(24)	5	(5)	45	(45)
- Mathematical Models en Methods	IW	11	(10)	-	(-)	-	(-)	11	(10)
- Numerical Mathematics and Applications Programming	IN	23	(23)	24	(23)	2	(2)	49	(48)
- Computing Centre and Systems Programming	IR	21	(19)	15	(14)	9	(10)	45	(43)
		73	(70)	63	(61)	20	(21)	156	(152)
Engineering and Technical Services	T	1	(1)	-	(-)	1	(1)	2	(2)
- Technical Projects	TP	5	(4)	4	(5)	2	(2)	11	(11)
- Technical Design	TO	1	(-)	11	(13)	1	(1)	13	(14)
- Workshops	TW	1	(1)	14	(12)	23	(24)	38	(37)
		8	(6)	29	(30)	27	(28)	64	(64)
General Services	G	1	(1)	2	(1)	-	(-)	3	(2)
- Buildings	GC	-	(-)	2	(2)	1	(1)	3	(3)
- Power Station [1]	GE	-	(-)	-	(3)	-	(10)	-	(13)
- Power Distribution	GS	-	(-)	5	(5)	6	(6)	11	(11)
- Housekeeping	GZ	-	(-)	2	(2)	28	(29)	30	(31)
- Guarding	GX	-	(-)	-	(-)	8	(8)	8	(8)
- Library and Information Services	GB	2	(2)	1	(1)	5	(5)	8	(8)
- Document Processing	GT	-	(-)	5	(4)	27	(28)	32	(32)
		3	(3)	17	(18)	75	(87)	95	(108)
Administrative Services	O	-	(-)	-	(-)	-	(-)	-	(-)
- Administration	OA	3	(3)	15	(14)	8	(11)	26	(28)
- Stores and Transport	OM	-	(-)	1	(1)	4	(4)	5	(5)
- Purchasing	OI	1	(1)	4	(3)	-	(-)	5	(4)
		4	(4)	20	(18)	12	(15)	36	(37)
Grand total		325	(310)	290	(283)	222	(236)	837	(829)

[1] The Power Station was incorporated in the Aerodynamics Facilities Department as of 1 January 1993

3 Activities

3.1 Fluid Dynamics

Summary

Contract and in-house technology research and development activities are executed in the areas of Experimental Aerodynamics, Computational Fluid Dynamics, Applied/Configuration Aerodynamics, Aeroelasticity, Aero-acoustics and Aerodynamic Facilities development and improvement. In 1993 the research and development activities for national customers increased. As a result of the decline in activities of the international aerospace industry, the total volume of experimental aerodynamic work under contract to foreign customers was relatively low.

The main thrust of the research and development activities in the field of Computational Fluid Dynamics (CFD) is directed towards achieving technology readiness in the area of propulsion/airframe integration and improving the capabilities in high-speed wing design and analysis. These activities concern the continued development and validation of computer code systems for Euler and Reynolds-averaged Navier-Stokes computation of flows about complex configurations (ENFLOW), for linearized potential flow computations around complex aircraft configurations (PDAERO), and for transonic aerodynamic analyses of wing-fuselage configurations (MATRICS-V). These research activities are carried out in close co-operation with Fokker Aircraft and are partly funded by the Netherlands Agency for Aerospace Programs (NIVR). Validation activities were executed partly in the framework of GARTEUR Action Groups (AD) AG 11, 15 and 17. As part of the BRITE/EURAM project ECARP, studies on mesh adaptation and multi-point airfoil design methods were continued.
Further activities involve the extension of the operational 2D unstructured Euler solver to Reynolds-averaged Navier-Stokes (RANS), and studies on turbulence models for the Reynolds-averaged Navier-Stokes equations as well as on the various aspects of Navier-Stokes large-eddy simulation (LES). In the latter area, collaboration with Twente University was established. Research on turbulent shear layers and boundary layer transition was performed in collaboration with the Aerospace Faculty of the Delft University of Technology and in GARTEUR Action Groups (AD) AG 07 and 14.
Radar Cross Section (RCS) prediction techniques under development, both for RCS analysis and design of military aerospace vehicles, were evaluated for their range of applicability.

In the area of applied/configuration aerodynamics of civil aircraft, the activities were aimed at supporting Fokker Aircraft in aerodynamic design studies, involving wing design, propulsion/airframe integration and ice accretion.
Within the framework of GARTEUR Action Group 13, existing computational methods for high-lift systems were evaluated by comparing computational results with wind tunnel measurements.
Preparations for a test in the Indonesian Low Speed Tunnel (ILST) to be executed in 1994 in the framework of collaborative high-lift research with IPTN, LAGG and Boeing continued. Work started also for a joint Fokker-IPTN-LAGG-NLR wind tunnel test in the ILST on propeller-airframe interference.
NLR also participated in the BRITE/EURAM ELFIN II (laminar flow) and Euroshock (transonic buffet phenomena) projects.

Within the scope of the collaborative research programme of the Western European Armament Group (WEAP, formerly IEPG), Technical Area 15, NLR has continued the verification and validation of the Euler and Reynolds-averaged

Navier-Stokes computer code system ENFLOW for fighter type aircraft exploiting high-angle of attack vortex lift. This work is partly funded by the Netherlands Ministry of Defence.

In the field of helicopter aerodynamics, NLR was involved in the NH90 project, and carried out research on rotor aerodynamics to improve upon the analysis of helicopter flying qualities. Part of the latter activities were executed in the framework of the BRITE/EURAM project HELISHAPE.

The activities in solving aero-thermodynamics design problems of the HERMES space vehicle using hypersonic flow solutions of the full Navier-Stokes equations, under contract to ESA, were continued.
Within the framework of the national AEOLUS programme funded by NIVR, research was initiated in the aero-thermodynamics analysis of the hypersonic inlet of an airbreathing spaceplane.

Activities in the area of aero-elasticity concentrated on the continued development, funded by NIVR and in close co-operation with Fokker Aircraft, of a pilot code (AESIM) for the computational aero-elastic simulation of transport type aircraft in transonic flow and on the continued research, funded by the Ministry of Defence and in collaboration with Lockheed Fort Worth Company, of Limit Cycle Oscillation (LCO) phenomena of fighter aircraft. The dynamic (flutter) characteristics of Thermal Protection Systems for spacecraft were investigated experimentally under contract to ESA.

In the field of propeller acoustics, the main activity, funded by NIVR, concerned the continued development of a computer code for advanced high-speed propellers. The comparison of calculated noise levels of propellers with experimental results, in the framework of GARTEUR (AD) AG 12, was completed.
The work on the transmission of sound through the rotor of a turbofan engine was continued with an additional experiment in the small anechoic wind tunnel.
The development of a model for the sound generation by supersonic ducted fans was initiated. The activities in the area of acoustic inlet liners comprised both theoretical and experimental work on the application of bulk-absorbing materials, and on the influence of splices in a liner on the sound field.
The recently completed test facility for low-frequency sound transmission through fuselage panels was used in tests of various panel configurations, including the effects of vibration damping tapes.
In the fields of propeller noise, turbofan noise and interior noise, NLR is participating in BRITE/EURAM projects SNAAP, FANPAC and BRAIN which started in 1993.

Test on a Fokker model in ground effect in the modernized transonic wind tunnel HST

The modernisation of the High Speed (transonic) wind Tunnel HST required calibration and validation tests, resulting in fine tuning of various components.

Other activities in the area of experimental facilities and equipment included extension of the capabilities of the Calibration Facility for model engines (ECF) and continuation of the development and fabrication of a new generation of internal strain gauge balances for force measurements in wind tunnels. Model engine calibration procedures were reviewed in the framework of GARTEUR (PT) AG 02.

Research

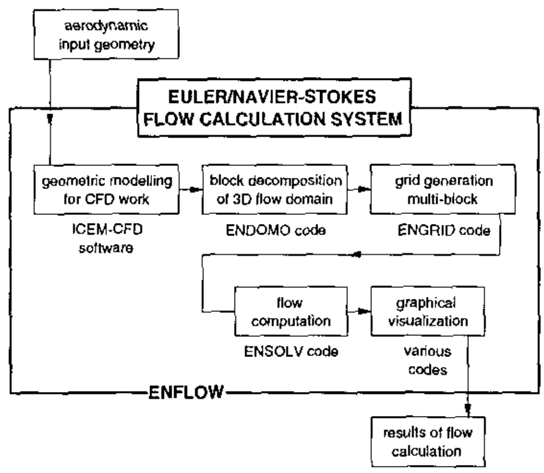
Computational Fluid Dynamics

Methods based on the Reynolds-averaged Navier-Stokes equations

ENFLOW (Euler/Navier-Stokes Flow calculation) is a system of CFD computer codes for industrial applications of the calculation of flows around aircraft and other aerodynamic configurations, such as missiles and models in wind tunnels. The ENFLOW system contains provisions for the calculation of inlet flows of turbofan engines, and of the effect of exhaust jets of jet engines. It is also possible to compute the effect of propeller slipstreams on the flow around a transport aircraft wing.

The CFD technology in the ENFLOW system is based on the use of multiblock grids, of fully-conservative central-difference methods, and explicit time-integration methods, accelerated by a multiblock/multizone multigrid method.

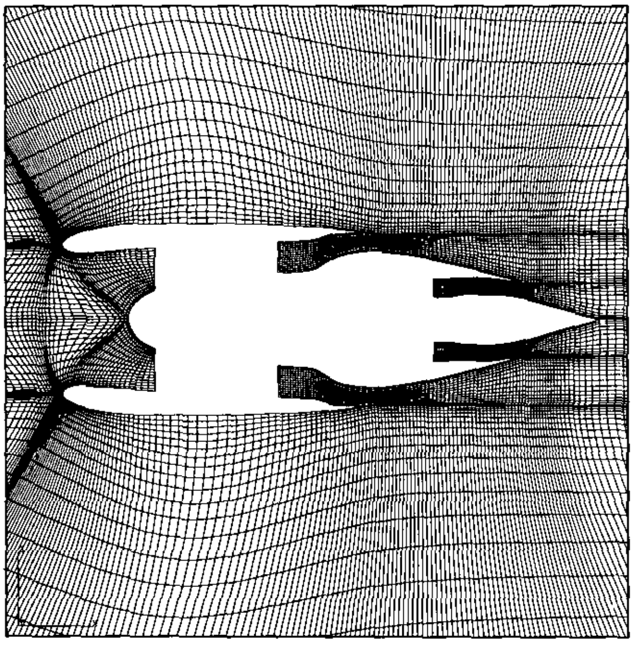
The ENFLOW system is in fact a set of standard CFD computer codes. These codes are loosely interfaced by standard files. The system contains codes for:
- preparing geometric shapes of surfaces in 3D space for CFD work,
- construction of multiblock grids in 3D space,
- execution of 3D-flow calculations, and
- graphical inspection and further processing of calculation results.



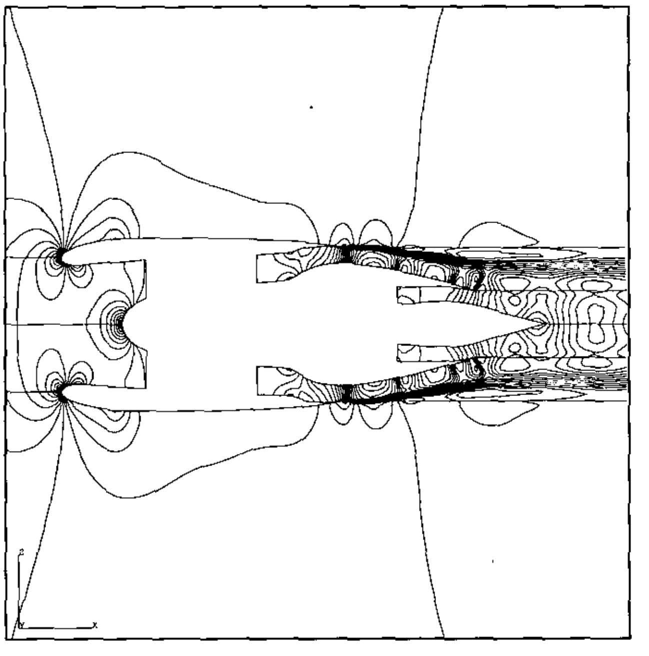
Schematic of the ENFLOW system for calculations of flow around aircraft

During 1993 the system was extended with the turbulence models of Johnson/King and of Cebeci-Smith. The former turbulence model is considered more suitable for transonic-flow calculations with shocks than the standard turbulence model of Baldwin-Lomax that was already available. The proper functioning of the new turbulence models was tested with calculations of, among other things, full 3D transonic flows with shocks around standard test wings (DLR F4 wing, ONERA M6 wing).

The ENSOLV flow solver was extended with boundary conditions for the calculation of inlet and outlet flows of jet engines.



Typical results of test calculations (cross section of multiblock grid)



Mach number distributions, shear layer, and shocks in cold fan jet

The ENGRID code in the ENFLOW system is used for the interactive construction of multiblock grids. This code was provided with new so-called elliptic methods for the construction of Navier-Stokes grids.

A renovation of the ENDOMO code for the construction of block subdivisions of flow domains was started; this work will continue in 1994. This renovation is aimed at reducing the effort for multiblock-grid construction.

To enable routine industrial applications of the ENFLOW system, further activities are carried out in the area of 2D grid adaption. For efficient and accurate calculations of the flow around a 2D single-element airfoil under a set of flow conditions (polar), a preliminary integration of a grid generator, a flow solver and a grid adaptor have been established (Hi-TASK). Typically, a complete polar of about ten angles of attack can be calculated fully automatically starting from the geometry and finishing with the aerodynamic coefficients, within an hour and a half.

The extension of an Euler solver based on unstructured grids to the level of Reynolds-averaged Navier-Stokes equations was started. This flow simulation system carries the acronym FANS (Fully Automatic Navier-Stokes). The geometry-adaptive automatic Euler grid generation algorithm was extended to an automatic Navier-Stokes grid generation algorithm. A two-equation turbulence model was selected and described. The Euler solver was extended to a laminar Navier-Stokes solver. Preliminary testing of this laminar Navier-Stokes solver was conducted.

Turbulence Research

Turbulence models are essential components in Reynolds-Averaged Navier-Stokes (RANS) methods. The success of RANS simulations strongly depends on the capability of the turbulence model to represent the relevant flow physics. The addition of turbulence models can significantly increase computing time and memory requirements. Turbulence models of different levels of sophistication are being investigated with respect to their physical as well as computational aspects. This is done through implementation in boundary layer codes as well as in RANS codes such as the ENFLOW system mentioned above.

The evaluation of algebraic models was almost completed; attention is now shifted to two-equation models.

The experimental investigation in the framework of GARTEUR (AD) AG 07 of the turbulent shear layer on a swept wing was continued. The measurements in the low speed wind tunnel LST were concluded. A comparison of the hot-wire results from NLR with the laser measurements obtained in the F-2 tunnel of ONERA in France showed some discrepancies. Some of these could be explained by higher order effects due to turbulent fluctuations. After correction for these effects the results showed good agreement.

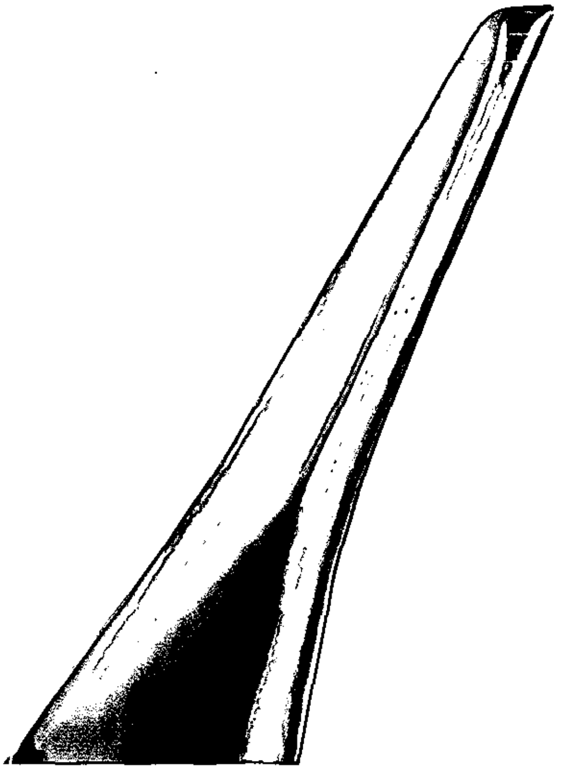
The Faculty of Aerospace Engineering of the Delft University of Technology (DUT) in collaboration with NLR performed additional turbulence measurements on the trailing edge region of the airfoil NLR 7702.

Despite the progress made in turbulence modelling for RANS it is doubtful if ever models will become available which can accurately model all types of complex flows which occur in aerodynamics. Large Eddy Simulations (LES) have the potential of alleviating some of the limitations of RANS turbulence models. LES models the small turbulent scales and directly computes the large scales. In this way more complicated turbulent flows can be computed, but at significantly higher cost than by RANS. A study has been conducted of the various aspects of LES. Further research into adaptive grid techniques, to accurately compute thin shear layers in high Reynolds number flows, as well as research into parallel processing, were found to be necessary to make LES a sufficiently efficient tool for aerodynamics.

Methods based on the Euler equations

Progress has been made in the validation of the ENFLOW system at the level of the Euler equations. Simulations for several aircraft configurations were carried out while taking into account the propulsive systems of these configurations, both in the case of high-speed propellers and in the case of turbofan engines. The configurations range from civil aircraft to missile configurations and complete fighter aircraft.

The objective of GARTEUR (AD) AG 17 is to validate Euler codes for complex geometries representative of integrated airframe/propulsion system configurations for transport aircraft. Three test cases are considered: a wing, a wing/body configuration and a wing-body-pylon-nacelle configuration. The computations for a wing were completed. The results compare well with those of other members of (AD) AG 17. In 1994 the remaining configurations are to be used for further code-to-code comparisons.



Calculated pressure distribution on a wing, a test case for validation of Euler codes

The subject of GARTEUR (AD) AG 15 is the validation of Euler codes for supersonic flow. The contribution of NLR, the validation and comparison of the computational results for one test case (analytically defined forebody), was completed. A proposal for the establishment of (AD) AG 24 for the validation of *Navier-Stokes methods for supersonic flows about generic missile configurations* has been set up.

Potential Flow Methods

The main activity in potential flow is the development of the MATRICS-V computer code system. This system is intended for accurate aerodynamic analysis of wing-body combinations representative of transport aircraft.

The MATRICS-V system consists of a grid generation part (MATGRID), and a flow solver based on the full-potential equation and an integral boundary layer method. The flow solver includes a special algorithm to compute aerodynamic forces, in particular drag and its physical components induced drag, wave drag and viscous drag. Extensive applications have shown that numerically accurate *and mutually consistent values for induced drag, wave drag and viscous drag are* obtained using a special procedure for extrapolation to zero discretization error.

The system has matured to the point where the analysis of transonic drag creep at fixed lift coefficient and fixed Reynolds number is feasible with turn-around times satisfying the requirements for industrial application.

Linearized Potential Flow Method

The PDAERO panel method for the support of the preliminary design of aircraft has been extended with the capability to analyze the flow over wings and winglike aircraft components, with accurate modelling of the thickness of these components. Validation of this capability has been carried out by comparing the PDAERO results with available aerodynamic data of an isolated wing, a flow-through nacelle and a wing/body configuration.

CFD Validation

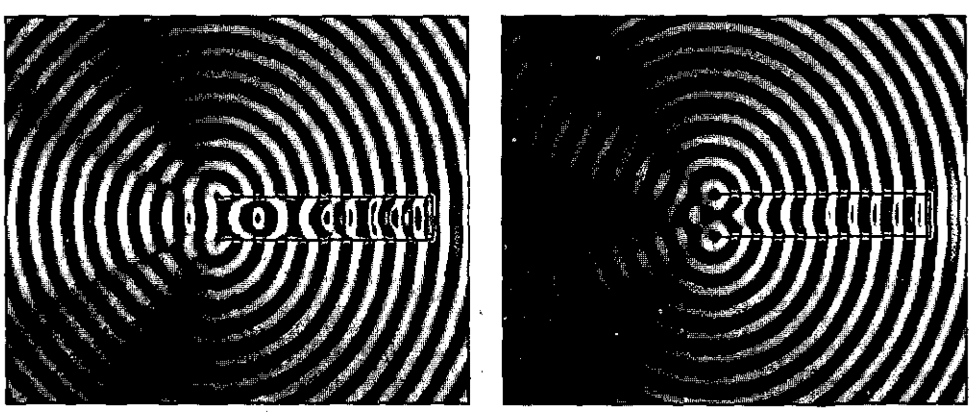
Comparisons with experiments are an essential part of the validation process of CFD codes. Work has started on the formation of a data base containing experimental data of sufficient quality for validation purposes. Part of this information comes from experiments executed in NLR's wind tunnels. NLR also contributed to the AGARD Working Group WG14 of the Fluid Dynamics Panel on "Selection of Experimental Tests Cases for CFD Validation".

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;
- boundary integral equation methods, both 2D and 3D;
- finite difference and finite element methods based on the direct solution of the Maxwell Equations (2D), to treat inhomogeneous media.

The range of applicability of the prediction techniques has been established. The high frequency prediction method is capable of computing a first estimate of the RCS characteristics of complete aircraft. The contribution to the RCS of cavity-like structures such as engine inlets can be predicted up to radar frequencies of about 1 GHz by means of the 3D boundary integral equation method. At higher frequencies the RCS characteristics have been analyzed by applying the 2D boundary integral equation methods to a rectangular inlet, both without and with a radar absorbing coating at the inside. At higher frequencies, increased levels of RCS were observed for the inlet without coating at backscattering angles near the front side. These high levels of RCS could be reduced significantly by covering the inside with a coating. This research and development work is carried out in collaboration with TNO-FEL and DASA Military Aircraft.



Calculated radar reflections from inside a rectangular engine inlet, with the incident field from left to right. The amplitude of the scattered electric field is shown, both from an untreated inlet (left-hand picture) and from an inlet provided with radar absorbing material

Aerodynamics of Wings of Transport Aircraft

In collaboration with Fokker Aircraft, design and optimization codes have been applied in 2D transonic airfoil studies and in 3D wing design studies. Theoretical drag analyses have been performed for a number of wing-body configurations.

The aerodynamics of high-lift systems was continued to be analyzed in the framework of GARTEUR (AD) AG 13. Draft versions were made of two analysis reports of previously executed wind tunnel measurements and numerical simulations (Reynolds averaged Navier-Stokes, Euler and viscid/inviscid interaction methods). NLR's contribution to this reporting focuses on the physical mechanisms of Mach number effects. It is concluded that compressibility effects on the flow about the leading edge slat can trigger a dramatic change of the flow around the complete wing. Further, instrumentation was developed for the NLR-Boeing-IPTN high-lift experiment in the Indonesian Low Speed Tunnel, aiming at studying the effect of sweep on wing leading edge slat characteristics. The experiment will be conducted in the beginning of 1994.

Attention was given to the problem of ice accretion on single element and multi-element aerofoil configurations.

Studies on the "multi-point' wing design problem were continued in the framework of the BRITE/EURAM project ECARP.

The applicability of the NLR computer code ULTRAN-V for transonic buffet prediction was investigated in the framework of the BRITE/EURAM project EUROSHOCK.

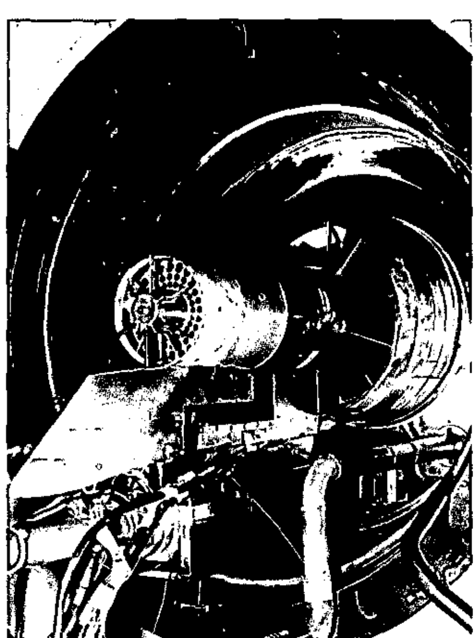
NLR also participated in an evaluation of various methods for the prediction of boundary layer transition on aircraft components on the basis of linear stability theory (the e^n-method). This was part of a collaboration within the GARTEUR (AD) AG 15.

Similar work, including a comparison with flight data, is foreseen in the BRITE/EURAM laminar flow project ELFIN II.

Propulsion-Airframe Interaction

Theoretical/computational propulsion-airframe interaction studies, using the ENFLOW and PDAERO codes were continued in collaboration with Fokker Aircraft, both for turbofan and for propeller configurations.

As part of the BRITE/EURAM DUPRIN project, two very high by-pass ratio engine simulators (Counter Rotating Ultra-high by-pass fan simulator - CRUF) were calibrated in the model engine calibration facility (ECF) of NLR. These simulators were subsequently used successfully in a DNW tests. Work started on the analysis of the results.



Calibration of an engine simulator in the model engine calibration facility

Propeller-slipstream/wing interactions will be studied experimentally in a collaborative effort of Fokker, NLR and Delft University of Technology from the Netherlands and IPTN, LAGG and the University of Technology in Bandung (ITB) from Indonesia. The test-set up was selected. The model design (using existing parts to be provided by NLR) was almost finished. The tests are scheduled for the second half of 1994 in the Indonesian Low Speed Tunnel ILST.

NLR participated in the GARTEUR Action Group on model turbofan calibration, (PT) AG 02. A test sequence was defined and a specific reference engine configurations will be tested in various European facilities. Also, tests were executed in the LST to demonstrate the attainable accuracy of thrust measurement.

Aerodynamics of Combat Aircraft

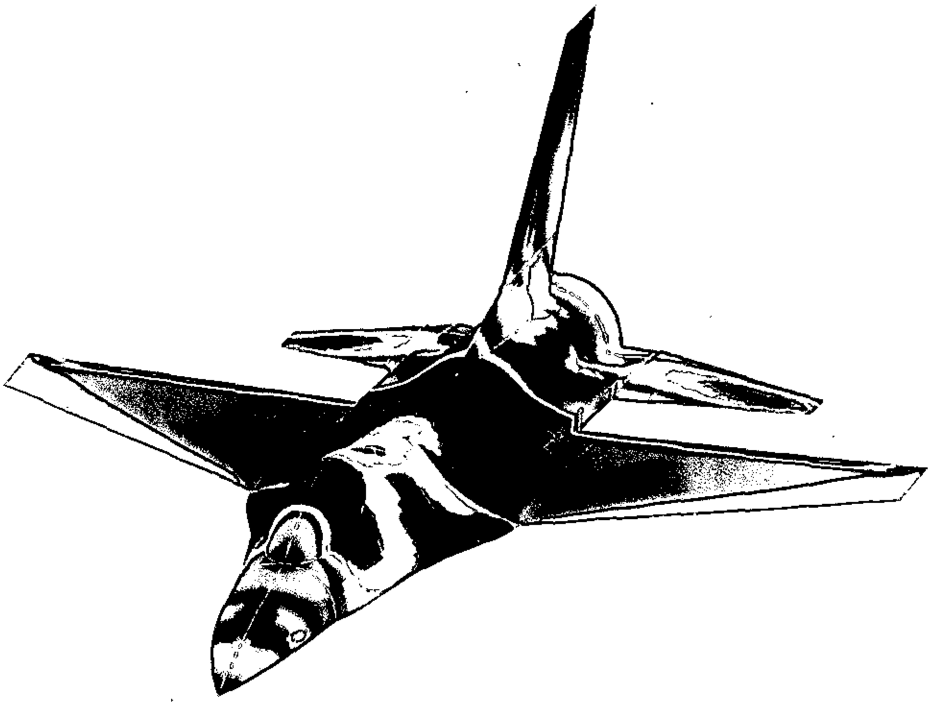
NLR participates in the collaborative research programme of the Western European Armament Group (WEAP, formerly IEPG) Technical Area 15 (TA15) "Computational Methods in Aerodynamics". NLR's contribution is partly funded by the Netherlands Ministry of Defence.

NLR is verifying and validating the CFD system ENFLOW, capable of solving the Euler equations as well as the Reynolds-averaged Navier-Stokes equations, for fighter-type aircraft exploiting high-angle of attack vortex lift. For a number of test cases, computational results are compared with experimental data. These test cases involve several geometries which are generic for modern fighter aircraft. Reynolds-averaged Navier-Stokes solutions were obtained for a sharp-edged isolated delta wing for transonic free stream Mach numbers and moderate angles of attack. Also some preliminary solutions for a rounded-edge isolated delta wing have been obtained. Navier-Stokes solutions were compared in detail with experimental data previously obtained in the HST as well as with previously obtained Euler solutions for these test cases. Although both the Euler and the Navier-Stokes solutions correctly simulate the primary vortex system induced at the sharp edges, the Navier-Stokes results showed a much better correlation with the experimental data than the Euler solutions. This is due to the fact that the secondary (turbulent boundary layer) separation caused by the adverse pressure gradient on the (smooth) upper surface induced by the primary vortex, as observed in the experimental data (but absent in the Euler solutions) is realistically captured by the Navier-Stokes method.

The status of development and validation of the ENFLOW system has reached such a level that the applicability of these methods to complete fighter aircraft is within reach. A project was started to compute the flow, based on the Euler equations, about a complete F16-A for several flow conditions.

In order to make the geometry description of the model suitable for numerical simulations, the geometry handling package ICEM/CFD was made operational at NLR. The geometry description of the F16-A has been modified such that it is suitable for numerical applications. Using this geometry description, the block-decomposition was performed using the package ENDOMO of the ENFLOW system. A start has been made with the grid generation, by applying ENGRID, the grid generator within the ENFLOW system.

Preparations were made for a wind tunnel test to be executed early 1994 in the transonic wind tunnel HST to study Reynolds number effects on asymmetric vortex shedding on a fighter-type prebody. The test is part of a collaborative effort with AerMacchi. Model design by AerMacchi was finished, whereas NLR concentrated on the required instrumentation.



Pressure distribution on a complete F-16 configuration calculated on the basis of the Euler equations

Helicopter Aerodynamics

NLR is involved in the NH90 project. This has led to an increase of research in helicopter aerodynamics. NLR has acquired the so-called CFT-code for the analysis of the handling qualities of a helicopter. The aerodynamic part of this code is based on a simple momentum/blade element theory. Work is in progress to replace this model by a more advanced vortex model. Initial calculations with a vortex model have been carried out for a helicopter in hover. Furthermore, the development and validation of aerodynamic codes for the simulation of dynamic stall of rotor blades and of dynamic inflow was continued.

NLR participates also in the BRITE/EURAM project HELISHAPE (Rotorcraft Aerodynamics and Aeroacoustics) by contributing to the formulation of a rotorcraft code based on a full potential model. This project started in 1993 and will last three years.

Hypersonic/Space Vehicle Aero-thermodynamics

In 1993 the national NIVR-funded AEOLUS programme was started, with Fokker Space and Systems, Stork Product Engineering, TNO/Prins Maurits Laboratory, Delft University of Technology and NLR as partners. The objective of this programme is to develop within the Netherlands the technology level needed for successful industrial participation in future European space transport programmes. The inlet of an airbreathing spaceplane was selected as a focusing subject for technology development. The activities of NLR within the AEROLUS programme are concerned with the aero-thermodynamic analysis and design of hypersonic inlets, sub-divided in engineering methods, CFD methods, and experiments. The main challenge is the analysis of the strongly three-dimensional features of such inlet flows including shock-boundary layer interactions, boundary layer bleeds, shear layers, etc.

The activities under contract to ESA in the area of aero-thermodynamic analysis of spaceplanes have been continued. A large number of flow solutions, based on the full Navier-Stokes equations, including equilibrium chemistry and surface radiation, have been generated in collaboration with Dassault. Both macro- and micro-aero-thermodynamic problems have been investigated, such as HERMES canopy heating (macro) and tile-intersection heating (micro).

Aeroelasticity

The development of a pilot code for the computational aeroelastic simulation of transport type aircraft in transonic flow (AESIM) was continued. The flow is modelled on the basis of a full potential representation. Various parts of the code were improved. The code was validated using several steady and unsteady, two- and three-dimensional test cases. A preliminary version of a user guide was compiled. These activities were made in close co-operation with 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 wave motions and flow separation. The analysis of the wind tunnel measurements was almost completed. Some additional processing of the data turned out to be necessary and was carried out.

The computational simulation of LCO was extended with an empirical model to represent the unsteady aerodynamic loads. Analysis of the wind tunnel data to provide the empirical information for this model was almost completed.

This research programme is carried out in a collaboration under an agreement with Lockheed Fort Worth Company (formerly General Dynamics), the US Air Force and the Netherlands Ministry of Defence.

Aeroacoustics

The development of a lifting-surface model for the aerodynamics and acoustics of propellers was continued with the implementation of single-rotating advanced propellers with supersonic helical tip speeds.

The activities of the GARTEUR Action Group (AD) AG 12 'Propeller Acoustics' were completed. The scope of this group was to compare the results obtained by the calculation methods of the participants with the results of acoustic wind tunnel tests on isolated propellers. One of the conclusions is that the NLR results compare satisfactorily with the measured data.

In the framework of the CEC-sponsored 'IMT-Aeronautics' or BRITE/EURAM programme, NLR participates in the SNAAP project, which comprises extensive acoustic and aerodynamic wind tunnel tests on advanced high-speed propellers and the development of computer codes for propeller acoustics.

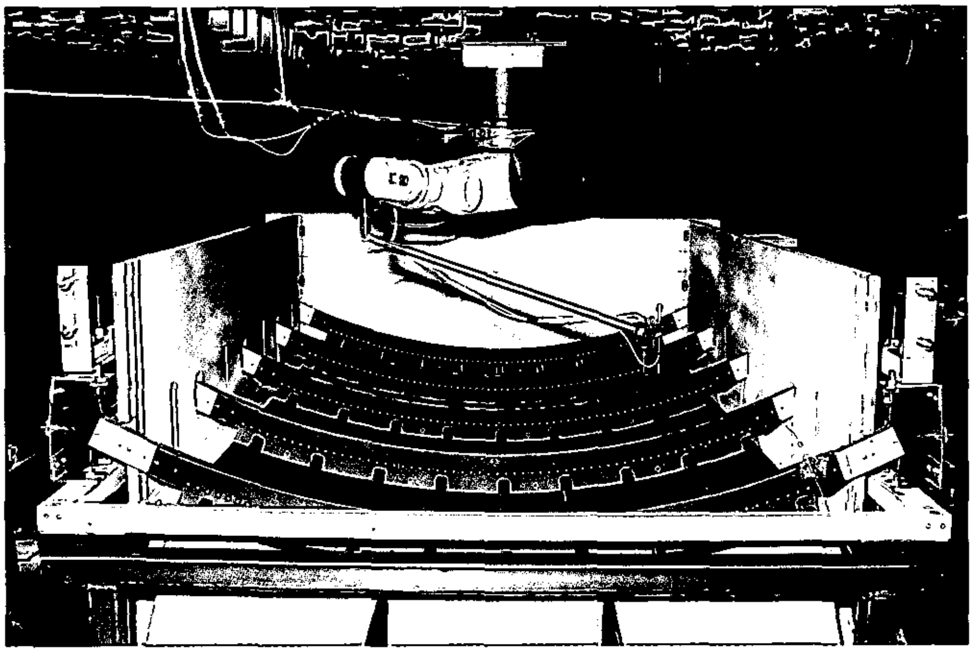
The study of the transmission of sound through the rotor of a turbofan engine was continued. Because of differences observed between the results of calculations and wind tunnel tests carried out in 1992, an additional test in the small anechoic wind tunnel was performed. This test revealed that the problems could be ascribed to unsteady transitions in the boundary layers of the stator vanes.

A computer program was made for the computation of the flow perturbations caused by the steady loading and thickness of a subsonic rotor. The modelling of the sound generated by a supersonic rotor ('rotor alone noise') was initiated.

The research on acoustic inlet liners focused on the application of bulk-absorbing materials. A theoretical model was completed for the propagation of sound in circular ducts without mean flow, lined with a bulk-absorber. An experimental method was developed for the determination of the acoustic characteristics of bulk-absorbers. Furthermore, the influence of splices in liners on the sound attenuation was investigated experimentally.

NLR co-operates with other European partners in the 'IMT-Aeronautics' project FANPAC concerning the prediction and reduction of fan noise, comprising an extensive test programme and code validation.

The recently completed test facility for the transmission of sound through fuselage panels at low frequencies was used to test various panel configurations, such as single and double wall panels. The application of vibration damping tapes at low frequencies was also investigated. During these tests some improvements were made to the facility. NLR participates in the 'IMT-Aeronautics' project BRAIN on the basic research of transmission mechanisms.



Test facility for measuring the transmission of sound through fuselage panels

Facilities and Equipment

The Transonic Wind Tunnel HST

After the major modernisation in 1992, involving a longer and optionally higher test section, new model supports and new tunnel control and model control systems, the HST was back in operation in January 1993 with Fokker as the first customer.

Since then a programme to further calibrate the flow field under various conditions and to further validate the results of certain standard tests was executed (in addition to "production" tests for customers).

This programme resulted in some adjustments of downstream components of the test section to further reduce buoyancy. With the newly developed high-accuracy balances, the repeatability over various wind tunnel entries with relatively long periods of time in between is now within one to two drag counts, independent of the type of supporting boom. Comparisons with test results before the HST modification indicated virtually identical results except for a minor shift in the drag level, possibly due to refinements in the buoyancy correction.

In the supersonic testing mode the best results were obtained with test section height set at 1.80 m (1.60 m before the modification). The Mach number distribution up to Mach 1.3 could be tuned closely to what it was before the modification.

The articulated model support boom, the most complex one of the three newly acquired booms, became ready for use towards the end of the year.

A predictive Mach number controller has been designed. It showed improved performance with respect to settling time, overshoot and power gradient violations during Mach transitions.

Tunnel control was gradually switched from manual mode via computer controlled mode to automated mode. In the automated mode, the various tunnel systems (such as model control data acquisition and processing and Speed/Mach control) operate in an integrated mode using a modern man-machine interface. A system for automated data-logging was introduced.

A start was made of an upgrade of the compressed-air system for propulsion simulation in the HST. The system can be used both for direct suction/blowing as well as for energizing Turbo Powered Simulators and miniature turbines for model propeller drives.

For special support interference assessment tests, a twin sting was developed, manufactured and applied successfully.

Low Speed Tunnel

Work was started to provide the Low Speed Tunnel LST with suction and hot compressed air blowing systems for reingestion tests on models of transport aircraft with thrust reversers in ground proximity. Also, the development of a special floor balance, mainly intended for non-aeronautical tests such as on models of cars, trains and ships, was completed.

Instrumentation and Measurement Systems

The development and acquisition of a series of new internal balances for use in the high speed tunnels were continued. Several units of each balance type will be manufactured, to assure sufficient redundancy in case of any malfunctioning. Two copies of the high-accuracy drag balances are now in operational use, showing equally good characteristics.

After the successful development of a six-component rotating shaft balance for tests on a model propeller hub in the LST, a smaller one was designed and built for tests in the HST.

The design of a new six-component half-span model balance for the HST has been completed. Manufacturing of the specially-developed high-accuracy load cells has started.

The application range of the data processing system APROPOS, in use with all NLR aerodynamic facilities, has been extended to include the processing of data of balance calibrations. A new software package for multi-component calibration data reduction is being implemented. The method of homogeneous transforms, used for the accurate determination of model attitudes and model loads in the HST, is now also available for the other wind tunnels of NLR.

Work was started to improve flow field measurements in NLR's wind tunnels. To this end rakes, instrumented with five-hole probes, are under development for measurements in wakes and slipstreams, and studies are in progress to acquire, develop and implement laser-based techniques such as Partial Image Velocimetry (PIV). In addition, a programme has started to implement the Pressure Sensitive Paint (PSP) technique in the high speed tunnels.

Propulsion and Acoustics Laboratory

From contracts with customers for the Acoustic Flow Duct Facility it became clear that the sound pressure levels in this facility should be increased to simulate a realistic sound field in either the inlet or the outlet of a turbofan engine. Some preliminary investigations were carried out with a small supersonic jet impinging on a flat plate as a noise source, leading to up to 20 dB higher sound levels in the frequency range from 1 to 6 kHz.

The flow quality of the Small Anechoic Wind Tunnel was re-investigated. To this end hot wire measurements were carried out at several positions downstream of the nozzle and at several heights.

The test facility for low-frequency sound transmission through fuselage panels was completed by implementing the software for plane wave excitation. After the first series of measurements the support of the panels was modified, leading to enhanced accuracy of the test results.

On-site work to upgrade the Calibration Facility for model engines with a balance system for measuring all six force components was started.

3.2 Flight

Summary

In the field of aircraft development, an important activity was the support in the flight testing of Fokker 50, Fokker 70 and Fokker 100 aircraft. The work for the Fokker 70 was dominant. It included data acquisition and data processing in an extensive runway performance programme in Granada, Spain.

The development of a new range of flight test equipment, under contract to the Netherlands Agency for Aerospace Programs (NIVR) and in co-operation with Fokker Aircraft, was continued. The new data acquisition units and the new video system were employed on board the Fokker 70 prototype. The flight path measurement system for runway performance and autoland testing, based on phase tracking GPS, underwent initial tests in NLR research aircraft.

A video-based method for the measurement of the change of the local angle-of-incidence of a wing due to load variations was flight-tested. Accuracies are in the 0.1 per cent class.

Within the scope of flying qualities and flight control systems, NLR contributed to a GARTEUR Action Group (AG) on low speed lateral/directional handling qualities design guidelines. A flight control system designed by this AG has been implemented in the NLR Research Flight Simulator (RFS).

NLR started an Active Flight Controls/National Fly-by-wire Testbed (AFC/NFT) project in co-operation with the Delft University of Technology (DUT). A study into an advanced robust flight control system, to be carried out under NIVR funding, has been defined.

The analysis of the symmetrical aerodynamic model and stall model of the Metro II research aircraft was completed.

Research on Take-Off Performance Monitor (TOPM) systems, supported by NIVR, was concluded by a flight simulator study with a TOPM type which in an earlier study had shown to have the largest potential to improve flight safety during take off. The test confirmed the potential benefit of the TOPM display.

Windshear research funded by NIVR was continued in several disciplines. The development of models of several airborne windshear detection systems was largely completed. An experiment with more than 240 simulated approaches through windshear was carried out on the NLR RFS. Within the framework of GARTEUR a start was made with setting up an European windshear database.

In the field of human factors, research was focused on the design of adequate techniques and procedures to exploit human capabilities effectively including flight deck display formats for 4D-trajectories, Head Up Displays (HUDs) and a 'workload toolbox' for civil and military applications.

In the field of aircraft operations, the Fairchild Metro II research aircraft was involved in flight trials using a Position Reference System incorporating an Inertial Reference System (IRS) and a Differential GPS (DGPS), an Experimental Flight Management System (EFMS) combined with a datalink and remote sensing scanners.

In the area of Air Traffic Management (ATM), NLR supported the Netherlands Agency for Air Traffic Control (LVB) and Eurocontrol. The evaluation of area conflict detection for the LVB resulted in specifications for the Amsterdam Advanced Automation (AAA) system. Means to increase the runway capacity of Amsterdam Airport Schiphol were studied.

Within the scope of the European Programme for Harmonized Air Traffic Management in Eurocontrol (PHARE), NLR in co-operation with the Defence Research Agency (DRA) of the UK, the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) of Germany and the Office National d'Etudes et de Recherches Aérospatiales (ONERA) of France, contributed to the development of an EFMS. When the EFMS was made available, it was installed in NLR's Metro II research aircraft and flight-tested. For the first time in the EFMS project a real "negotation-process" to establish a 4D-tube for the aircraft took place in-flight using a digital data link.

NLR received a contract from Thomson-CSF to build the multi-radar tracker part of the Eurocontrol ATC Radar Tracker and Server (ARTAS).

Together with the Centre d' Etudes de la Navigation Aérienne (CENA) of France and the Eurocontrol Experimental Centre, NLR studied the preparation of a multi-sector and multi-centre demonstration of advanced ATM.

NLR continued participation in the activities of the EC programmes EURET, ATLAS and SWIFT.

In the field of aircraft environmental research, numerous calculations of noise loads were made for civil airports and military airbases. Under contract to the Netherlands Department of Civil Aviation (RLD), investigations were made of the emissions of exhaust gases by aircraft.

NLR completed the development of a method for the determination of external risks around airports. The method was used in the study on the development of Schiphol.

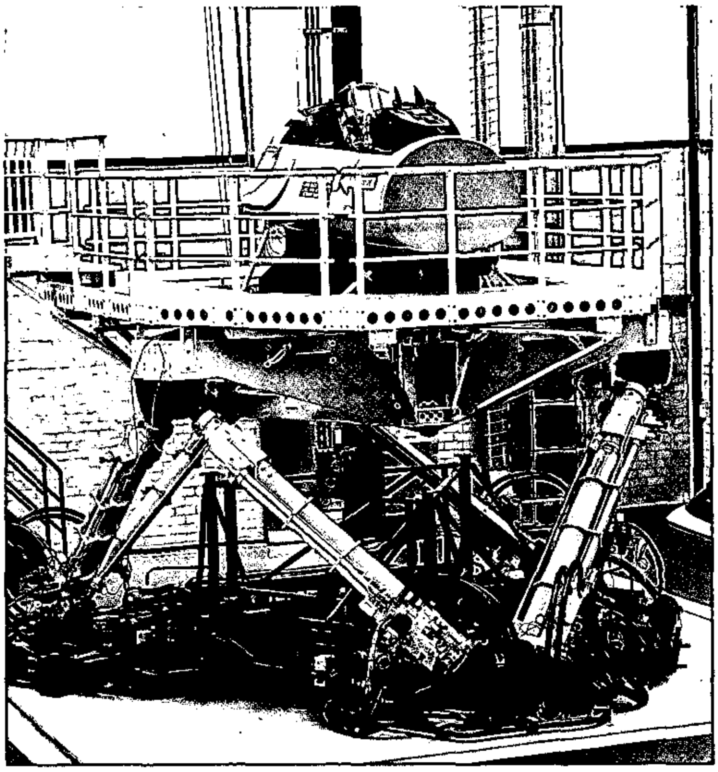
The Royal Netherlands Air Force (RNLAF) was supported by NLR in operational training in different exercises, and in the investigation of accidents with RNLAF aircraft.

NLR continued its contribution, together with Fokker and DAF Special Products, in the design and development phase of the NH90 programme for a future NATO helicopter.

With regard to facilities and equipment, the new Cessna Citation II research aircraft, jointly owned by NLR and the DUT, was accepted from the manufacturer. By the end of the year, NLR ended the operations with the Queen Air research aircraft.

The development of the National Simulation Facility (NSF) was continued. A visual system was purchased, the new host computer was installed and an F-16 mock-up became available.

NLR continued the development of the Research Flight Simulator (RFS) and the NLR ATC Research Simulator (NARSIM). These simulators (the RFS equipped with a glass cockpit) were used in many experiments to support customers in the Netherlands and abroad.



National Simulation Facility with F-16 MLU cockpit mounted

Aircraft Development

Flight Test and Flight Test Instrumentation

Evaluation and Certification of the Fokker 50, 70 and 100.

The Measurement, Recording and Data Processing system MRVS developed by NLR was used in the flight trials of the Fokker 50, Fokker 70 and Fokker 100. A team of NLR personnel provided system support and was responsible for the operations of the system during the flight tests.

Fokker 50

Flight tests with the Fokker 50 prototype were mainly concerned with the new P&W 127 engine. Other tests were dedicated to de-icing systems. Preparations were started to support the test programme of a new digital autopilot system.

The flight test programme of the 'Enforcer', a maritime patrol version of the Fokker 50, was supported by NLR personnel operating, controlling and maintaining the flight test instrumentation system. The first phase of the flight test programme was completed.

Dedicated flight test instrumentation systems were installed in two Fokker 50 "Utility" aircraft, a new version of the Fokker 50 with an enlarged cargo door, also apt for parachutist dropping. A special wake rake for flow field measurements around the cargo door was developed for these tests.

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 started with the maiden flight on 2 April 1993. The flight test measurement system for this programme is based on the system used in the earlier second Fokker 100 prototype but incorporated many newly developed items. An extensive runway performance programme was carried out in Granada, Spain. During a two-month period, NLR and Fokker personnel worked closely together, realizing a production of well over 600 take-off or landing runs. Final post-processing of the trajectory data took place at NLR in Amsterdam, before the data were transferred to Fokker.

Fokker 100

NLR's flight test instrumentation system installed in the prototype aircraft was used for further development of a number of avionic systems and for the evaluation of ice detection sensors in the Fokker 100. Other tests were aimed at the evaluation of a new main landing gear. A measurement system was installed in a production aircraft. Flight trials mainly consisted of thrust-reverser tests.

The Production Flight Test system (PFT) was used for the factory acceptance of all new Fokker 100 aircraft.

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. A number of new systems became available and were used on board the Fokker 70 prototype. The new data acquisition equipment performed very well. A new system, based on differential phase tracking GPS was introduced for flight path measurements during runway performance and autoland testing. This prototype system was evaluated on board the Fokker 70, after initial tests in NLR research aircraft.

Military Flight Test Support

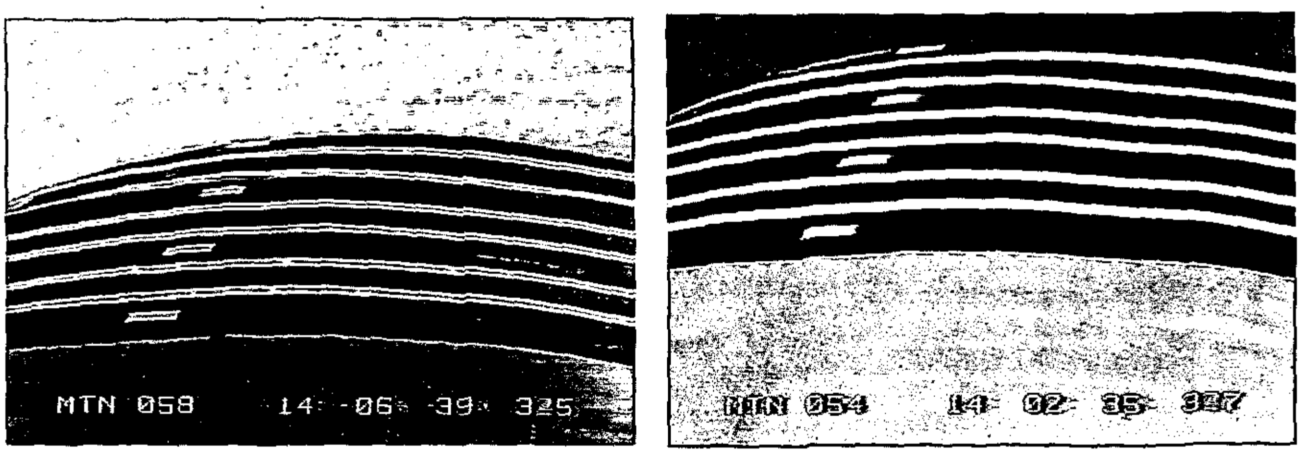
NLR assisted the Royal Netherlands Air Force during flight tests with F-16 aircraft and during air defence flight trials. New test equipment was developed.

A Stability Augmentation System evaluation programme was conducted for the operation of the Bölkow 105 helicopter provided with extra armor.

Measurement and Analysis Techniques for in-Flight Research

The development of a technique for measuring in-flight the change due to torsion of the local angle-of-incidence of a wing continued. A video- and an accelerometer-based system concept have been tested. Initial results show the video-based system to be superior. Accuracies are in the 0.1 per cent class.

Wing deflection measurements by means of a video system. Video hard copies of a marker pattern on the wing in two flight load conditions (on the left: 0.25 g, on the right: 2 g). Wing deflection is derived by image processing techniques from the shift and rotation of the pattern.



NLR presided a GARTEUR (FM) Exploratory Group on "In-Flight Laser Doppler Anemometry". Results of flight test Laser Doppler measurements of the airspeed distribution in a boundary layer will be published.

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 introduction of advanced, fly-by-wire lateral/directional flight control systems.

Following recommendations of GARTEUR Flight Mechanics Action Group (FM) AG 04, the successor (FM) AG 06 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). NLR has implemented these flight control systems in its Research Flight Simulator (RFS) to be used in the principal investigation.

AFC/NFT (Active Flight Controls/National Fly-By-Wire Testbed)

NLR is co-operating with the Delft University of Technology (DUT) in the AFC/NFT (Active Flight Controls/National Fly-By-Wire Testbed) project. A top-down study in the desired functionality of the NFT was started, using demands obtained from Fokker, DUT, RLD, LVB, NIVR and NLR. Simulation models and basic control laws were derived. A project for a study into advanced robust flight control system has been defined. The project will be harmonized with activities of a GARTEUR (FM) Action Group on Robust Flight Control to start in 1994.

Mathematical Models of Aircraft

The aerodynamic model of the Fairchild Metro II research aircraft is being determined in a co-operative project of NLR and the Faculty of Aerospace Engineering of the Delft University of Technology. The Non-Stationary Measurement Method (NSM) and advanced parameter identification techniques are used in this project. A report on the results of the analysis of the symmetrical aerodynamic model of the aircraft was completed. The report 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. TOPM systems are aimed at improving crew situational awareness by presenting real-time performance information on the status of the take-off. Such systems could enable the crew to take corrective actions in a timely manner in case take-off conditions are adversely affected. The objective of the study is to examine the potential safety benefits of such systems. Three types of TOPM were developed, ranging from a Type I system, which displays the difference between actual and expected performance, to a Type III system, which continuously predicts the ability of the aircraft to continue or to abort the take off. A previous NLR study, using fixed-based part-task flight simulation configured for a one-man crew, showed a Type III TOPM to have the largest potential to improve flight safety during take off. NLR's moving base Research Flight Simulator was used to assess further the flight crew decision making process for conventional take offs and for those aided with a type III TOPM display. The simulator was programmed with the simulation model of a Fokker 100 aircraft. Six qualified airline crews acted as test subjects. An important aspect of this study was the scrutiny of the crew procedures. The test confirmed the potential benefit of the TOPM display observed in the earlier part-task flight simulator study. The strength of a TOPM appeared to be the capability of detecting insufficient performance at an early stage of the take-off.

Windshear

Under a Windshear Masterplan, supported by the Netherlands Agency for Aerospace Programs (NIVR), the Netherlands Department of Civil Aviation (RLD), KLM Royal Dutch Airlines and the Royal Netherlands Meteorological Institute (KNMI), windshear research was conducted in several disciplines.

The development of models of several airborne windshear detection systems was largely completed. A reactive system was modeled and tested, as was a forward-looking laser detector. The forward-looking performance was modeled to be a function of the amount of precipitation.

The development of models of several ground-based windshear detection systems was started. A ground-based Doppler weather radar (TDWR) was modeled and tested. Several radar beam scanning modes were incorporated, such that the location of the windshear hazard detected determines which mode is activated.

More than 240 simulated approaches through windshear were flown by KLM airline crews. Windshear detection systems and flight procedures were tested at various windshears.

The GARTEUR Flight Mechanics Action Group (FM) AG 05 "Flight in Windshear Conditions" continued its work, especially in non-real-time simulations combining flight through windshear using forward-looking detection concepts with flight procedures. A start was made with setting up a European windshear database by determining the scope of the occurrence of windshear within the European theatre from a questionnaire sent to about 90 European airlines. Airlines turned out to be co-operative and interested, some already having accumulated about 80 cases of suspected windshear between them.

Application of Voice in the Cockpit

In a National Technology Project the TNO Human Factors Research Institute and NLR are carrying out research into the 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

Preparations were made for NLR's participation in the EUCLID CEPA Research and Technology Project 6.5 (Crew Assistant), which is due to start in 1994. NLR will utilize its expert knowledge on military operations, mission preparation systems, artificial intelligence and real-time software for airborne applications.

Human Factors

The operational and economic demands for more effective air transport systems necessitate a careful consideration of the future role of humans in operating such advanced systems. Designing adequate techniques and procedures to exploit human capabilities more effectively is a major issue in present and future NLR research.

The development of flight deck display formats, enabling the crew to handle so-called 4D trajectories, represented a key element. The information requirements were defined in close collaboration with ATC specialists and operational civil pilots, enabling the development of prototype displays for 4D navigation.

The user interfaces on the flight deck will comprise means for communicating and negotiating with Air Traffic Control. Three different data link-crew interfaces were designed and evaluated in a systematic 'human in the loop' simulation. Crew performance aspects like head-out time and crew interactions were evaluated by applying human factors related measurements like eye/head tracking equipment and automatic classification of communications. Full duplex data link was not found to be acceptable in the terminal area with present day procedures and near future equipment. The results revealed, however, new opportunities for improving air-ground communication effectiveness.

Research on the development of a practical 'Workload toolbox' for flight deck applications was continued. Civil pilots participated in an experiment exploiting several workload measurement techniques in one comprehensive scenario. The research should result in a battery of measures to enable a systematic study of crew strategies, attentional state and interactions with advanced user interfaces.

Military applications of the 'Workload toolbox' were evaluated in an in-flight experiment with the RNLAF Slingsby aircraft, planned and executed in close cooperation with experienced fighter pilots. Pilot acceptance and in-cockpit reliability of newly developed digital recording equipment including physiological sensor technology proved to be high.

Head up display issues involving selective attention and focussing problems of pilots, were studied using the F-16 cockpit design simulator. The difficulties in defining an overall mission-compatible Head Up Display (HUD) format were discussed with international experts and collaborators in both the military and civil domain. Standardisation is hampered by problems of varying information needs, resulting clutter and selective attention.

An integrated approach is becoming more and more critical as military technology transfers to the civil domain. Overall, the consensus is that the design of the more promising Helmet Mounted display formats will require new roads to be followed as HUD formats do not seem to transfer well.

Within the scope of the European Programme for Harmonized Air Traffic Management in Eurocontrol (PHARE), NLR defined a comprehensive research programme on the development of suitable human-machine interfaces for future controller working positions required for Air Traffic Management. The programme, called the Ground Human Machine Interface (GHMI) project, will be chaired by NLR.

Human factor requirements serve an increasing role in driving design guidelines as well as the evaluation and validation process of new so-called human centered systems. NLR started the process of integrating complex human factors background material and knowledge in a practical format to assist aircraft developers and users in their certification needs regarding human factors issues. This project is known under the name of CODEP (Cockpit Operability and Design Evaluation Procedure) and was tested first on helicopter cockpits.

Training and simulation are supported by two major EUCLID projects, both involving considerable human factors aspects. The first is RTP 11.1, on 'Simulation based training system concepts', and the second is on 'Simulation techniques'. Both projects include the majority of the simulation industry.

Collaboration is extensive with NASA AMES, FAA, USAF and European partner institutes including universities and TNO.

Aircraft Operations

Research Aircraft

Beech Queen Air 80

With the Queen Air research aircraft several flights were made to check the approach and runway lighting systems of all ILS-equipped instrument runways in the Netherlands.

Fairchild Metro II

A series of experimental and demonstration flights were made at Amsterdam Airport Schiphol, using the Microwave Landing System (MLS) ground installation and a programmable Electronic Flight Instrument System (EFIS) in the aircraft.

As was the Queen Air, the Metro II was also used to film the approach and runway lights of all ILS instrument runways. A flight was made to check the Precision Approach Path Indicators (PAPI) at Schiphol.

Remote sensing flights were made with the optical scanner CAESAR over different areas in the Netherlands, including flights for measuring "stress" in trees. In some flights, CAESAR was combined with the PHARS synthetic aperture radar to generate data that simulate the results of future space experiments.

A Position Reference System, consisting of an Inertial Reference System (IRS) and a Differential GPS (DGPS), with carrier phase tracking, has been tested during a number of dedicated flights.

An Experimental Flight Management System (EFMS) combined with a datalink was subject of a flight test programme at Eelde Airport.

A number of flights were executed to test sensors and special probes.

Air Traffic Management

Air Traffic Control

Research and development in Air Traffic Control has been carried out under contract to the Netherlands Agency for Air Traffic Control (LVB), and, mostly in co-operation with European industries and other research institutes, for Eurocontrol and the European Community (EC). Activity areas were: aircraft and radar models, surveillance (SSR mode S), ATC simulation and automation, controller working position, the aeronautical telecommunication network (ATN) and man-machine interface/human factors.

Extensions of an existing model for the determination of collision risk between aircraft in flight has been investigated for airspace with Automatic Dependent Surveillance (ADS) and ATC intervention.

In a co-operation of the Netherlands Department of Civil Aviation, the US Federal Aviation Administration and Eurocontrol, the development of the Radar Sub System (RSS) of the SMART-system (Simulator for Multi-radar Analysis for Realistic Traffic) was contracted to NLR. The integration of RSS with the Trajectory Sub System (TSS), built by the German company Orthogon, was completed.

The program JUMPDIF was recoded in the ADA language in order to serve as a basis for further developments.

Support to the Netherlands Agency for Air Traffic Control (LVB)

The evaluation of area conflict detection, short term conflict detection and flight plan monitoring functions has resulted in validated specifications for the Amsterdam Advanced Automation (AAA) system. Large-scale evaluation of both functions was continued. Prototyping work was done for displays and input devices for this system.

Research for automation support to the Netherlands Agency for Air Traffic Control (LVB) for the period after the acceptance of the AAA system was continued, with emphasis on flight path monitoring. Means to increase the runway capacity at Amsterdam Airport Schiphol were studied.

NLR supported the LVB in the procedural development and validation of converging runway operations aimed at increasing the Schiphol runway landing capacity.

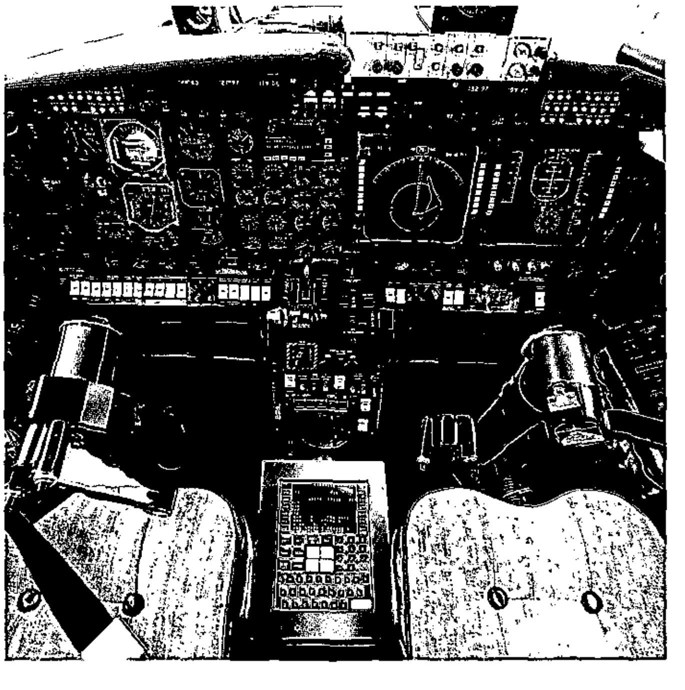
NLR contributed to the improvement of the LVB ATC training simulator.

SICAS panel of ICAO

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, SSR mode S used for advanced surveillance and as a data link and the airborne Traffic Alert and Collision Avoidance System (TCAS).

Support to Eurocontrol

Within the framework of the 'Programme for Harmonized Air traffic management Research in Eurocontrol' (PHARE) NLR contributes to the development of an Experimental Flight Management System (EFMS). 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 digital data link communication and pilot-EFMS interface.



Cockpit of NLR's Fairchild Metro II research aircraft equipped with Experimental Flight Management System (EFMS)

All software modules, written in the Ada computer language, were combined at the EFMS integration site in Bedford, UK. Then, the EFMS was made available to all partners for initial validation tests. The EFMS was installed in NLR's Metro II research aircraft, together with two programmable EFIS displays and a Primary Access Terminal featuring a colour touch screen for system control. A VHF datalink and a ground station completed the test set-up for the first flight conducted near Eelde Airport.

It was the first time in the EFMS-project that a real aircraft/ground "negotiation-process" to establish a four-dimensional tube for the aircraft took place in-flight.

In co-operation with other European research 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 co-operation with CENA (Centre d' Etudes de la Navigation Aerienne) and EEC (Eurocontrol Experimental Centre) NLR studied the preparation of PHARE Demonstration 3, a Multi-Sector, Multi-ATC Centre demonstration of advanced ATM developed by PHARE partners and intended to be operational in the period 2000 - 2010.

Eurocontrol has selected Thomson-CSF and NLR to build ARTAS (ATC Radar Tracker and Server). NLR is subcontractor to Thomson-CSF and will be responsible for the multi-radar Tracker. The development of the tracker under POD-STD2167A was started. In this development, the JUMPDIF prototype tracker, developed at NLR, is used as a basis. In co-operation with Thomson-CSF and subcontractors SYSECA and Signaal Apeldoorn (responsible for the man/machine interface and the server, respectively), a joint system definition phase was completed, resulting in the so-called allocated baseline for the ARTAS system.

Work was done under existing and new Eurocontrol contracts for the development of facilities for testing ARTAS, part of Eurocontrol Radar Analysis and Support System for Plot and Track evaluation (RASS). A quality assessment facility (MTRAQ) for mono- and multi-radar tracking systems is being developed under contract to Eurocontrol. MTRAQ enables a tracker's aircraft detection behaviour and state vector estimation accuracy, to be analyzed interactively at several abstraction levels. MTRAQ is a key constituent in RASS, to be used for off-line evaluation and validation of existing (e.g. MADAP) and newly developed (e.g. ARTAS) trackers. Object oriented analysis and design methods and CASE tools are used. Implementation is in C++ and OSF/Motif. The project is in the architectural design phase.

NLR started making improvements to the Multi-Radar Trajectory Reconstitution II (MURATREC II) program. The user interface was re-designed and extended, using the Eurocontrol standard library. A preliminary release of an improved MURATREC II was shipped to Eurocontrol Experimental Centre in order to facilitate integration into the radar analysis system.

Support to the EC

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

In the EC's programme EURET, NLR continued participating 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 and ground-to-ground data communication system. EURATN will be used to validate the draft ICAO standards and will also be used for experiment demonstrations within PHARE with advanced automation tools and the PHARE Demonstration 3.

Co-operation with NASA

A study funded by Schiphol Airport and NLR on several automation concepts for Air Traffic Control (ATC) was continued, using the NLR ATC Research Simulator (NARSIM) and an extended version of the Center/TRACON Automation System (CTAS) configured for Amsterdam Airport Schiphol, of which the baseline version was developed by the NASA Ames Research Center.

An infrastructure for future joint NASA-NLR Air Traffic Management (ATM) research experiments has been created by linking NARSIM at NLR with the CTAS-compatible, full-motion Advanced Concepts Flight Simulator (ACFS) at NASA Ames. Multiple simulated arrival flights of the ACFS for Schiphol in the Netherlands Airspace were conducted in an initial 'long line' experiment. The NASA ACFS was controlled by human pilots on the basis of data-link clearances from the fully-automated CTAS at NLR. Additional automatically controlled air traffic was generated by NARSIM.

Aircraft Environmental Research

Calculations of Noise Loads

Noise loads were calculated for the actual situations at the large civil airports and at several military airbases in the Netherlands. In addition, calculations were made for growth scenarios 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, Physical Planning and the Environment, NLR took care of the management of the noise monitoring networks near the airbases of Geilenkirchen and Brüggen in Germany. Amsterdam Airport Schiphol was assisted in the design and realization of a noise monitoring network.

Distribution of fuel burned by civil aircraft in 1992 in the Netherlands airspace between 36,000 and 45,000 ft altitude

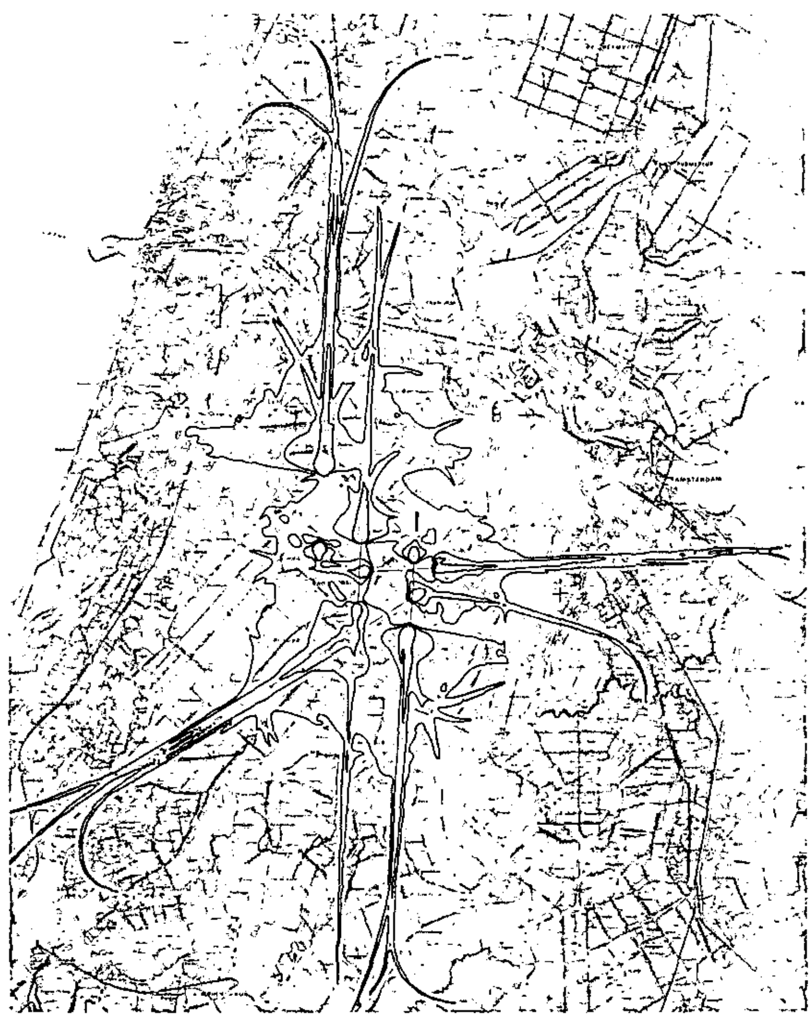
Calculation of Air Pollution

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

Accident Investigation

NLR supported the RNLAF in the investigations of accidents with RNLAF aircraft. NLR staff take part in the investigation team, mainly to investigate possible technical and operational causes of the accidents. In addition, instruction material was prepared for RNLAF pilots to provide 'lessons learned'.

NLR supported the Netherlands Department of Civil Aviation (RLD) in investigations of accidents with civil transport aircraft.



Calculated individual risk contours for Amsterdam Airport Schiphol

Risk Analyses for Airports

NLR completed the development of a method for the determination of external safety risks around airports. By this method the distribution of the individual risk can be calculated, as well as the societal risk, the probability of an accident involving more than a given number of casualties on the ground, and the associated confidence intervals. A software package was produced to implement the model. The package was used to carry out the external risk analysis for numerous development options for Amsterdam Airport Schiphol. The results were used in the 'Environmental Impact Analysis Procedure' that supports decision making on the development of Amsterdam Airport Schiphol.

Training and Instruction

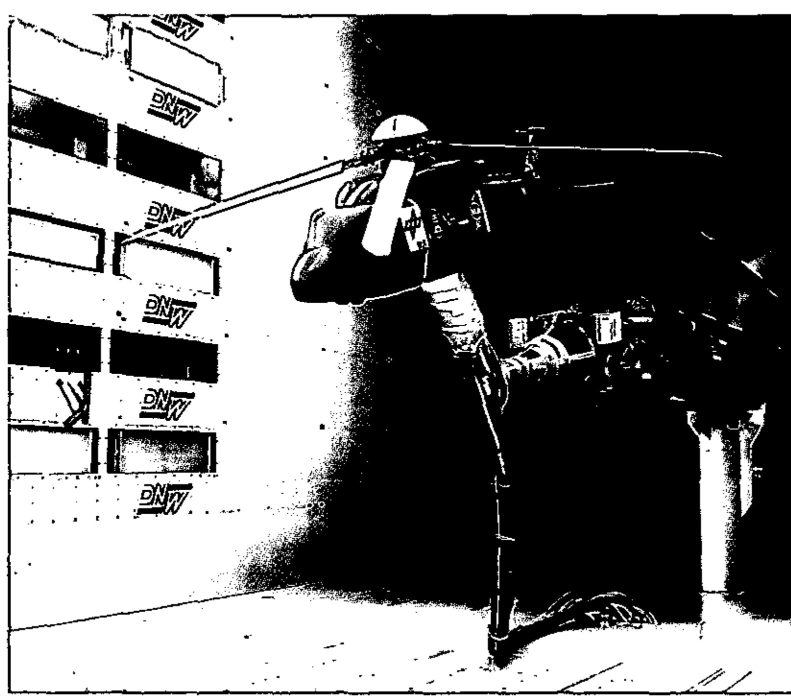
NLR assisted the RNLAF in operational training. NLR staff participated in exercises such as TACPOL and REDFLAG. The support consists of assistance with the preparation and organization of the exercises, the evaluation and debriefing of the missions flown, and of briefings on topics relevant for the specific exercise. After the exercise, the results are analyzed and documented.

NLR staff also provided instruction at the Royal Military Academy. A course on tactical use of fighter aircraft was given and a workshop was held.

Helicopters

NLR participated in the activities of the GARTEUR Group of Responsables for Helicopters. Contributions were made to the GARTEUR Action Groups (HC) AG 06, "Mathematical Modelling for the Prediction of Helicopter Flying Qualities", (HC) AG 07, "Helicopter Performance Modelling" and (HC) AG 08, "Helicopter Vibration Prediction and Methodology".

The Netherlands Department of Civil Aviation (RLD) was supported in connection with the Helicopter Airworthiness Study Group (HASG) for drafting JAR 27 and 29.



Scale 1:4 model of an NH90 with powered main rotor in the German-Dutch Wind tunnel (DNW)

In co-operation with Fokker and DAF Special Products, NLR takes part in the Design and Development phase of the NH90 programme for a future NATO helicopter. Wind tunnel tests were conducted in the LST using a model designed and manufactured by NLR. In addition, tests were carried out using an NH90 fuselage model with a powered main rotor in the German-Dutch Wind Tunnel (DNW), in close co-operation with the NH90 partners and with DLR.

The Royal Netherlands Air Force (RNLAF) and the Royal Netherlands Army were assisted extensively in the activities related to their transport helicopter and armed helicopter procurement programmes.

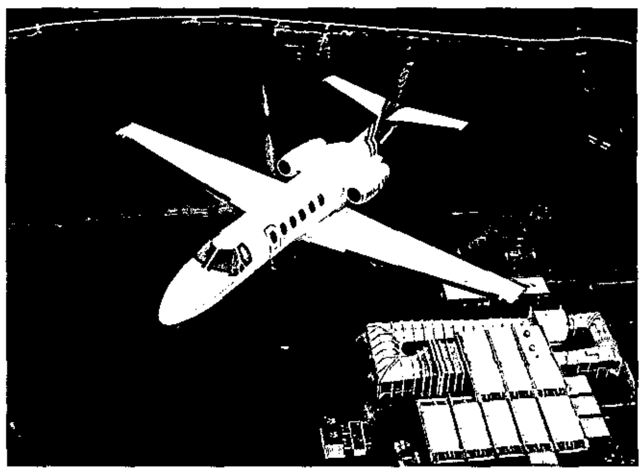
The RNLAF was supported in the introduction of the newly procured Search and Rescue helicopters.

A test programme for the Royal Netherlands Navy (RNLN) for the certification of Lynx helicopter operations on board the RNLN M-frigate was partially concluded.

Facilities and Equipment

Cessna Citation

The new Cessna Citation II research aircraft, jointly owned and operated by the Delft University of Technology and NLR, was accepted from the manufacturer on 12 March and ferried from Wichita to Amsterdam in three days. A satellite GPS receiver was tested in the first flight test programme carried out by NLR with the Cessna Citation.



Cessna Citation II research aircraft of NLR and Delft University of Technology, above the German-Dutch Wind Tunnel (DNW)

Queen Air

By the end of the year, operations with the Queen Air 80 research aircraft were terminated.

Avionics Research Testbed (ART)

Two EFIS displays and a Primary Access Terminal were installed in the Metro II research aircraft for flight testing the Experimental Flight Management System (EFMS). The VHF-bidirectional digital datalink between aircraft and ground station was tested by transmitting data from the aircraft to the NLR Air Traffic Management Research Simulator NARSIM. All other arrangements were made to be able to connect the EFMS to the standard flight test instrumentation system of the aircraft.

National Fly-by-wire Testbed (NFT)

The Citation research aircraft will be converted into a testbed suitable for Active Flight Controls research. The definition phase was continued. An executive summary stating the potential Active Flight Controls projects was prepared.

Research Flight Simulator (RFS)

Many modifications made to the Research Flight Simulator (RFS) facility were utilized in a large number of simulator experiments performed. The glass cockpit has led to increased flexibility in running experiments with various aircraft types. The development of the programmable Flight Management System, to enable different aircraft to be programmed, was continued. The acceptance of the new flight simulator interface system will enable the transport cockpit to be connected to the simulation computer with a single glass-fibre cable for all digital data transport.

National Simulation Facility (NSF)

NLR has continued the development of the flexible and versatile National Simulation Facility (NSF) as an extension to its existing flight simulation facilities. A visual system was procured from Evans & Sutherland. It consists of a dome on which two overlapping high-resolution images will be projected. The projectors are head-slaved, and will provide nearly 360 degrees unobstructed vision. The images are computed by a computer image generator allowing mission rehearsal type applications.

A new host computer was installed and integrated with a new real-time task scheduler. An advanced digital sound generation system was procured and installed. It enables the pilot to be exposed to virtually any sound, from aerodynamic hiss and missile explosions to human-like messages. The system can be upgraded to allow three-dimensional sound generation.

Functional requirements were detailed for many subsystems. Conversion and implementation of the MLU avionics software is continuing. An F-16 mock-up, developed to be used in conjunction with the NSF, became available. It was used for research into head-up-display standardization concepts and in a demonstration programme on the use of advanced landing aids with F-16s.

Facilities for Measurement and Processing of Flight Test Data

The technological developments in the field of sensors were closely monitored. A newly developed five-hole sensor for highly dynamic directional airspeed measurements was tested by measuring in flight directly behind the propeller. Initial results were promising. The dynamic range is up to 2 kHz and the directional range is ±30°.

Two recording devices for flight test instrumentation systems were acquired: an Ampex DCRSi type recorder for digital data streams of up to 107 Mbit/s and a smaller system for data streams up to 2.2 Mbit/s based on standard video recording techniques. The smaller system is intended for use in fighter aircraft test programmes.

Proposals for a new data processing system, received from several suppliers, were studied. A new system will be delivered in 1994. It will also accommodate high density digital data recordings of the Ampex DCRSi type.

Calibration and Test Equipment

The avionics and integration test facility providing programmable IRIG PCM, ARINC 429 and MIL-STD 1553 data streams was further developed and used for testing flight test instrumentation packages in the laboratory.

The accreditation of the pressure calibration facility by the Netherlands Calibration Organization (NKO) was renewed. The quality assurance system described in the new quality manual was internally audited. Technical developments included the completion of the improvement of the angle calibration set up and the implementation of a major update of the pressure calibration software.

Working groups were started to prepare a thorough overhaul of all major test, calibration and maintenance systems for flight test instrumentation equipment.

NLR ATC Research Simulator

The development of the NLR ATC Research Simulator (NARSIM) was continued. The performance of the host computer has been increased, and the controller workstations have been extended with advanced functionalities in support of LVB and European customers. Two high-performance workstations have been acquired, for software and tool development. NARSIM was moved to a new building.

Avionics-ATC Integration

In NLR's Avionics-ATC Integration project (AAI), the datalink between the ATC Simulator (NARSIM) and NLR's Fairchild Metro II research aircraft was established. Experiments were carried out with both facilities to test this connection for data transfer in both directions.

3.3 Structures and Materials

Summary

Activities were strongly focused on the application technology of composites, and on the characterization of fibre metal laminates and the assessment of their applicability in damage tolerant structures. A further intensification of research in collaboration with European aerospace partners took place. The supporting role for aircraft operators is gradually being extended to include more fleet elements, also of other nations.

For the F-16 fleet usage monitoring project, the desirability of increasing the number of aircraft monitored and the number of flight parameters to be recorded were assessed.

In a more general sense the feasibility of introducing health monitoring in addition to usage monitoring was considered, in particular for new aircraft to be introduced in service.

The re-analysis of existing flight load data under contract to the US Federal Aviation Administration was completed. An extension of NLR's advisory role in a US programme of flight load measurements was planned.

In a collaboration with Fokker Aircraft, the application of advanced thermosetting composites in primary aircraft structures is studied with the aim of realizing a technology demonstrator. NLR's contribution includes the development of stiffened panel concepts using structural optimization methods. Test panels were produced, inspected and tested. The fabrication and inspection methodology used in these development cycles is tuned to the industrial environment.

Of particular significance is the sensitivity to impact damage. Different studies address this aspect of structural safety and durability. Damage propagation in composite structural elements is evaluated in the GARTEUR Action Group (SM) AG 12. Impact damage tolerance and associated repair methodology are developed under the EUCLID Research and Technology Programme CEPA 3 - RTP 3.1. Improvement of compressive strength is the subject of the BRITE/EURAM collaborative project BE 5880.

Simultaneously, the development of composite structural concepts that enhance crashworthiness of aircraft structures continues. A special skin geometry was developed that will improve the survivability in water impacts.

Under contract to DAF Special Products, a crash tube was designed for the NH90 helicopter nose landing gear that adds a specified energy absorption capability.

Evaluation of aluminium alloy/fibre laminates continues, funded by the Netherlands Agency for Aerospace Programs (NIVR). Two families of laminates using aramid or glass fibres (ARALL and GLARE) have been developed to the stage of commercial availability. In addition to superior fatigue crack growth properties, residual strength in the presence of fatigue damage and, also, of open holes remains a critical characteristic for application in fatigue sensitive zones of the airframe.

In support of a lower wing skin panel demonstrator programme initiated by Fokker Aircraft, the development of fatigue cracks and the associated residual strength of uniaxially reinforced ARALL was studied in structural details featuring stress concentrations.

In the BRITE/EURAM programme BE 2040, the potential application of biaxially reinforced GLARE as fuselage skin panel material was investigated. Partly in support of this project, a new facility for testing of full-scale curved fuselage panels was designed.

Aircraft Loads

Current airworthiness requirements define design gust load conditions either by means of a discrete design gust of specified shape and magnitude, or in terms of a continuous turbulence representation, indicated as PSD Model. Actual severe turbulence may occur in patches of limited duration. NLR developed a method whereby the design gust is defined in terms of a patch with a specified energy content. The method, indicated as a worst case gust model, provides the highest load that may be induced by the specified gust patch.

Under contract to NIVR, tail load measurements are carried out on a Fokker 100 aircraft operated for KLM by Air Littoral. The purpose of these measurements is to get statistical data on the operational load experience of the empennage structure.

Under contract to RLD and the Federal Aviation Administration (FAA), NLR takes part in the FAA Aging Aircraft Research Program. NLR has gathered existing European load data from different sources and has re-analyzed the data to obtain the same format. Thus, a unified gust load data base covering two million flight hours has become available. In addition, NLR acts in an advisory role with regard to the instrumentation and data processing for the planned flight load measurements in large transport aircraft as well as commuter aircraft within the United States.

The Fatigue Load Monitoring programme of F-16 aircraft of the Royal Netherlands Air Force (RNLAF) has been continued. Four aircraft within each squadron are equipped with a four-channel digital solid state recorder, measuring wing root bending moment, speed, altitude and c.g. acceleration or engine RPM.

On the basis of the monitored usage data, methods have been developed to reduce the operational fatigue life consumption by means of a judicious use of store configurations.

In addition, NLR is carrying out Load and Usage Monitoring programmes for other fixed-wing aircraft and helicopters within the RNLAF and Royal Netherlands Navy and foreign Air Forces.

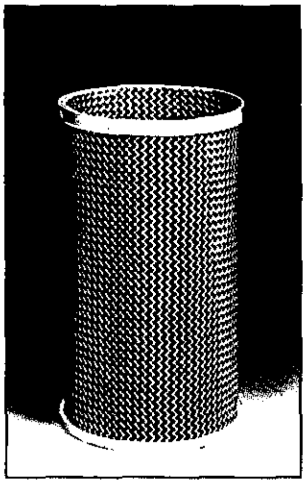
Dynamic Analysis of Structures

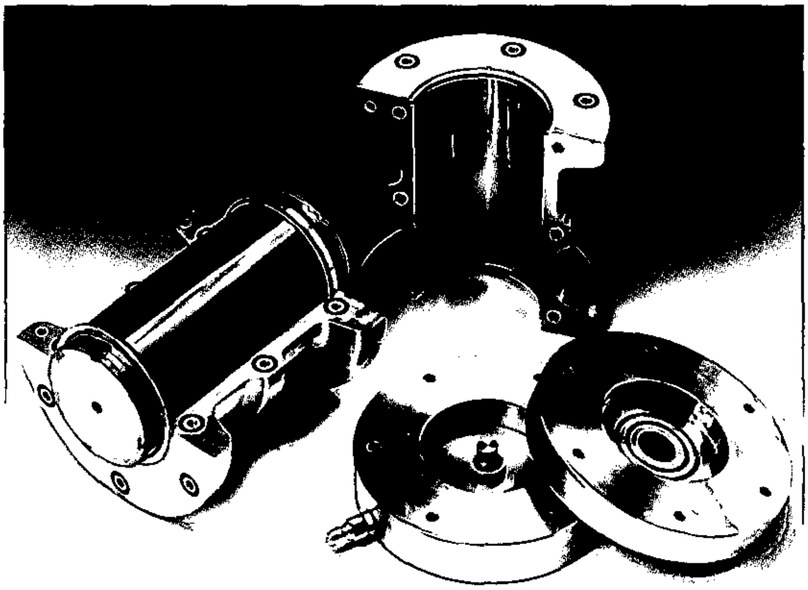
Under contract to NIVR, a method for the prediction of noise transmission through a fuselage wall was further developed. The dynamic behaviour of the exterior fuselage structure in combination with cabin panelling and the cavity in between was modelled, to enable the method to rank different structural wall concepts for design studies. Also, the description of damping in the analysis method is being improved. Moreover, methods to increase the damping, such as 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. It is now focused on the preliminary design phase. A preliminary design program, ADAS, is further developed in co-operation with the Faculty of Aerospace Engineering 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 of the postbuckling behaviour of panels loaded in compression or shear was completed. As a follow-on programme under contract to NIVR, an investigation of final panel failure and damage behaviour in an impact damaged panel was started. To be able to translate damage behaviour measured in small coupons to real structures, an intermediate level of so-called structure relevant specimens is being developed under the EUCLID CEPA 3 Research and Technology Project 3.1.





Composite crash tube prototype and manufacturing tools

Tools are being developed to analyze the static strength and buckling behaviour of composite spars. Analytical results for different access hole geometries in the web were verified experimentally.

The investigation of the crashworthiness of aircraft structures is a new activity. A composite crash tube to absorb a specified amount of energy was developed for a helicopter landing gear under contract to DAF SP.

The improvement of the crashworthiness of civil transport aircraft is studied in a BRITE/EURAM research project AE 2002. A stretchable composite skin concept, the so-called stretch skin, is developed for the improvement of the water impact behaviour of helicopters.

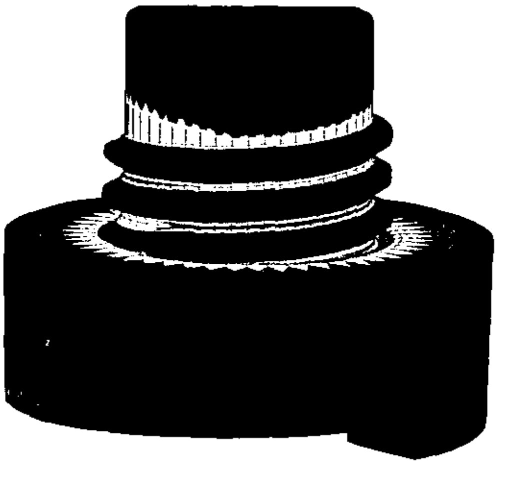
Damage Tolerance of Materials and Structures

The structural safety associated with the damage tolerance of lap joints in ageing aircraft is addressed in a programme under contract to the RLD, co-sponsored by the 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 better understanding of multiple site damage (MSD) and 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. Initial results obtained with an extremely fine-meshed model of the crack tip zone revealed a plastic constraint effect on the stress distribution very different from current assumptions.

Advanced crack growth models are being implemented in the standard damage tolerance analysis program NASGRO. This activity is performed under contract to ESA as part of a NASA-ESA collaboration programme.

Also under contract to ESA, the crack growth in bolts is being tested and analysed in great detail.



Stress distribution in an axially loaded bolt

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.

Evaluation of aluminium alloy/fibre laminates continues under NIVR funding. Two types of laminate have been developed, ARALL and GLARE, and they are commercially available. Aramid fibres are used in ARALL laminates and glass fibres in GLARE laminates.

Fibre/metal laminates have fatigue crack growth properties far superior to monolithic aluminium. However, other mechanical properties, such as fatigue crack initiation, residual strength and blunt notch strength are only little better, if at all. This necessitates the development of prediction methods for these properties. As part of an ongoing NIVR programme, NLR continued an experimental investigation into the residual strength of ARALL laminates with cracks at the thickness transition of bonded-on doublers, and an investigation into the blunt notch strength of ARALL. Based on the results of a full scale test on an ARALL3 lower wing skin panel, a new research programme was defined in co-operation with Fokker and the Faculty of Aerospace Engineering of the Delft University of

Technology. NLR's contribution to this programme consists of three items. The first is the experimental determination of the fatigue crack initiation period at open holes under flight simulation loading conditions. The second is a study into the load bearing capability of doubler run-out structures containing fatigue damage. And the third is the calculation of the residual stress distribution around holes in fibre metal laminates. All three investigations are being done for both ARALL and GLARE laminates.

Potential applications of biaxially reinforced GLARE as fuselage skin material is being investigated in the BRITE/EURAM programme BE 2040. NLR contributes to this programme by performing biaxial static and fatigue tests using the previously developed cruciform specimen. In addition, a new methodology has been developed for testing full-scale fuselage panels.

For several years a great deal of effort has been put into the study of the influence of defects on the compressive strength of composite laminates. In 1993 the BRITE/EURAM programme Damage Tolerance of Composites was completed. NLR's contribution concentrated on the development of surface layers that protect against impact damage. Also in 1993, an evaluation of the compression strength of different composite materials after impact was completed, under the aegis of the TA 21 programme of the Western European Armament Group (WEAG, formerly IEPG).

Work funded by the Ministry of Defence under the WEAG TA 31 programme on Life Cycle Concepts for Aero-Engine Components continues. In 1993 a detailed evaluation of dwell crack growth (sustained load crack growth) in Inconel 718 at 600°C demonstrated that the crack growth process is controlled by high temperature oxidation, not by creep. This means that it is not appropriate to model crack growth in terms of fatigue and creep, and it seems likely that crack growth under combinations of cyclic loads and sustained loads will be predicted adequately by existing fatigue crack growth models. Low Cycle Fatigue (LCF) testing was started. The results so far are in good agreement with test data from other laboratories.

Materials Characterization

The fatigue and fracture properties of aircraft aluminium alloys have been reviewed in a chapter for a Handbook on Fatigue Crack Propagation in Metallic Structures. This review draws on much of the work done at the NLR and elsewhere over the past 20 years, including the NIVR-sponsored programmes on damage tolerant aluminium-lithium alloys. The evaluation of damage tolerant sheet will be continued in 1994 with testing of the recently developed ALCOA alloy C188.

The fatigue crack growth properties of the damage tolerant aluminium-lithium plate alloy 8090-T8171 have been investigated as part of the programme of GARTEUR (SM) AG 07. This alloy compares well with 2024-T351 plate, although there are variations in properties through the thickness of the plate. The reasons for such variations are being investigated.

The compression failure behaviour of composites is being studied in the BRITE/EURAM programme ICOMP, with the aim of developing composites with improved compression strength.

As part of the completion of the WEAG TA 21 programme, resin cure models were developed to enable the description of the effects of cure time and temperature on the chemical reaction kinetics and the viscosity profile of the resin during curing. These cure models may be used to optimise the cure cycle for a particular product.

A new GARTEUR programme was defined for investigating cadmium-free protective coatings which are less detrimental to the environment. NLR's contribution will be funded by NIVR.

Failure Analysis

1993 was a busy year for service failures in aircraft operating in the Netherlands. Examination of failed components showed that corrosion and fatigue contributed in many cases, owing to design and/or maintenance deficiencies. Wherever possible, remedial actions were suggested.

An investigation under contract to the RNLAF was done to determine the effect of countersunk edge corrosion on fatigue crack initiation and fatigue life. A surprising result was that changes in locations of the fatigue origins did not change the fatigue life.

A method was developed to determine overtemperatures in gas turbine blades by means of the coarsening of precipitates.

Engine Materials

Plasma-sprayed porous seals that can be directly applied to compressor casings were evaluated for the RNLAF. These seals are intended to replace soldered-in strip seals worn away during service.

In the BRITE/EURAM programme BE 3339, the effect of new erosion resistant Ti/TiN multilayer compressor coatings on base metal fatigue properties was determined and explained in terms of stresses introduced during the coating process.

The microstructures of WC-Co coatings were investigated to explain their wear resistance. The corrosion resistances of other wear resistant coatings (NiB, NiP and hard chromium platings) and of conventional compressor coatings (including NiCd) were tested.

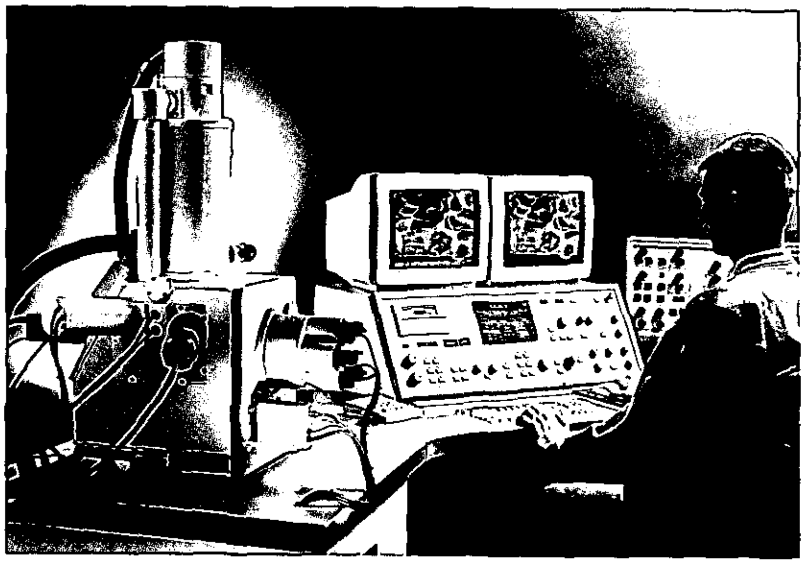
The new method to strip coatings and to clean engine components by means of ultra high pressure water jets was compared with existing techniques.

As part of the COST 501 Round II project, improved NiCoCrAlY and CoNiCrAly coatings were tested in NLR's burner rig at 900°C (hot corrosion testing) and 1100°C (oxidation testing).

Facilities and equipment

Mainly to support failure analysis activities, an additional scanning electron microscope has been installed. This fully digitized microscope (a Zeiss DSM 962), increases the already available potential of NLR in the field of material characterisation, microstructural and fracture surface analysis. With the new microscope, NLR is well provided with electron microscopes for failure investigations and contract research for the next decade.

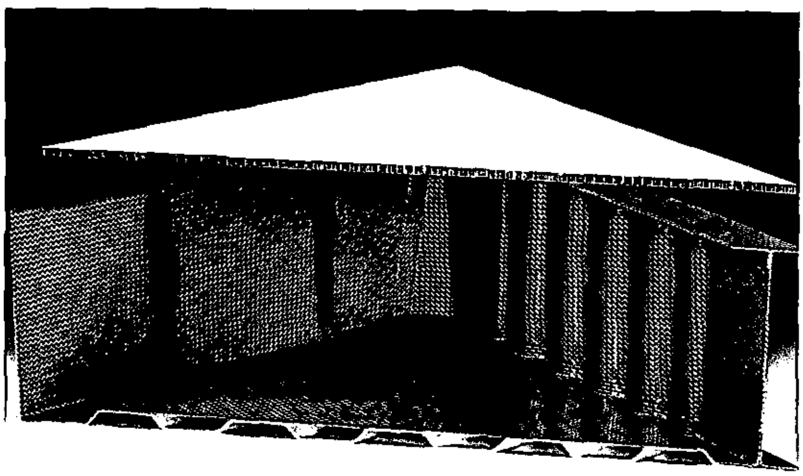
In response to industrial needs, a test facility for fuselage panel structures under simulated differential pressure and fuselage bending is under construction. This system will be made operational by the middle of 1994; in order to accept the first test panels (Fokker 100 fuselage) at the end of 1994.



Zeiss DSM 962 Scanning Electron Microscope, used for failure analysis

A production technique has been developed for generic subfloor parts of helicopters for crashworthiness in case of water impact. The structural configuration is based on the stretch skin concept.

To reduce the production costs of thermoplastic fibre reinforced parts, a new production concept has been evaluated and implemented. It features a superplastic membrane production technique in combination with heating panels and an autoclave. This work was carried out under contract to NIVR.



Helicopter subfloor structure based on stretch skin concept

A further evaluation of the ASCOR test for stress corrosion testing of aluminium alloys was started. The main objectives of the investigation are to establish the significance of the criterion for determination of stress corrosion crack initiation lives and to find out whether a threshold stress for stress corrosion micro cracking can be defined.

3.4 Space

Summary

The preparations for an experiment with a two-phase heat transport system on board of the Space Shuttle were continued. This TPX experimental system 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 Belgian and Dutch industries. In 1993 the flight modules of the components were integrated and delivered to NASA. The TPX flew on Shuttle flight STS-60 in February 1994.

NLR continued its participation in the development of the Italian-Dutch X-ray satellite SAX, partly funded by the Netherlands Agency for Aerospace Programs (NIVR). 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 this software in a functional model of the on-board computer for the AOCS; and the development of a Test and Simulation Assembly (TSA) for these tests. The development work was finalized by the end of the year.

The development of a set of modular Test and Verification Equipment (TVE) for ESA was continued, in co-operation with Fokker Space & Systems (FSS) and Adelsy of Switzerland. The TVE has to support the integration, testing and verification of the AOCS.

A Baseline Selection Phase for the STOF project (Slosh Test Orbital Facility) has been started. Its goal is to determine the options for a micro-satellite for the investigation of forces exerted upon a manoeuvring spacecraft by a liquid sloshing in a partially filled tank. This micro-satellite is to be launched from the Space Shuttle. The project is performed in co-operation with FSS. Inputs are obtained from NASA, ESA and the University of Groningen.

A study on Modular Payload Systems for microgravity experiments was started under contract to NIVR. Modules were studied for optical diagnostics, optimization of image acquisition, electronic service, data storage and microgravity disturbance measurements. Under contract to FSS, a study was started for a small automated microscope (COBAM) for cell biology in space. For Alenia a study was continued on the use of interferometry for the observation of fluids with free surfaces, with special attention to laser diodes as light sources.

Most of the activities in the framework of the Dutch Utilization Centre (DUC) concentrated on the participation in the Columbus Attached Pressurized Module mission simulation, scheduled for 1994. NLR is responsible for a Biology Facility, encompassing a Glovebox and the High Performance Capillary Electrophoresis instrument and the supporting infrastructure at NLR. The work is done in co-operation with industries and Principal Investigators.

Under contract to NIVR, the study on the automatic execution of microgravity experiments (ARMADE-project) was continued. A proposal has been prepared for ESA/NIVR to use the results of this study in the realisation of a model payload in ESA's Columbus Automation and robotics Testbed (CAT). This proposal was made in co-operation with several industries. A commercial robot system was installed in NLR's space robotics laboratory to support the integration and functional tests.

Under contract to the Netherlands Remote Sensing Board (BCRS), the microwave imaging instrument on board ERS-1 was used for oil slick detection.

The ERS-1 images were received by NLR's Fast Delivery Facility, and subsequently processed and disseminated to make the products available to the North Sea Directorate in less than 24 hours.

In 1993 a feasibility study was started under contract to BCRS and the Space Research Organization Netherlands (SRON) for a Netherlands Earth Observation Network (NEONET). The study, carried out in co-operation with other research institutes and FSS, aims to provide the definition of a national infrastructure for the Netherlands scientific and operational user community.

In 1993 NLR was selected by the European Community (European Environmental Agency Task Force) for the processing and photographic restitution of Landsat Thematic Mapper imagery. The images will be the basis for photo interpretation work of the CORINE Land Cover programme to assess land cover in five East European countries.

Under contracts to the BCRS and the Western European Union (WEU), flights were performed with the optical sensor CCD Airborne Experimental Scanner for Applications in Remote Sensing (CAESAR) and the microwave sensor Phased Array Synthetic Aperture Radar (PHARS) on board NLR's Metro II research aircraft.

For the EUCLID RTP 9.1 study "Technology concept and harmonisation", NLR acts as national representative in an internal consortium lead by the Office National d'Etudes et de Recherches Aérospatiales (ONERA) of France.

In co-operation with the International Institute for Aerospace Survey and Earth Sciences (ITC), a user consultation study was carried out for a global forest cover monitoring system for the UN Food and Agriculture Organization (FAO), using satellite imagery. Results were presented during an FAO meeting of Experts on Global Forest Resources Assessment in Finland.

NLR's Space Division obtained an ISO 9001/AQAP-110 quality assurance certificate.

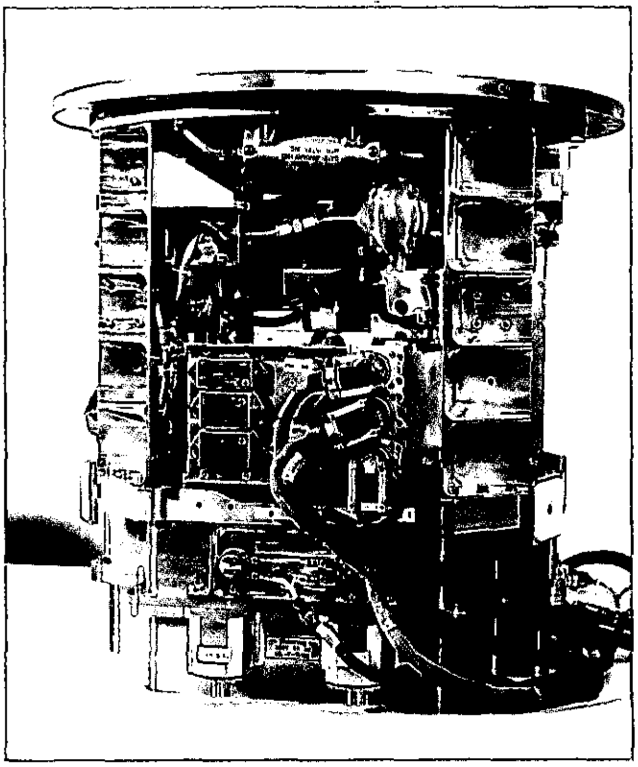
Two-Phase Experiment

In the framework of the in-orbit Technology Demonstration Programme of the European Space Agency (ESA), an experiment has been 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), Fokker Space & Systems (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 1993 the flight modules of the components were tested and calibrated. The next activity, at SABCA, was the integration of the components in the two-phase loop structure. Final integration of the loop with the control electronics and software and the system testing took place at NLR.

The flight test sequence was programmed as an autonomous sequence, for which only a switch-on by an astronaut will be necessary.

In November the Two-Phase Experiment (TPX) was delivered to ESA and shipped to Kennedy Space Centre. At the end of 1993 the TPX experiment was to be placed in the flight GAS canister for Space Shuttle flight STS-60, in February 1994. The work is performed partly under contract to ESA and NIVR and partly under NLR's basic research programme.



Two-phase heat transport system in flight configuration for testing on a Space Shuttle flight

SAX

NLR continued its participation in the development of the Italian-Dutch X-ray satellite SAX under contract to Fokker Space & Systems (FSS). FSS is subcontractor for the Attitude and Orbit Control (AOCS) of this satellite. The participation of NLR includes the development of the application software for the AOCS. This application software consists of the Basic Attitude Control (BAC) modules and the Extended Attitude Control (EAC) modules. The BAC modules carry out the primary attitude control functions required for the safety of the satellite, and the EAC modules control the attitude during the observations. NLR also performs the integration and testing of the software in a functional model (FUMO) of the on-board computer for the AOCS, and develops a Test and Simulation Assembly (TSA) for these tests.

This Test and Simulation Assembly consists of a Front End connected to and placed in the vicinity of the satellite, and a test computer. 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. NLR also supports the subsystem-level tests at Alenia, Turin.

The first version of the BAC software was delivered to Alenia (Turin) in December 1992, where the AOCS subsystem tests were started. In response to AOCS requirement changes, two further BAC versions were tested at the TSA and delivered to Alenia (Turin). An EAC version was preliminary tested at the TSA. The EAC baseline test work was finalized.

Further work on BAC and EAC versions is foreseen, to meet requirements changes and refinements. During subsystem tests at Alenia (Turin), the high quality of the TSA-tested software was proven.

Testing and Simulation

The development of modular Test and Verification Equipment (TVE) for the European Space Agency (ESA) was continued. This TVE has to support the integration and testing of the various components of the Attitude and Orbit control System (AOCS) and the verification of the correct functioning of the control loops during various stages of integration, both without and with hardware in the loop. The satellite rotational dynamics and in-orbit environment are simulated in real-time in the host computer of the TVE.

Data flow is routed to and from the satellite via two databuses, of which the MACS (Modular Attitude Control System) bus is used for transferring the simulation data output (sensor data) to the controller and the commanded actuator data to the simulation. The OBDH (On Board Data Handling) bus is used for the communication of telemetry and telecommands, the on board handling of payload (experiment) data and the controlling of the AOCS computer. The TVE is the successor to the Test and Simulation Assembly (TSA) which was developed for ESTEC, FSS and Alenia, to be used for the operational testing of ISO and SAX AOCS. The work is carried out in co-operation with FSS and Adelsy (Switzerland).

Microgravity Technology/Payloads

The performance of the WSM instrument ("ballistometer") has been analyzed in some detail with respect to errors in accelerometer data and in their configuration. In addition, the theory of an arbitrary ballistometer configuration has been further developed. This should permit to configure a ballistometer from accelerometers installed at convenient locations rather than in a prefabricated frame.

The Baseline Selection Phase for the STOF project (Slosh Test Orbital Facility), under contract to ESA, was started. The goal is to determine the options for a micro-satellite for the investigation of forces exerted upon a manoeuvring spacecraft by a liquid sloshing in a partially filled tank. This micro-satellite, called SLOSHSAT, is to be launched from the Space Shuttle. The project is performed in co-operation with FSS. Inputs are obtained from NASA, ESA and the University of Groningen.

A study on Modular Payload Systems for microgravity experiments was started. Modules for optical diagnostics, optimization of image acquisition, electronic service, data storage and microgravity disturbance measurements were studied.

In connection with the ESA study Life Science Facility Technology, a study for a small automated microscope (COBAM) for cell biology in space was started under contract to FSS.

For the Fluid Science Laboratory a study was continued, under contract to Alenia, on interferometry for the observation of fluid with free surfaces, with special attention to laser diodes as light sources. The study was extended to the impact of thermo-mechanical disturbances on optical alignment.

Telescience and Utilisation

The concept of telescience has been introduced in microgravity, to increase the efficiency of experiment development and execution by exploiting telecommunication opportunities in payload design, development and operations. Hands-on experience involving Dutch scientists has been obtained in a pilot experiment in the Anthrorack during the D-2 mission in co-operation with DLR.

In parallel, technological developments to prepare for telescience have been continued. As part of an ESA/NIVR project, a testbed has been developed for smart telescience camera concepts. This will allow the study of remote use of high performance cameras.

For the past few years, NLR has co-ordinated the Dutch activities in the development of a Dutch Utilization Centre (DUC). After a DUC Pilot had been prepared and demonstrated, a proposal was made to utilize the user support organization concept in the activities with the Crew Work Station Testbed at ESTEC. The work, mainly under contract to ESA/NIVR, concentrated on the preparation of a participation in the Columbus Attached Pressurized Module (APM) mission simulation, scheduled for 1994. NLR acts as the Facility Responsible Centre (FRC) for a Biology Facility, encompassing two multi-user facilities and experiment-dedicated equipment. Multi-user facilities are a flight-representative Glovebox and a liquid analysis system, the High Performance Capillary Electrophoresis instrument. The activities are performed in co-operation with FSS, Comprimo, Bradford, ICT, BSO and several principal investigators. The Dutch Utilisation Centre will be operating in a real space mission for the first time during the Spacelab IML-2 mission (July 1994). A Dutch experiment in the Critical Point Facility will be supported by a science team in a DUC-room at NLR's laboratory in Amsterdam.

Space Robotics

Under contract to NIVR and in co-operation with FSS, a study is being made on the tele-operation of space robots. A review of tele-operation needs was made, as was a review of the scope of a required test facility. A European Robot Arm (ERA) and AMTS tele-operation experiment plan was defined and a feasibility study of real-time simulation of flexibility, contact dynamics and force/position control was completed.

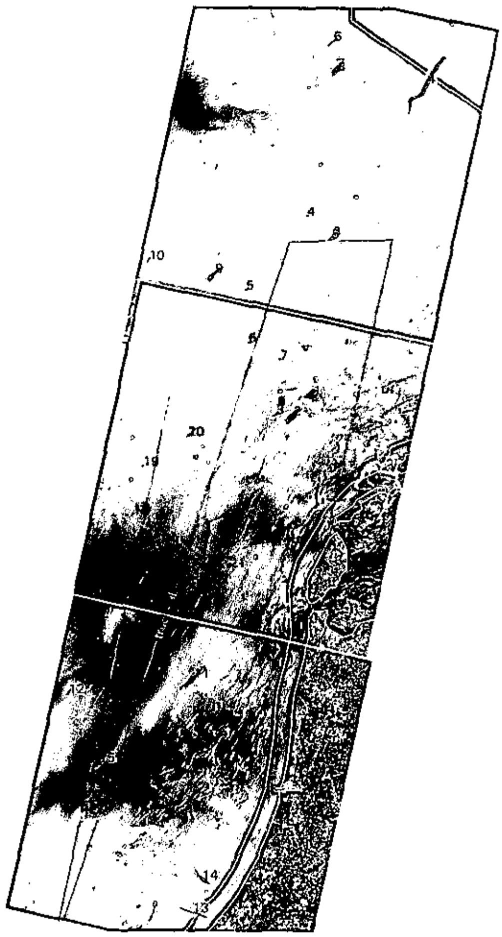
Under contract to NIVR, a study is being made on "Automation and Robotics for Microgravity Applications DEmonstrator" (ARMADE). The purpose of this study is the development and demonstration of technologies for internal (inside the spacecraft) automation and robotics, to be implemented in microgravity facilities. A proposal has been prepared for ESA/NIVR to use the results of this study in the realisation of a payload model for the Columbus Automation and robotics Testbed (CAT). This proposal was made in co-operation with FSS, Comprimo, SPE and ICT.

Under contract to ESA, a study on the specification and design of a flat-floor facility at ESTEC was made. The feasibility of such a facility was analyzed with regard to the application in the ERA robot arm development programme.

Remote Sensing

Under contract to BCRS, the microwave imaging instrument on board ERS-1 was used for oil slick detection. The aim was to examine the usefulness of Fast Delivery imagery from the European Remote Sensing Satellite (ERS-1) of the North Sea in addition to existing surveillance techniques already employed by the Ministry of Transport's Rijkswaterstaat North Sea Directorate. The ERS-1 images were received by NLR's Fast Delivery Facility, and subsequently processed and disseminated to make the products available to RWS within less than 24 hours.

A feasibility study under contract to BCRS and SRON for a Netherlands Earth Observation Network (NEONET) was started. The study, carried out in co-operation with the Royal Netherlands Meteorological Institute (KNMI), the National Institute for Public Health and Environmental Protection (RIVM) and FSS, aims to provide the definition of a national infrastructure for the Netherlands' scientific and operational user community. This infrastructure should meet the long term demand of the users and, as part of the international network, should allow active participation of Dutch user groups in international earth observation activities.



Radar images received from the ERS-1 satellite, used to study detection of oil slicks in the North Sea

NLR was selected by the European Community (European Environmental Agency Task Force) for the processing and photographic restitution of Landsat Thematic Mapper imagery. The images will be the basis for photo interpretation work of the CORINE Land Cover programme to assess land cover in five PHARE countries (Bulgaria, Poland, Rumania, Czechia and Slovakia) The work is performed with NLR's Remote Sensing Data processing system (RESEDA) using the user interface FIRST, developed in-house.

Under contracts to the BCRS and the WEU, flights were performed with the optical sensor CAESAR and the microwave sensor PHARS on board NLR's Metro II research aircraft.

NLR in co-operation with ITC carried out a user consultation study for a global forest cover monitoring system for FAO, using satellite imagery, (RESPAS). The results of the study were presented at an FAO meeting of Experts on Global Forest Resources Assessment. The meeting called attention to the urgent need for an end-to-end forest cover monitoring system using a dedicated satellite. In 1993, under contract to NIVR, a trade-off study was made on the possibility of such a dedicated satellite.

Upon request from FAO, the NLR participated in a fact-finding mission for a satellite environmental and natural resources monitoring system for the Asia and Pacific region.

The kick-off of EUCLID RTP 9.1 "Technology concept and harmonisation", which is part of CEPA 9 (Advanced technologies for Surveyance Satellites) took place. For this study NLR acts as national representative in an internal consortium lead by ONERA. A start was made with a preliminary design of an optical sensor.

As in previous years, NLR acted as National Point of Contact (NPOC) for the distribution of Landsat, ERS-1 and NOAA (National Oceanic Atmospheric Administration) remote sensing data for Eurimage and, on behalf of Système Probatoire Observation Terrestre (SPOT)-Image, for the distribution of SPOT data within the Netherlands.

Facilities and Equipment

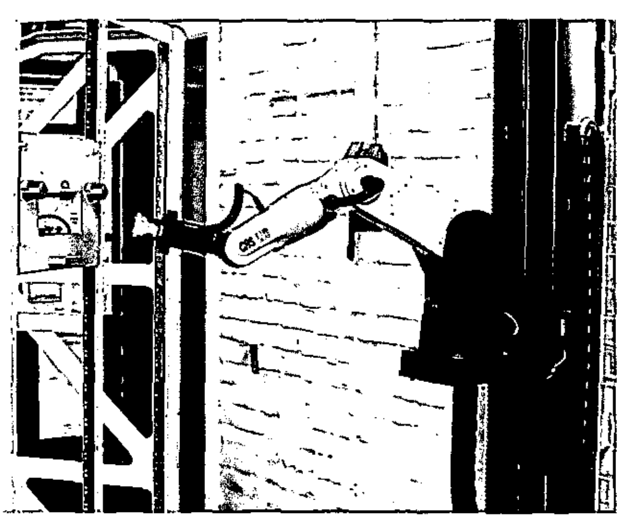
The two-phase ammonia loop has been used for testing the flight modules of the components of the Two-Phase Experiment (TPX). Adaptations of the loop were made for accurate control of the liquid/gas flow at low flow velocities.

The Test and Simulation Assembly (TSA) has been in operation to support the integration and testing of the Application Software (ASW) of the SAX Attitude Control Computer in a real-time simulation environment.

The user-friendliness of the Personal Computer (PC) program Genii-plus, purchased for the development and analysis of optical systems, was improved.

The robot system selected in 1992 was delivered, and tested in the Space Division's Robotics laboratory. The system was integrated with a vertical track. Operations are being prepared using a tool for Computer Aided Engineering, ROBCAD.

In the context of the Dutch User Support Organisation (DUSO), NLR started the implementation of a Dutch Utilization Centre (DUC) at its laboratory in the Noordoostpolder. A PC-based hardware/software and communications infrastructure has been defined and is being implemented step-by-step. It will allow support of Dutch Principal Investigators during the definition, implementation and operation of their experiments. The potential fields of application are microgravity research, science and earth observation.



Robot system integrated with a vertical track in NLR's Space Robotics Laboratory

3.5 Informatics

Summary

Mathematical models and methods have been developed for predictive control of the Mach number in the HST wind tunnel, for control of systems described by differential/algebraic equalities and inequalities, for force/position control of constrained manipulators, for the determination of the collision risk between aircraft during flight for airspace with Automatic Dependent Surveillance (ADS) and ATC intervention, for fusing data of several tactical mission sensors together with intelligence information for application to the NH90 helicopter, and for the computation of confidence regions of computed contours of risk due to aircraft accidents in the vicinity of airports.

A turbulent version of the multi-block production flow solver EDDS has been designed, implemented and tested for a single airfoil and a multi-element airfoil. First versions of mathematical and software designs of a multigrid approach have been prepared. In the development process, architecture and construction principles are applied enabling engineers from different disciplines (mathematics, physics, software engineering) to co-operate on a single product, supporting the execution of the activities in a way compatible with ISO 9001 standards.

Further development of the ISNaS software platform concerned the extension of the functionality of the user shell and the development of a tool for managing versions of source codes. In addition, the toolkit GENUINE for generating command-line, full-screen and graphics (OSF/Motif) interfaces for interactive applications was further developed and the first version of a Document Repository was realized.

In collaboration with NEC, a direct numerical simulation code developed by NEC has been evaluated. This code is parallelized by means of domain decomposition and by parallelization of the linear solver contained in it. In the context of a study agreement with IBM, a laminar flow solver of NLR has been parallelized on a cluster of four workstations by using domain decomposition based on the multi-block structure of the solver.

In the development of the Mission Support System MSS/C, the integration testing of the software for mission preparation and information control was completed. A system compatibility test was successfully completed at Lockheed Forth Worth. The Royal Netherlands Air Force was given support in the preparation of the test and evaluation of MSS/C.

In the field of airborne electronics, main research and development items were: the development of integrated navigation systems, performance assessment and applications 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 (HIRF) endangering airborne electronic equipment. To support ATC studies, NLR developed a Data Link Processor Unit (DLPU) which provides digital communication between airborne avionic systems and ground based air traffic control centres. A major upgrade of the software of the DLPU was completed and airworthiness approval was obtained from the Netherlands Department of Civil Aviation (RLD).

NLR headed an international consortium that developed a demonstrator system supporting experiments with near-real-time rectified image transmissions, real-time compression schemes and encryption. The system has been imple-

mented in the European Space Operations Centre (ESOC)'s operational Meteosat dissemination system.

NLR has contributed to the microgravity sounding rocket programme of the European Space Agency (ESA) by designing and delivering the subsystems for digital control, data acquisition and data processing of an experiment module designed by Fokker Space & Systems (FSS). The module, Cells in Space (CIS)-4, was launched successfully.

Data acquisition equipment designed by NLR for the German-Dutch Wind Tunnel (DNW) was successfully installed.

The initial implementation of the project NICE, NLR's Infrastructure for Computer aided electronics Engineering, has been completed. The Avionics Test Facility and the Automated Calibration System have been extended.

NLR's Informatics Division obtained an ISO 9001/AQAP-110 quality assurance certificate.

Mathematical Models and Methods

A teleoperation experiment plan has been established. Research items concerning planning, observability and controllability have been identified. Since the trend in space application is to more automation, systems for Failure Detection, Isolation, and Recovery (FDIR) were identified as important.

Investigations of algorithms for fusing data of several tactical mission sensors together with intelligence information have started for the application to the NH90 helicopter.

The applicability of artificial neural networks has been investigated in three application areas, viz. sensor fusion, control and image segmentation and interpretation. The research will be continued, specifically for image segmentation and interpretation.

To support the design of controllers for systems described by differential and algebraic equalities and inequalities, representations of convex polyhedral sets have been investigated. Necessary and sufficient conditions for representations to contain the minimum number of equations have been obtained. Moreover, similarity transformations between minimal representations have been defined for the tailoring of a representation in order to minimize the number of computations.

Force/position control methods for constrained manipulators have been evaluated by simulation studies.

Recent developments in the theory of dynamical systems, based on concepts such as attractors and incremental unknowns, have been evaluated with respect to their applicability in Computational Fluid Dynamics. Multigrid methods, large eddy simulation and stability analysis have appeared as most promising application areas.

A turbulent version of the multi-block production flow solver EDDS has been designed, implemented and tested for both a single airfoil and a multi-element airfoil. Grid sequencing was incorporated in this version, as a first step on the road to improving the efficiency of the solver. Initial versions of mathematical and software design of a multigrid approach have been prepared. In the development process, architecture and construction principles are applied enabling engineers from different disciplines (mathematics, physics, software engineering) to co-operate on a single product, supporting the execution of the activities in a way compatible with ISO 9001 standards.

Software Platform

The ISNaS information system for flow calculations based on the Navier-Stokes equations has developed into a software platform that has turned out to be indispensable for the functional integration of NLR's computing infrastructure and for meeting the requirements of the ISO 9001 standard. The platform was further developed. Work was done for the extension of the functionality of the user shell. This shell enables users to select, start and operate programs and to manipulate data files and on-line documentation from a single terminal or work station in the computer network without knowing on which computer the program runs or where the files involved are located. All implementation aspects (e.g. networking details) are transparent to the users. Development work was done on the tool SR for managing versions of source codes. SR is part of the Software Repository toolkit that supports software configuration management. The development of the toolkit GENUINE for generating command-line, full-screen and graphics (OSF/Motif) interfaces for interactive applications was continued. Work was done on the design and realization of the first version of the Document Repository.

At present the main users of the platform are developers of flow simulation software. Developers of control and simulation methods for systems such as manipulators, aircraft and wind tunnels are emerging as another group of users. Parts of the platform, in particular SR, are used also in several NLR projects for software version control.

Parallelization

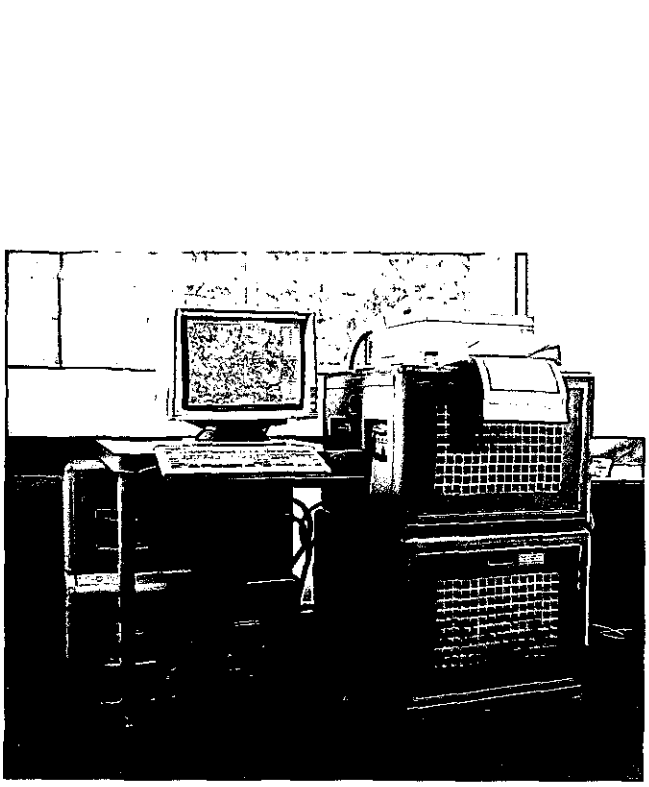
In collaboration with NEC, the parallelization of existing software, originally developed for vector supercomputers and the evaluation of parallelization tools supporting the engineering process of flow simulation software on distributed memory computer architectures were started. An NLR Euler code has been delivered to NEC to support research activities. NEC has provided NLR with a direct numerical simulation code. This code has been evaluated in co-operation with the University of Groningen. Parallelization of this code is performed by means of domain decomposition and by parallelization of the linear solver contained in it. The code is part of a real-time visualization system of NEC that will be made operational by NLR on the Cenju-3 distributed memory parallel computer that will be delivered by NEC to NLR in 1994.

In the context of a study agreement with IBM, and in co-operation with the University of Leiden, a laminar flow solver of NLR has been parallelized on a cluster of four workstations by using domain decomposition based on the multi-block structure of the solver.

Mission Preparation Systems

Integration testing of the software for the mission preparation and information control (MP/IC) functions of the Mission Support System MSS/C was completed. Integration was performed under a multi-level secure operating system, a special version of UNIX complying with the B1-level trusted system criteria. Special attention was paid to the interfacing of MSS/C to Command and Control Information Systems (CCIS) with the CCIS testbed developed for this purpose. At Lockheed Fort Worth Company the System Compatibility Test (1) was prepared and successfully performed.

Optical disk sets with electronic continuous maps and terrain data were produced for the participating air forces. One full-scale system on which demonstrations for Air Force staff could be given was installed at NLR.



The deployable Mission Support System/Computer Aided Mission Preparation at Airbase Level (MSS/CAMPAL) ready for field evaluation

Support was given to the Royal Netherlands Air Force in the preparation of the Operational Test and Evaluation of the MSS/C system, to take place in the first quarter of 1994.

Within the scope of the AGARD Support programmes, two specialists of NLR on the subject of mission preparation systems visited Greece in order to discuss the development and functions of the Hellenic Air Force Mission Planning System.

Aircraft Tracking Systems and Evaluation Tools

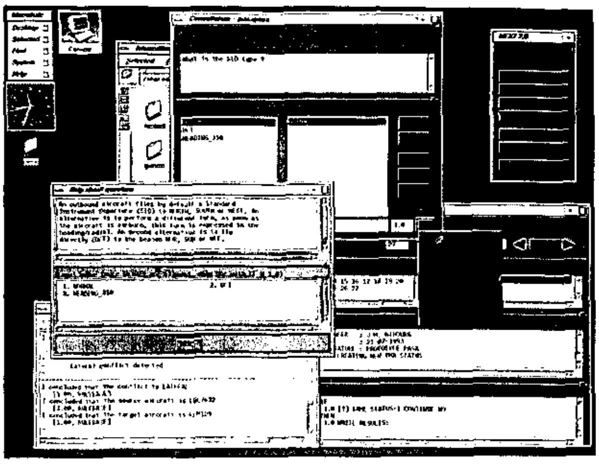
Development work in the area of mathematical models and methods for aircraft tracking systems and evaluation tools is mentioned in Chapter 3.2, Flight.

Expert Systems and Computer Based Training

The NLR Engineering X-pert system Toolkit (NEXT), a development environment for knowledge-based systems, has been extended with a graphical user interface, based on OSF/Motif. Also, the possibility of coupling NEXT to relational databases has been realised. The basis has been laid for a knowledge base full screen editor, which supports static verification of knowledge bases.

Under contract to the Netherlands Agency for Air Traffic Control (LVB), a *feasibility study "Procedural Approach Student Achievement (PASA)" has been* performed, to investigate the use of knowledge technology for measuring the technical performance of student ATC controllers. The point of departure was the basic ATC training course, PAT, which is conducted on the Ferranti ATC simulator. A laboratory system is being developed, using the NLR Engineering X-pert system Toolkit, NEXT.

Under contract to LVB, a number of modifications to the Ferranti ATC training simulator have been carried out to upgrade the aircraft performance model and to obtain greater ease of operation for the blip drivers.

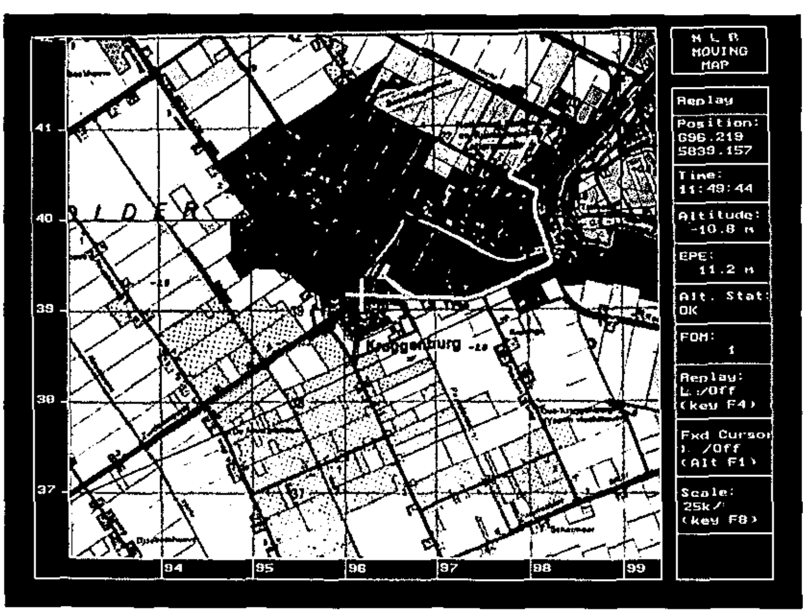


Graphical user interface of NLR Engineering X-pert system Toolkit (NEXT)

Electronic Systems for Airborne Applications

NLR is involved in the design and development of the NATO Frigate Helicopter (NFH) mission system for the NH90. The NFH mission system will be capable of correlating data from the NFH mission sensors and other sources to obtain an accurate (synthetic) representation of the tactical environment in which the NFH is operating. This capability is referred to as Synthetic State Determination (SSD). NLR will design a flight-qualified software module to be implemented in the NFH mission system. A detailed specification for the SSD module was written, and a number of technical solutions were identified.

An electronic moving map navigation system has been developed using the real-time output of a Precision Light Weight military GPS receiver (PLGR). The system, implemented on a high-end portable Personal Computer with high resolution colour screen, is intended to enable helicopter crew to accurately navigate in unknown terrain or under bad weather conditions.



GPS-derived position and track shown on a scrolling map, displayed on a notebook Personal Computer

The Navstar GPS satellite navigation system is entering its operational phase: 23 operational satellites were launched at the end of 1993. This system may eventually replace other positioning systems such as TRANSIT, Omega and even TACAN, either as a stand-alone system or in combination with systems such as INS (Inertial Navigation System), MLS (Microwave Landing System) and TRN (Terrain Referenced Navigation). Within NATO, the Working Group WG/5, "On GPS and other advanced navigation systems" deals with these matters. A member of NLR's staff was chairman of this WG. Among other things, this group provides exchange of information on new navigation technologies and systems and it initiates, designs and maintains STANAGs (Standardization Agreements) for example on GPS and DGPS (Differential GPS).

Under contact to the Royal Netherlands Navy, NLR developed and built a prototype shipboard adaptive antenna for the GPS system, which potentially is able to reduce the influence of jamming signals. A concept test programme was set-up aiming at the demonstration of the effectiveness of it on a frigate.

Data Link Processor Unit (DLPU)

Following the development of one prototype and the delivery to Eurocontrol of twelve production versions of the Data Link Processor Unit (DLPU) in 1989, NLR has successfully completed a major software upgrade of the DLPU. Added functionality of the DLPU allows Eurocontrol to conduct experiments involving ATC information exchange between pilot and controller and to transfer weather reports from ground data bases to a cockpit printer at pilot's request. The upgrade was carried out conform RTCA document DO-178A and has been certified by the Netherlands Department of Civil Aviation. After completion of the software upgrade for the prototype unit, the production units were returned to NLR in batches. Subsequently, each batch of units was upgraded and airworthiness certificates were obtained. Eight units have been upgraded in 1993. The remaining units will follow in 1994.

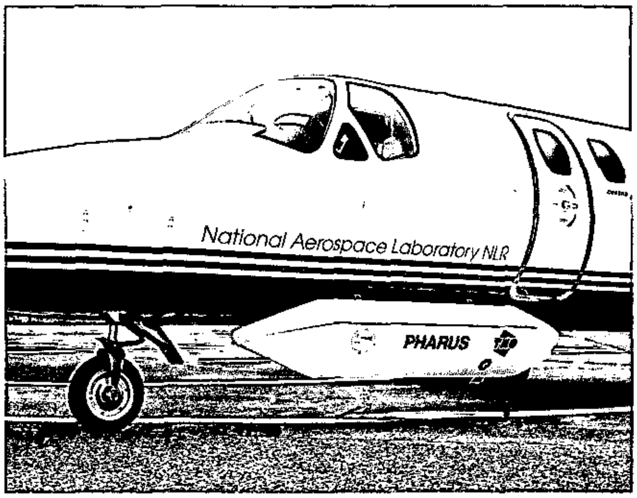
F-16 Mid Life Update

Within the framework of the co-development programme for the MidLife Update (MLU) of the F-16, three members of the NLR staff were detached at Lockheed Forth Worth Company, Texas. Their duties included making contributions to the definition of the Interface Control Document about the F-16 MLU avionics architecture, in particular for the European subelements. In addition they worked on the design of test cases for several functional parts of the Modular Mission Computer software.

PHARUS

The PHARUS project consists of the definition, the design and the construction of a fully polarimetric synthetic aperture airborne radar, to be flown on a research aircraft of NLR. The project is in the middle of the construction phase; the system is scheduled to be available at the growing season of 1995.

PHARUS is a co-operation of the Physics and Electronics Laboratory TNO (FEL-TNO), the Faculty of Electrical Engineering of the Delft University of Technology (DUT) and NLR. A major part of NLR's contribution is the operator control and the design and construction of the electronics for the acquisition, digitization, preprocessing and recording of the radar measurements. Another responsibility of NLR is the construction of the external container in which the radar is integrated with a complex cooling system. This container is to be carried by the new Citation II research aircraft of NLR and DUT, equipped with instruments for a precise (mm's) determination of trajectory and attitude of the radar.



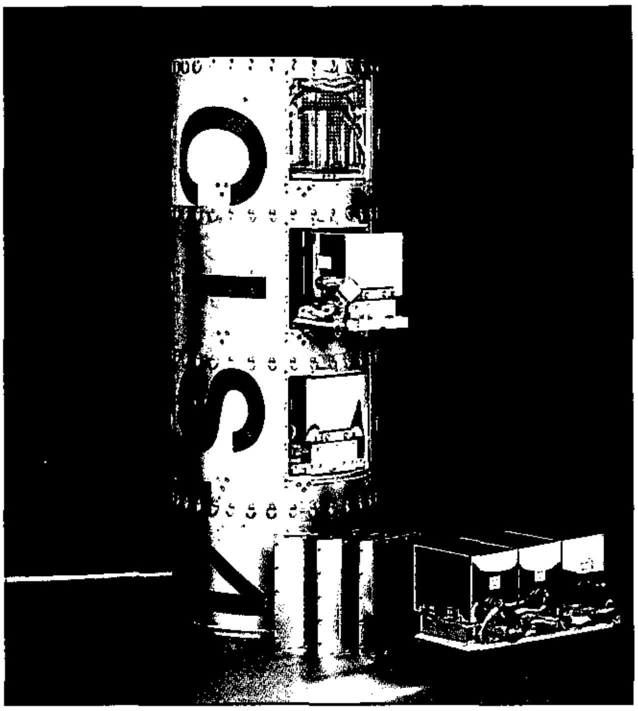
Mock-up of the external container for a Synthetic Aperture Radar mounted to special hardpoints of the Citation II research aircraft

Electronic Systems for Space Applications

Under contract to the European Space Operations Centre (ESOC), the project MERID (Meteosat Real Time Image Dissemination) was executed. The MERID system is based on the METEODIS (Meteosat Dissemination) demonstration system developed by NLR in a previous project. In the MERID project, the demonstration system has been 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 the value for operational use. At the same time, data dissemination gaps resulting from the 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. Performance tests have shown that the MERID system enables all Meteosat image data (three spectral channels) to be disseminated 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 the European Space Agency (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-4 was launched in November 1993, carrying many biological experiments under microgravity conditions lasting six minutes. A new distributed control concept has been introduced to manage a complex of so-called smart experiment subsystems. One of these subsystems is the Smart Thermal Interface Plate (STIP), a temperature control system that can operate either autonomously or remotely controlled by a facility controller on a Personal Computer. CIS-4 contained nine such STIPs; in all, CIS-4 contained 29 microprocessors.



Cells In Space (CIS)-4 module for life science research incorporating service electronics developed by NLR *(photograph courtesy FSS)*

Multimedia Applications

NLR in co-operation with Signaal Special Products (SSP) has developed a concept for a space qualified CD-ROM drive, intended for storage of system software and maintenance documentation in the Columbus Attached Module. The design, based on a MIL-Standard device, includes all necessary adaptations to meet the specific environmental and interfacing requirements of the Columbus module. The system is extendable to Rewritable Compact Disk and Interactive Compact Disk systems. A detailed analysis, under contract to Matra-Marconi Space, on the qualifiability of critical electrical and mechanical components and techniques was started.

A multimedia telecommunication system has been developed for efficient and effective real-time interactive tele-education and tele-instruction applications. The concept is based on audio, graphics, text, line-drawing and low frame-rate video communication using new methods to minimize end-to-end delay times. A possible application area is astronaut-ground communication in manned space projects.

Ground stations

The operational remote sensing system ARTEMIS, developed by NLR for the Food and Agricultural Organisation (FAO) of the United Nations, has been extended. With assistance of NLR, the system was re-installed at a new location in Rome, Italy.

Signal Conditioning, Wind Tunnel Instrumentation

In April 1993 the European Transonic Wind Tunnel (ETW) has officially accepted a large amount of signal conditioning and data acquisition equipment for its cryogenic wind tunnel. This equipment was developed and manufactured earlier under a contract awarded by ETW to NLR two years ago. The contract included the 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 co-operation 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 has delivered and installed conditioning units of a new generation, primarily aimed at parameter setting and remote control of maintenance. Each unit contains a transputer which takes care of internal data processing, filtering and external communication.

Computer Aided Design of Electronics

In the further development of the NLR infrastructure for Computer Aided Electronics Engineering (CAE), emphasis was put on the optimization of the co-ordination between the individual tools, in order to obtain an error-free transfer of data between the different design phases. Examples are: schematics to printed circuit boards, printed circuit board and structure, as well as schematics and simulation. Important features were the expansion of network communication capabilities and the introduction of a Windows-based user interface.

Environmental Conditions

Previously, in co-operation with Germany, Sweden, the UK and France, a model was established of the electromagnetic environment a fixed-wing aircraft may encounter during flight, the so-called High Intensity Radiated Field (HIRF) environment. In 1993 this model was extended with the environment rotary aircraft may encounter: the field strengths can be even higher because these aircraft may operate closer to high power transmitters. The HIRF models will be the basis for the certification requirements of new aircraft and avionics. In particular the increasing dependability of aircraft on complex avionic systems, fly-by-wire and full-authority digital engine control, has urged the aviation authorities to increase the field strength level in Electromagnetic Interference (EMI) susceptibility tests.

Visualization

In the framework of GARTEUR (AD) AG 16: Eurovis, the common development of a particle tracer has been evaluated in order to develop new visualization modules more effectively. Such modules have been defined, and the concept of the common visualization tools system has been adapted to commercially available general purpose tools. Experience of NLR and partners in Eurovis have been used to define the GRAVICS System: a system for graphic control and visualization of CFD processes.

Satellite Attitude Control

As mentioned in Chapter 3.5, Space, NLR develops attitude control software for the Italian-Dutch scientific satellite SAX (see also Chapter 4, Capita Selecta). The software, optimised with respect to the available memory, has been coded, tested and verified in a simulated satellite environment. Subsequently, it has been integrated 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. At the end of 1993 this subsystem integration was successfully completed for the main part of the software. As a result of the subsystem integration, a number of requirement changes appeared necessary. The software has been updated in order to meet these new requirements.

Networks

NLR produced software for heterogeneous visualization experiments under 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. NLR is responsible for the visualisation part, and participates in networking and validation strategies.

High Performance Computing and Networking (HPCN)

NLR participates in HPCN initiatives. Nationally, discussions with industries, research institutes and universities on the establishment of a national programme for HPCN are continuing. Application areas will include Computational Fluid Dynamics and complex reactive systems.

Internationally, the institutes CIRA, FFA and INTA, and several aerospace industries joined the GARTEUR Working Group on Informatics (WGI) having HPCN as one of the main subjects, founded by NLR along with DLR, ONERA and DRA. NLR chaired the WGI from April 1993. Information on subjects such as software engineering, European cross networking and storage servers was exchanged, but the main activity was concerned with HPCN at the institutes and in national and international initiatives. A work plan for the introduction of HPCN at the research institutes was made.

Computer Facilities

The hardware facilities of NLR's computer network include an NEC SX-3 supercomputer, several UNIX servers and a Control Data CYBER 962 mainframe. A communication network based on TCP/IP connects these facilities with workstations, X-terminals, PCs and other terminal equipment all over NLR. Wind tunnels, simulators and other testing facilities are also connected to the network. NLR's network is also connected to networks of major customers and to international networks. The number of stations connected to NLR's network increased to 470 from 300.

The number of software packages for general use on computers in the entire network grew rapidly. New are packages for graphics, for automatic backup and for application design.

The use of the computer facilities, especially of the supercomputer, showed considerable growth. To allow this growth, several improvements were made.

The memories of the supercomputer were extended to: 1 GB for the central memory, 4 GB for the Extended memory and 60 GB for the disc memory.

A file server providing a file system with a virtually unlimited storage capacity has been installed. It can be accessed by the user systems via Ethernet and by the central system via FDDI with 100 Mbps. It consists of a normal UNIX file system combined with a tape robot.

The communication link to Fokker was upgraded to 2 Mbps from 128 kbps.

Preparations were started for enabling the tape robot to be used for automatic backup procedures for all the computer systems at NLR, for the introduction of a new UNIX sever specially equipped for software development, and for the upgrading of the data communication connection between the two NLR establishments to 34 Mbps from 2 Mbps.

Environmental Testing

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

In NLR's EMC laboratory, tests were carried out on various equipment, under contract to military and civil, both national and international customers. This laboratory comprises an anechoic, shielded room and a variety of test equipment including spectrum analyzers, generators, amplifiers, antennas and other sensors, and control and data processors. In order to be able to meet new and far more stringent EMI and HIRF requirements for aircraft electronic equipment, plans were established to upgrade the EMC facility.

The calibration laboratory for electromagnetic quantities was certified again by the Netherlands Calibration Organisation NKO, now part of the NKO/STERLAB/STERIN organisation. All technical procedures for the calibration of working standards were revised and implemented in an Automated Calibration System. The quality system for the facility was revised and documented in the quality handbook of the calibration facility. As most of NLR's electronic test instruments are calibrated by this laboratory, the traceability of measurements carried out at NLR is guaranteed.

3.6 Engineering and Technical Services

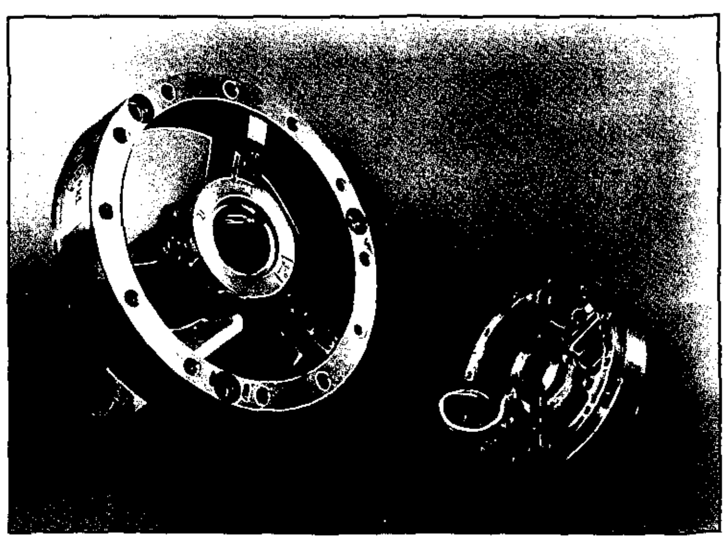
Many wind tunnel models and associated pieces of equipment have been designed and manufactured, often using assistance from specialized companies, for various customers.

Unusual techniques were adopted in some cases. For example, helicopter models were made of glass cloth reinforced epoxy resin. A dedicated workshop was installed for machining work pieces made of carbon composites. Experience has been gained in manufacturing wind tunnel equipment for cryogenic use in the European Transonic Wind Tunnel (ETW).

Measurements of the aerodynamic loads on rotating propellers of powered wind tunnel models are required more and more frequently. To meet these requirements, several rotating six-component strain-gauge balances were developed. They were successfully used.

Manufacturing of newly designed half-model balances and internal six-component sting balances was begun.

Attention is being paid to reducing manufacturing costs and delivery times. A Quality Handbook on wind tunnel models has been drafted.



Rotating strain-gauge balances, measuring all six load components acting on powered model propellers

4 Capita Selecta

4.1 Modernization of the High Speed Wind Tunnel

The NLR transonic wind tunnel HST dates from the early 1960s and has proven to be a valuable test facility for both national and international aerospace development projects. Over the years, continuing effort was put into keeping up its test equipment with the developing experimental technology. However, the fundamental characteristics of the facility itself remained essentially unchanged. In the mid-1980s plans were developed to improve the facility in terms of performance and productivity in order to preserve its functionality and attraction for the aerospace industry.

As a first step, it was decided to modify the test section and model support system in order to comply with present-day user demands, and also to replace the outdated, mostly manual, control systems by modern computer-based control technology. At the same time integration of these tunnel control systems with the data acquisition and processing systems was envisaged, paving the way to a high degree of automation of the testing process.

Hardware replacement and implementation of the basic control software were finalised at the end of 1992, and in the course of 1993 the HST came available again for its users. But before this became possible, quite some effort had to be spent on the optimisation of adjustments to the test section geometry, familiarisation with and tuning of the control systems variables, calibration of the test section flow parameters, and, most importantly, experimental validation of the 'new' HST.

The most prominent features of the modified HST test section, including some results of calibrations and comparative validation tests, are reported here.

Test Section and Model Support

One of the prime motives for the modification of the test section and the model support system of the HST was the experience that over the years the design limits of the original support system became more often inadequate to comply straightforwardly with the increasing user requirements with regard to model angles and sweep ranges. In many cases user requirements could be met by the use of special adapters, such as bent stings, Z-stings, roll adapters, etc., but at the expense of tunnel occupancy time, support stiffness and strength, and inevitably with some loss of measurement accuracy and repeatability. A feasibility study showed that these user requirements could only satisfactory be met with a configurable model support system, adaptable to specific types of testing.

Fig 1 - One of the first models tested in the new test section of the HST

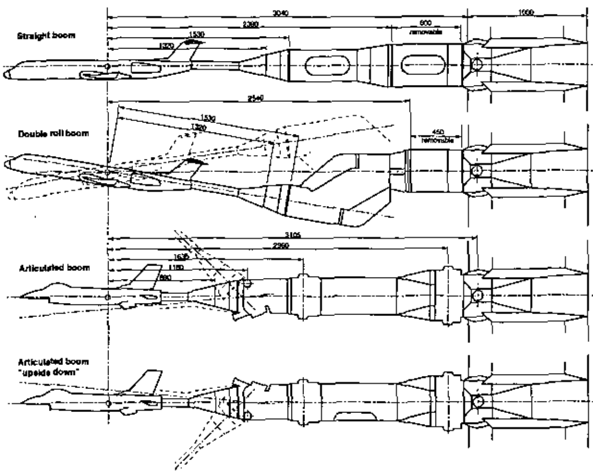


Fig 2 - Model support configurations

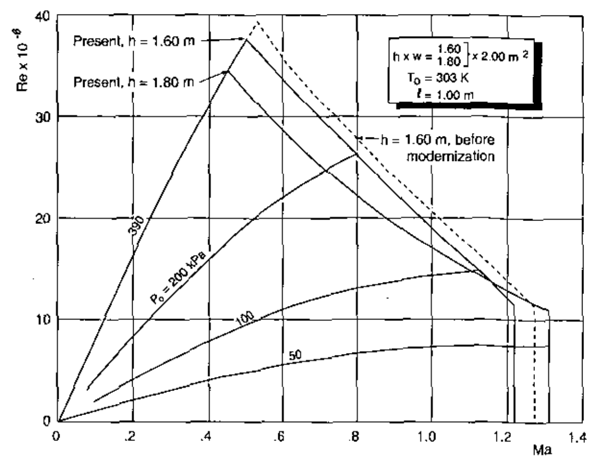


Fig 4 - Mach number vs Reynolds number envelopes

Figure 2 shows the new model support system, which consists of a vertical strut as the common base structure with three functionally different support booms: a straight, a double roll and an articulated support boom.

The straight support boom was designed for minimum support interference. It has no yaw capability and a limited incidence sweep range. It is primarily intended to be used for accurate drag assessment, typically for tests on civil aircraft models under cruise conditions. The double roll support boom has combined incidence and yaw capability for tests on models with wings, but it will also be used for tests on launcher type models, requiring a combination of incidence and roll angles. The roll sweep range is almost a full 360 degrees. The articulated support boom will be used when combinations of large incidence and yaw angles are required, as may be the case for tests on fighter type models.

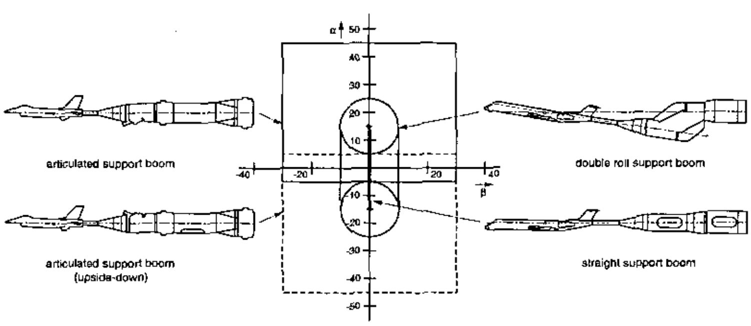


Fig 3 - Ranges of model attitudes for the three support configurations

Figure 3 shows the incidence and yaw angle sweep ranges of the three support configurations.

Notably the articulated support boom, with its high incidence capability, made it necessary to increase both the length and height of the test section. The effective test section length, i.e. the length of the slotted lower and upper walls, was increased from 2.50 to 3.65 m. With this longer test section more flexibility has been obtained with respect to the choice of model length and/or axial model position when using the straight and double roll booms, which are available in short and long versions. The increase of the height of the test section, from 1.60 to 1.80 m, had the disadvantage of a decrease of the maximum Reynolds number. Mainly for this reason it was decided to incorporate a remotely controlled adjustable support structure for the top and bottom walls, such that either height can be selected.

Performance and Calibration Tests

A series of tests was carried out in order to optimize several geometrical adjustments, notably in the transition region from the test section to the diffuser. These tests were followed by calibrations of the test section flow for a wide variety of test section and model support configurations.

Figure 4 shows the new performance map of the HST in terms of Reynolds number versus Mach number. As had been predicted by means of pilot experiments, a slight loss of maximum Reynolds number has resulted, mainly caused by increased losses associated with the increased length of the slotted walls. Comparison of the 1.60-m height configuration with the situation before the modification shows a loss of maximum Mach number in the supersonic regime, but this disadvantage is

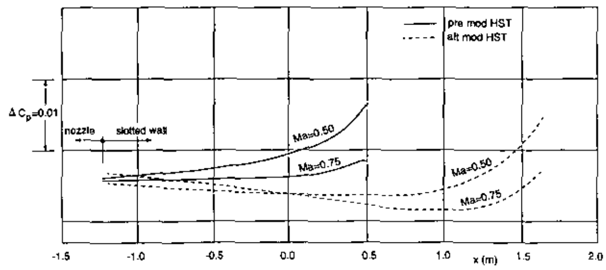


Fig 5 - Results of calibrations: pressure distributions along the centre line of empty test section; drawn line before, dotted lines after modification

more than compensated for by the 1.80-m height version, owing to favourable effects on the tunnel compressor performance.

An example of the results of the test section flow calibrations is given in figure 5. It shows the static pressure distribution along the test section centre line, both before and after the modification, measured in the empty test section (i.e. without support boom), by means of a long static pressure tube protruding from the settling chamber through the nozzle into the test section. The effective increase in test section length is evident.

Following the calibration tests a series of validation experiments with a reference model was executed, in order to be able to analyze the quality of the new test environment.

First of all some experiments dating from before the modification with the same reference model were repeated, and furthermore the model was measured on different model support configurations. A concise comparison of some of the results of these validation tests is given in figures 6 and 7.

Figure 6 shows the results of measurements of the reference model mounted on the new straight support boom, together with results measured before the modification with the same model mounted on the former straight boom. The comparison shows good agreement, giving confidence in the continuity of the flow quality before and after the modifications.

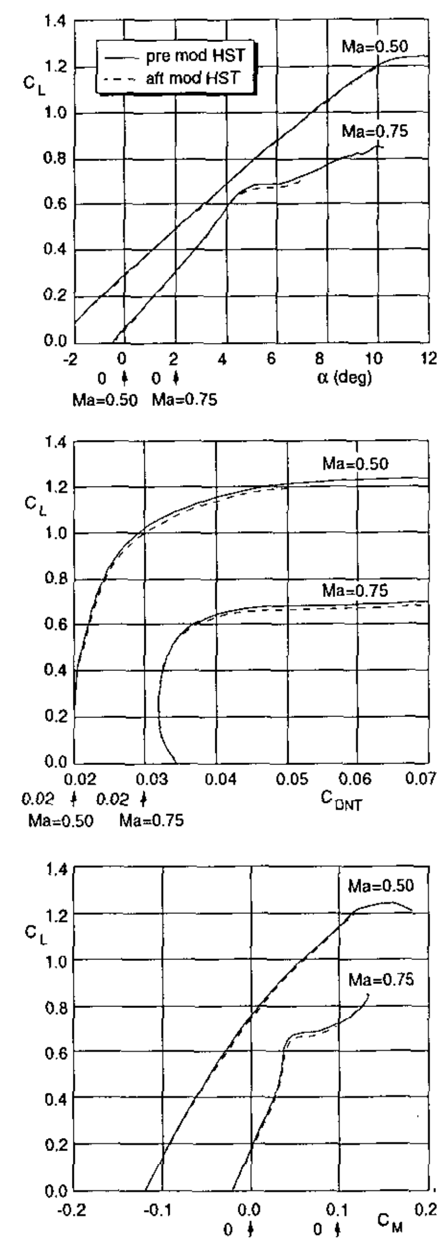


Fig 6 - Comparison of tests with reference model SKV8 (WF) before and after the modernization of the HST

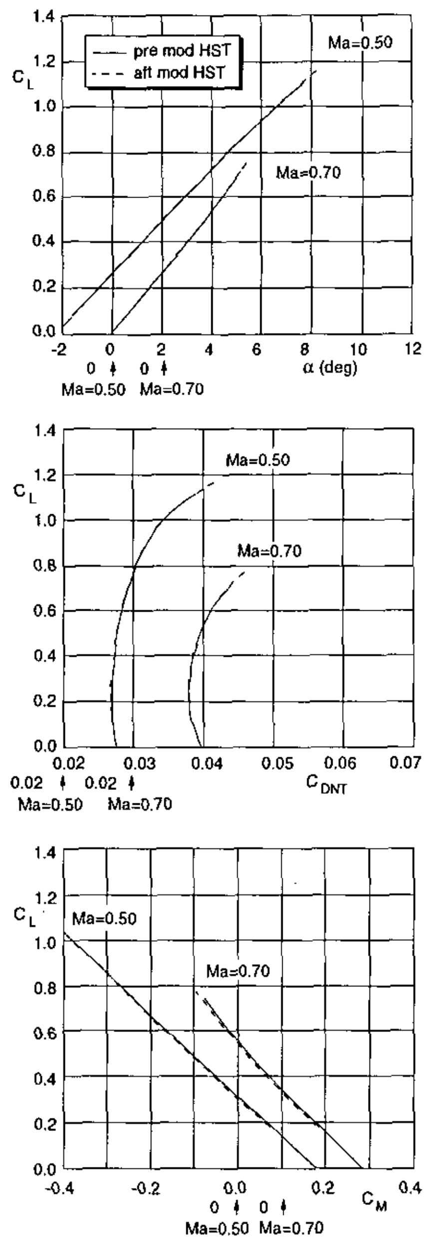


Figure 7 shows a comparison of data measured with the reference model in the new test section, and mounted on the new straight and double roll support booms respectively. The good agreement shown in both figures is also encouraging with respect to the correction procedures that are applied on the measured data.

Finally, figure 8 shows the results of noise measurements, carried out as part of a long term project aiming at detailed flow quality assessment. Again, as predicted on the basis of earlier pilot experiments, the graph shows a favourable decrease of the noise level in the test section flow. This result was obtained by carefully configuring the model support strut and its passage through the slotted test section walls, which had been found formerly to be the main source of the noise in the test section flow.

Conclusion

In summary, analyses of the first results of the validation tests, following the modifications of the HST in 1992, are promising. NLR will pursue its plans to further modernize the HST, of which this modification was the first step.

Fig 7 - Comparison of tests with reference model SKV8 (WFVH) on straight boom and double roll boom

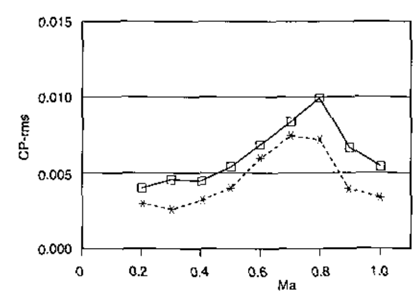


Fig 8 - Comparison of noise levels measured in the test section before and after the modernization

4.2 NLR's Contribution to the SAX Satellite

The SAX mission

In the universe, many phenomena generate X-rays. However, the Earth's atmosphere completely absorbs this radiation originating from space, and therefore scientific research of celestial X-ray sources can only be done through spacecraft outside the Earth's atmosphere. The Italian Space Agency (ASI), supported by the Netherlands Agency for Aerospace Programs (NIVR), is developing the SAX (Satellite per Astronomia In raggi X) satellite (Fig. 1). The mission of SAX is to perform a systematic and comprehensive observation of celestial X-ray sources in the energy range of 0.1–300 keV, with particular emphasis on spectral and variability measurements. SAX will be put into orbit by an ATLAS 1 launcher in the last quarter of 1995. The planned orbit is circular with an inclination of less than 5° and an initial altitude of 600 km. The nominal mission lifetime will be two years, with a design goal of four years.

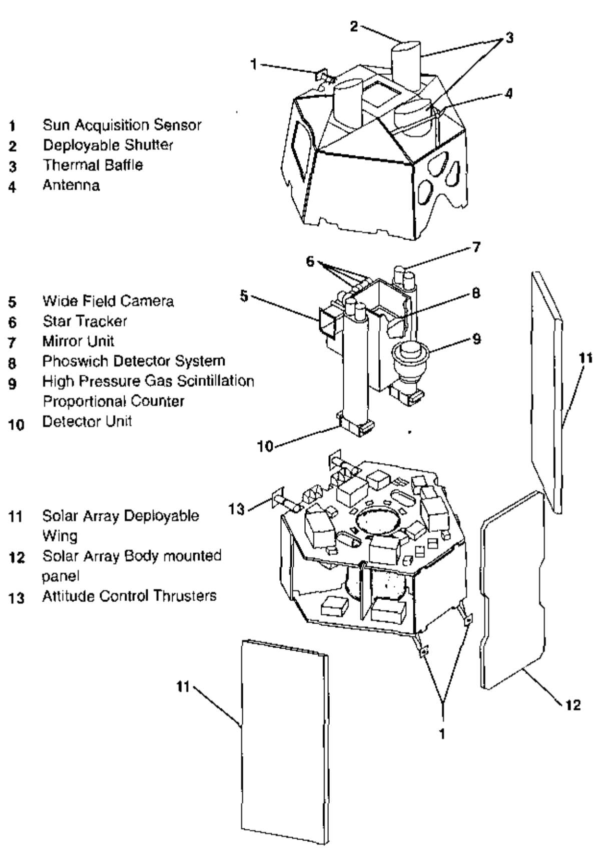


Fig 1 - Schematic of the Satellite per Astronomia in raggi X (SAX)

The SAX Attitude and Orbit Control Subsystem

The Attitude and Orbit Control Subsystem (AOCS) of the satellite is being developed by Fokker Space & Systems (FSS) under contract to Alenia Spazio of Rome, Italy. The AOCS has to command the Z_c-axis of SAX, the pointing direction of the main instrument, to any direction (within the pointing constraints) with an accuracy of 90" and the Y_c-axis with an accuracy of 16.5 arcmin. The AOCS also has to safeguard the satellite against violation of the so-called safe pointing domain. This safe pointing domain is defined mainly by the fact that the main scientific instrument, the Narrow Field Instrument, would be damaged by radiation from the sun. Therefore, the angle between this instrument and the sun vector must be at least 60°. When ground commanding is unavailable and after safeguard violations, the AOCS has to acquire and maintain a safe attitude autonomously. Another requirement to the AOCS is that it remains operational after any Single Point Failure in one of the AOCS units.

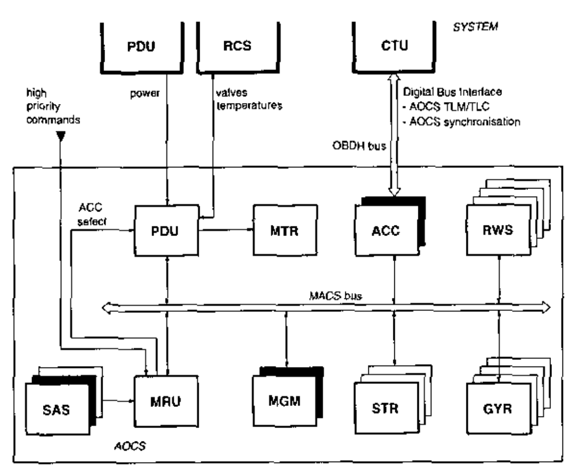


Fig 2 - Simplified block diagram of the SAX Attitude and Orbit Control System (AOCS)

The AOCS subsystem hardware (Fig. 2) consists of:

- The Attitude Control Computer (ACC). This computer is based on a 80C86 microprocessor extended with a 8087 co-processor. The ACC is fully redundant. Two identical, independent, computers are integrated into one unit. One of the two is cold standby.
- A set of attitude sensors: three sun acquisition sensors, two quadrant sun control subsystem containing thrusters that will be used for orbit adjustment.
- A set of service units: a Monitoring and Reconfiguration Unit (MRU), and a Power Distribution Unit (PDU).

The AOCS is equipped with a subsystem bus, the so-called 'Modular Attitude Control System bus' (MACS-bus), which is the interface between the AOCS units and the ACC which controls the AOCS. The ACC is also interfaced to the spacecraft 'On-Board Data Handling bus' (OBDH-bus) for ground communication with the AOCS via the spacecraft Telemetry/ Telecommand (TM/TC) link.

The AOCS is controlled by software running in the ACC. This software is divided into two packages: the Basic Software (BSW) and the Application Software (ASW). The BSW, developed by Alenia Spazio, provides operating system services (scheduler) and basic interface services. The ASW, developed by NLR under contract to FSS, provides all attitude control tasks and manages the application-dependent communication with the ground (via the OBDH) and with the AOCS units.

To meet the requirements of high reliability and high operational flexibility, the ASW has been further subdivided into two parts: the Basic Attitude Control (BAC) software and the Extended Attitude Control (EAC) software. The BAC software is extremely reliable and safe. It is (initially) stored in Read Only Memory (ROM) in the ACC. The main purpose of this software is to provide the functionality needed to acquire and keep a safe satellite attitude after power-up and fall-back. A large part of this software is devoted to the health checking and redundancy management of the AOCS units. The BAC software furthermore contains the data handling functions needed to submit the state of the AOCS to the ground and to transfer the control to the Extended Attitude Control software on ground command. The EAC software provides all functions required for the AOCS, including the control laws for accurate control of the spacecraft attitude, required for pointing the X-ray instruments at celestial sources, and the generation of full attitude reconstruction telemetry. The EAC software is stored in Random Access Memory (RAM) of the ACC and can be loaded and/or modified on ground command.

Application Software Development

The ASW development consisted of four steps. First, the architecture of the software was developed. Then, support was given to FSS in the detailed functional requirements specification of the software. As the AOCS hardware has been developed in parallel with the AOCS software, this activity has been highly iterative. In parallel, the detailed design and the code of the software were developed. Finally, the BAC and EAC software were integrated and tested in a dedicated development environment, using a non-real-time closed loop simulation package.

The main constraint that had to be taken into account during the development was the capacity of the microprocessor with respect to memory size and execution speed. During the design phase of the software a number of iterations were necessary to meet these constraints. These iterations have increased the complexity of the software.

The ASW development was done on a dedicated development system (HP-9000). A suite of Computer Aided Software Engineering tools were used for requirements analysis and architectural and detailed design.

The Quality Assurance procedures and tools applied during the development have been certified as meeting the requirements of the ISO 9001 and NATO AQAP-110 international standards for Quality Systems.

Testing and Verification of the SAX AOCS Application Software

In order to verify that the AOCS software meets its functional requirements, it was tested independent of the software development at several levels. Besides testing at the development level as described above, the AOCS ASW was tested at the:

- ASW Hardware-Software Integration and Test level,
- AOCS Subsystem Integration and Test level,
- Spacecraft System Integration and Test level.

The AOCS Subsystem Integration and Test and Spacecraft System Integration and Test are performed by Alenia Spazio in Turin, Italy.

NLR carried out the ASW Hardware-Software Integration and Test (HW-SW I&T) phase. The purpose of this phase was to integrate the AOCS ASW with BSW and ACC, and to test the software through real-time, closed-loop tests, without using any other AOCS HW units in the test set-up. In the context of the SAX project NLR also developed the required test equipment, called SAX Test and Simulation Assembly (SAX TSA).

SAX TSA Development

The SAX Test and Simulation Assembly (SAX TSA) is a further development of the existing MACS TSA. This is the standard ESA Test Equipment for AOCS equipped with MACS-bus and OBDH-bus, which can be used at different levels of AOCS integration and test.

The SAX TSA consists of a VAX Host computer (VAX 4000-200) and a Front End, interconnected by an Ethernet interface (Fig. 3). The Front End is equipped with a VME-based multi-processor system, which handles all communication between Host and Front End and further communication to the Front End MACS-bus and OBDH-bus interfaces.

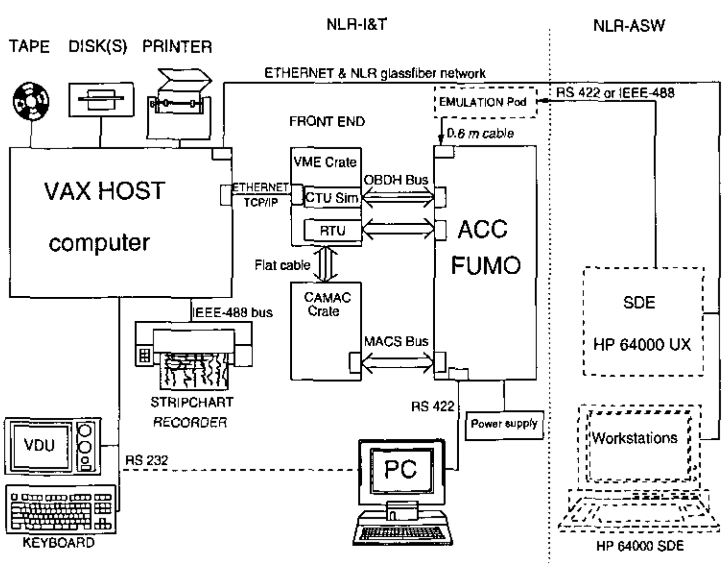


Fig 3 - General set-up for the SAX ASW Integration and Test

The SAX TSA provides various tools to be used during tests, for:

- sending automatically series of commands to the AOCS under test via the simulated OBDH TM/TC link, similar to a ground station;
- monitoring the TM from the AOCS under test;
- monitoring the traffic on the MACS-bus between ACC and AOCS units;
- simulating the spacecraft attitude motion and the units that are not included in the AOCS under test;
- displaying test data for on-line monitoring;
- archiving test data for later analysis.

An extended version of the SAX TSA was delivered to Alenia Spazio, where it is used for SAX AOCS subsystem integration and test.

ASW Hardware-Software Integration and Test (HW-SW I&T).

The purpose of the HW-SW I&T phase was to integrate the AOCS ASW with BSW and ACC, and to test the software through real-time, closed-loop tests. The software under test, ASW integrated with BSW, was run in a Functional Model (FUMO) of the ACC in real time. The spacecraft attitude motion and the AOCS units not included in the test set-up were simulated by the SAX TSA. The ASW was run at a cyclic basis of 2 Hz. At the start of each AOCS cycle, the ACC read the simulated AOCS unit data from the TSA Front End, and transferred the data to the ASW. The ASW then performed its attitude control task: it calculated the satellite attitude and attitude errors from the sensor readings and calculated the control torques required to bring the satellite attitude to the desired attitude. The calculated control torques were then used to command the (simulated) AOCS actuators. Synchronized every half-second by the ACC, the SAX TSA Host read the data from the Front End together with the commands which the ACC had sent to the simulated AOCS units. Using the commanded control torques as inputs, the SAX TSA Host calculated the satellite attitude motion over the next half-second time interval and sent the associated sensor data to the Front End, where they were read by the ACC at the start of the next cycle, etc.

In addition to the attitude motion and sensor data, the SAX TSA Host also simulated the AOCS housekeeping data, such as unit on/off status, health data, and temperature data.

Various equipment failure modes were also simulated, such that the ASW health monitoring and redundancy management functions could be tested.

Via the OBDH link, the SAX TSA received telemetry data from the ACC under test, comprising housekeeping data and attitude reconstruction data (sensor data). Furthermore, the SAX TSA monitored the communication between ACC and AOCS units on the MACS-bus. Via the SAX TSA Host, telecommands were given to the ACC under test, to switch units on or off, to switch to another operational mode, etc.

By the method used, not only the functioning of the software could be thoroughly tested, but also the protocol and timing of the communication between ACC and the (simulated) AOCS units could be verified.

At HW-SW I&T level, only functional tests (rather than performance) were carried out. Sets of functional requirements were tested in one test run. The test runs were devised by the test engineer and laid down in a Test Scenario document. This was basically a list of time-tagged test triggers such as commands, required to test the different ASW functions, and the expected results or events.

Test execution was automated as far as possible, under control of Test Sequences. These are test-specific pieces of software, basically the translation into computer code of Test Scenario's time-tagged test triggers. The Test Sequences were executed by the Host computer, which controlled the tests and enabled the test data to be monitored. For each test, specific Test Sequences were developed.

In the way described above, all testable ASW BAC and EAC functional requirements were tested and verified. The different steps in the test and verification process were made traceable and verifiable via associated documents (Integration and Verification Plan, Test Plan, Test Reports and a Requirements Verification Control Document).

Document Control

The SAX AOCS ASW development and HW-SW Integration and Test was a large project, where numerous documents were generated by the parties involved. This required document control and filing of incoming and outgoing documents. To this end the IM-Personal database management system was used. At the end of the project, the database contained some 1300 entries and the archive contained some 100 binders with documents!

Project Planning

For the project planning the CA-SuperProject software package was used. The planning was updated with actual hours on a four-week basis.

Present Project Status

At end of 1993 the integration and test activities at NLR had been completed. The subsystem integration test activities, executed at Alenia Torino's premises, had been finished for the BAC functions. The tests of the EAC software, while integrated with the real sensors and actuators were continuing. The ASW development team gives on-site consultancy during these tests.

The ASW has proven to be of high quality, attributable to the use of computer aided software engineering tools and the strict adherence to software programming standards and product assurance principles. The delivered ASW code consists of approximately 15,000 executable statements, written in the language ANSI-C. During the integration of this software with ACC and BSW, about ten software bugs have been detected, which is below the industry average for delivered software after external delivery. During the subsystem integration test at Alenia Torino premises, no software bugs have been detected in the BAC software, and only about five minor bugs in the EAC software.

During the subsystem integration, the real units appeared to have different failure properties than had been expected during the specification of the health check functions. As a result, the detailed functional requirement specifications have to be updated to be in-line with the observed unit behaviour, and the ASW will be adapted to meet these new requirements. The resulting activities are expected to be finalised in the summer of 1994.

4.3 Development of a TRN/INS/GPS Integrated Navigation System

Introduction

Several navigation sensors are currently being used in civil and military aviation. They include the Terrain Referenced Navigation system (TRN), the Inertial Navigation System (INS), and the Global Positioning System (GPS). These sensors have different, complementary characteristics. TRN provides actual clearance height and geo-referenced positioning, but it has a poor performance over flat terrain. INS is a totally autonomous navigation sensor, but its position accuracy degrades with time. GPS operating in the military high-accuracy PPS mode provides very high accuracy positional information, but its performance can be degraded by jamming or high dynamics of the aircraft.

Combining sensors of these three types into one integrated navigation system should lead to a robust navigation system, providing the best navigation solution available at all moments of the operational flight.

In order to investigate the technical feasibility and operational advantages of such an integrated navigation system, NLR has executed a contract for the investigation, realization, and performance assessment of an integrated navigation system using information of three navigation sensors. The contract was carried out under a National Technology Programme (NTP) initiated by the Netherlands Ministry of Defence. The programme was named TRIANGLe, for TRn Ins ANd Gps Locationer, and started 1 January 1990.

Objectives and Constraints

The overall objective of the programme was to develop, build, and validate a prototype of an integrated navigation system. The heart of the integrated navigation system is a data merging algorithm that integrates data from the three navigation sensors. The main technical objective of the programme was therefore to develop and evaluate an algorithm that merges data from a TRN, an INS, and a GPS receiver (GPS), thereby providing an integrated navigation solution. This integrated navigation solution should be robust, in case one or more sensors should fail or if their performance should deteriorate. An additional objective was to rely on sensor models to the lowest extent possible.

The data merging algorithm developed was implemented using the Ada programming language. The data exchange between the navigation sensors and the processing unit, in which the data integration algorithm was residing, was accomplished by means of a MIL-STD-1553B data bus.

The output format and output rate of the integrated navigation system were designed such that they were identical to those of a standard INS. In this way, integrated navigation data could be transferred over the aircraft mission bus in exactly the same manner as the standard INS data.

TRN/INS/GPS Data Integration

From a theoretical point of view, the most accurate integrated navigation solution would be obtained by merging all available sensor data in one large Kalman filter. This integration method would, however, require extensive computing power. Moreover, very detailed sensor information, which is often company confidential, must be known to arrive at the best performance. Therefore, a 'smart' sensor integration concept was applied. A 'smart' sensor provides not only position and velocity data, but also an associated covariance matrix, all of this based upon the manufacturer's detailed knowledge of the sensor. The covariance matrix provides a statistical measure of the estimated accuracy of the navigation sensor.

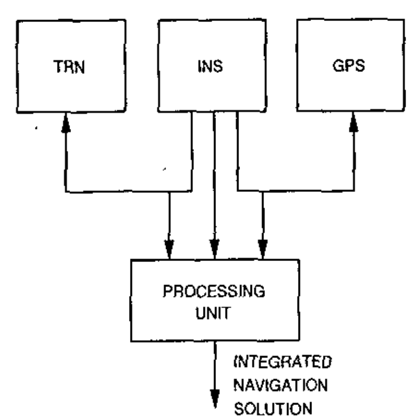


Fig 1 - Functional architecture

As Figure 1 shows, data from the INS is locally merged in the GPS receiver and TRN system. The two resulting data streams, GPS/INS and TRN/INS, are merged in a processing unit. The integrated navigation solution is then made available in an INS-like format.

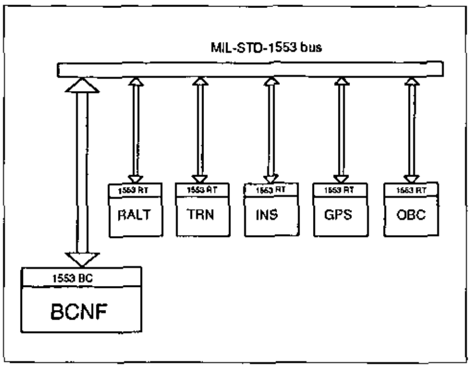


Fig 2 - Hardware architecture

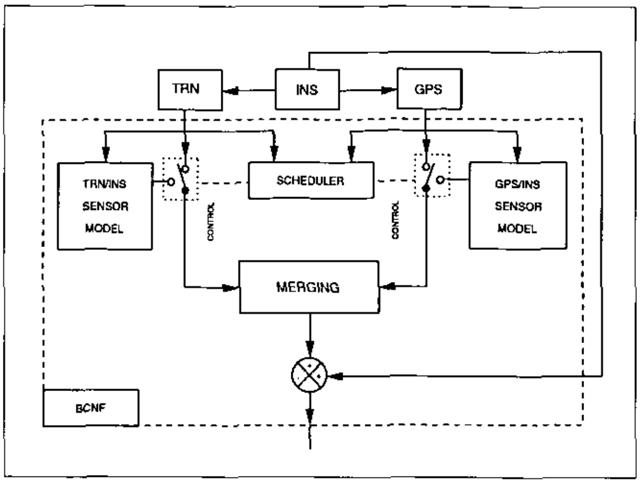


Fig 4 - Navigation Filter

The hardware architecture is shown in Figure 2. The three navigation sensors and a processing unit where data merging occurs were configured around a MIL-STD-1553B data bus. This processing unit, the Bus Controller/ Navigation Filter (BCNF), has two functions. It controls the data output of each sensor on the MIL-STD-1553B bus (Bus Controller-BC), and it merges the data from the navigation sensors (Navigation Filter-NF).

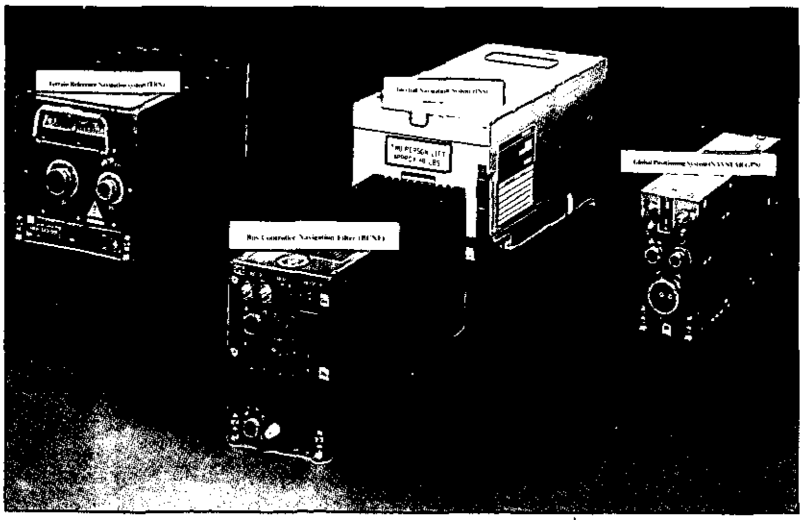


Fig 3 - The Bus Controller Navigation Filter and three navigation sensors

Figure 3 shows the three navigation sensors, in the background, together with the BCNF.

A radar altimeter which was used only by the TRN system was connected to the MIL-STD-1553 bus. An On Board Computer (OBC) which supplied initialization data for the integrated navigation system (Lat, Lon, time) was also connected to the bus. The OBC further played a major role in the aircraft instrumentation for data recording.

If this setup would be installed in an operational aircraft, the BCNF would act on one side as a Bus Controller retrieving the navigation sensor data from the local 1553 bus. The other side would act as a remote terminal on the aircraft mission 1553 bus. Its data output format would mimic the output of a stand alone INS (i.e. same number of words, same update rate etc.). Consequently the combination TRN/INS/GPS/BCNF would act as a navigation cluster and could replace the INS in an operational aircraft without the need of major changes to existing on board software.

Development and Evaluation of the Navigation Filter

Navigation Filter

The navigation sensors used are 'smart' sensors, consisting of the actual sensor and a Kalman filter. Inputs for the Kalman filter are the sensor's raw measurements; outputs of the Kalman filter are filtered state estimates and associated error covariance matrices.

The navigation filter basically consists of three parts (Figure 4):
a scheduler, a sensor model (TRN/INS, GPS/INS), and a merging algorithm.

Scheduler

The task of the scheduler is to ensure that only valid output data of the individual navigation sensors is used by the merging algorithm. The scheduler determines the validity of the individual navigation sensors by interpreting several parameters. First the availability of the navigation sensor on the 1553 bus is checked. Then the specific status message for the individual navigation sensor is interpreted, in order to ensure that the output data to be used is valid. This approach contributes to the robustness of the integrated navigation system.

The scheduler determines the performance of the navigation sensors by interpreting specific status messages from the navigation sensors. For the GPS navigation sensor use was made of the Figure Of Merit (FOM) indicating a positional error. In addition, the GPS receiver channel states were monitored indicating if and how the GPS receiver was tracking satellites. For the TRN navigation sensor use was made of a dedicated message indicating valid covariance output. In addition, a radar altimeter status message was monitored to ensure that output data used was valid.

Merging algorithm

When all sensors function correctly, the merging algorithm computes a solution based on a weighted average of the sensor data. The weighting factors are a function of the covariance matrices associated with the smart sensor output data of each navigation sensor. Whenever one or more of the navigation sensors fail or if performance deteriorates, as determined by the scheduler, actual sensor data is no longer used. Sensor data are then taken from the corresponding sensor model. This results in somewhat larger values of the covariance matrix, leading to lower weighting by the merging algorithm.

Sensor Model

The merging algorithm automatically uses the navigation sensor model data when the actual sensor data are degraded due to system failure or due to external causes (GPS jamming, for example). As shown in Figure 4, two sensor models are present, one predicting the GPS/INS sensor behaviour, and one predicting the TRN/INS sensor behaviour. The GPS/INS sensor model consists of a GPS receiver error model, and a Kalman filter merging INS and GPS data. The TRN/INS sensor model consists of a TRN error model, a radar altimeter error model, and a Kalman filter merging INS and TRN data.

When actual sensor data are available, the sensor models are continuously calibrated by the GPS and TRN sensor measurements. When sensor measurements are no longer available, the sensor models can provide predicted sensor data to the merging algorithm. The sensor models data are used to 'coast' through time periods when actual sensor data are not available. In this way the integrated navigation system provides an accurate and robust navigation solution.

Evaluation of the Navigation Filter

The evaluation of the navigation filter was carried out in three phases: a functional evaluation of the navigation filter algorithms, a real-time evaluation in the laboratory, and actual flight testing.

During the functional (non-real-time) evaluation phase the navigation filter algorithms were tested and optimized using PROMISE (PRocess Oriented Machine Independent Simulation Environment), a generic simulation tool developed by NLR. To this end, functional simulations were used to generate synthetic sensor test data, viz. TRN, INS, and GPS sensor data, using sensor models. They were also used to exercise the navigation filter's algorithms and to evaluate its performance: accuracy, numerical stability, etc.

Simulated sensor test data as well as actual flight data, recorded during an early sensor evaluation flight, were used to exercise the navigation filter.

Implementation of Airborne Software

The navigation filter algorithms were implemented in a flight-qualified computer, the BCNF, in order to undergo additional real-time laboratory testing and flight testing.

The BCNF carries out the bus control of the MIL-STD-1553B bus and the acquisition of TRN, INS, GPS, and Radar Altimeter (RALT) messages of the MIL-STD-1553 bus. The BNCF also executes the scheduler algorithm, the sensor models and the merging algorithm, and controls the output of the integrated navigation solution on the MIL-STD-1553B bus.

Hardware

The hardware used was a VME-based system. Inserted in a standard 1/2 ATR short cabinet were five MilSpec computer boards: two Motorola 68020 CPU boards, two memory boards and one MIL-STD-1553B interface board. The CPUs were running at a clock rate of 16 MHz and had a mathematical co-processor installed.

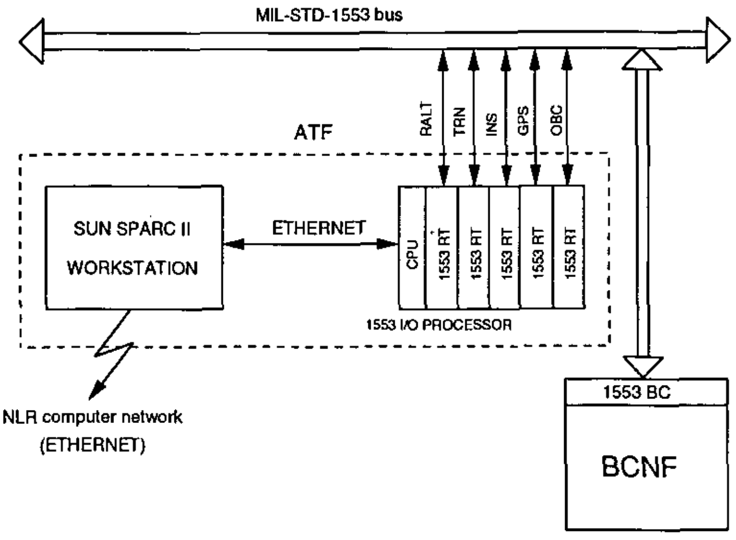


Fig 5 - Architecture of the Avionics Test Facility

Software

The Ada programming language was chosen for the implementation of the merging algorithm. The Ada programs are executed in their own environment, i.e. multitasking Ada Real Time Kernel (ARTK).

The bus controller and navigation functions were divided over the two processors. The first processor performed the bus controller activities and the scheduler algorithm. The second processor executed the sensor model algorithms and the actual merging algorithm itself.

The integrated navigation solution was made available on the 1553 bus by defining two 1553 messages. The first BCNF message, NF01, was defined such that it had exactly the same format and update rate as the INS message. The second BCNF message, NF02, with an update rate of 1 Hz, provided additional information, such as error information, fault codes, and a BCNF Figure Of Merit (BFOM).

Real-Time Laboratory Testing

To evaluate the integrated navigation system before flight testing, a real-time Avionics Test Facility (ATF) was developed. The ATF was specifically used to evaluate the developed prototype of the integrated navigation system on its real-time behaviour. During the real-time testing the ATF created an environment for the processing unit (BCNF) which simulated the other avionic subsystems (i.e. navigation sensors).

As Figure 5 shows, the BCNF communicates with the navigation sensors via a MIL-STD-1553B databus. The BCNF retrieves data from a TRN, an INS, a GPS and a Radar Altimeter (RALT). Initialization data for the INS and GPS are retrieved from an On Board Computer (OBC).

The ATF acted therefore as TRN, INS, GPS, RALT, and OBC. The ATF responded to data requests from the different sensors and received the data originating from the BCNF. The hardware of the ATF consists of a Sun SPARC II workstation and a dedicated VME system which acted as a 1553 I/O processor, interconnected via an Ethernet datalink. The workstation is connected via an Ethernet datalink to the NLR computer network for retrieval and storage of sensor data files.

The ATF used sensor data generated by PROMISE simulations, as well as sensor data that had been recorded during actual flights. The functions evaluated during real-time testing were:

- The bus controller tasks.
- The scheduler and sensor models. To accomplish this, it was required to modify sensor status data, thereby simulating degraded sensor performance 'forcing' the integrated system to use the sensor models.
- The merging algorithm. This was accomplished by accurately timing in-going sensor data messages and resulting BCNF messages.

The ATF is capable of storing real-time BCNF output for later evaluation. During simulation, an operator-specified selection of those messages can be displayed. For later evaluation of the results the BCNF messages which were generated during the non-real-time PROMISE simulations could be correlated with the BCNF messages generated during the real-time simulation.

Flight Testing and Evaluation

NLR's Fairchild Metro II research aircraft was used as test aircraft. It was equipped with a special antenna rack mounted on top of the fuselage, on which antennas for GPS and the jamming measurement system were mounted. A programmable Electronic Flight Instrument System (EFIS) was installed in the cockpit. The EFIS display unit showed flight track deviation and navigation information based on INS and GPS derived positions. A Position Reference System (PRS) based on photogrammetry was used during the flight testing.

Flight Profile

A flight test programme was set up to test the performance of the data integration algorithm, to determine the position and velocity accuracy, and to determine the robustness of the integrated TRIANGLe equipment under operational conditions. In addition, the improvement with respect to the individual navigation sensors was assessed. In order to assess the robustness of the integrated system, the TRN and the GPS navigation sensors were degraded. For degrading the performance of the TRN, about 75% of the flight profile was flown over essentially flat terrain. The performance of the GPS receiver was degraded by jamming.

The flight profile consisted of a racetrack composed of four legs. In each leg at least one Photo Area (PA) was defined. Over these areas, photo updates were made by the PRS. To assess the effects of altitude, the test profile was flown at two altitudes, namely 500 and 2000 ft. During a number of flight tests, the navigation sensors were maximally taxed in order to assess the accuracy and robustness of the navigation filter.

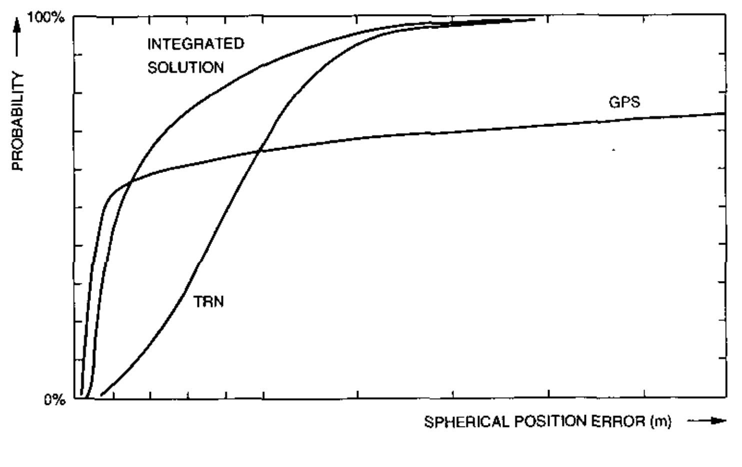
Results and Conclusions

The navigation filter provided a very robust solution during the complete operational flight test envelope. Even when the GPS performance was degraded by jamming or when the TRN performance was degraded due to flat terrain, a good navigation solution was provided.

Figure 6 shows the probability distribution of the spherical error. The results are given for TRN and GPS as smart (INS-aided) sensors alone and for the integrated Navigation Filter (NF). Although GPS as regards the smaller errors is somewhat more accurate than the NF solution, the superior performance of the NF implementation as regards the larger errors is very clear. In case the GPS system is disturbed, the integration with the TRN solution enhances the robustness and the attainable accuracy considerably.

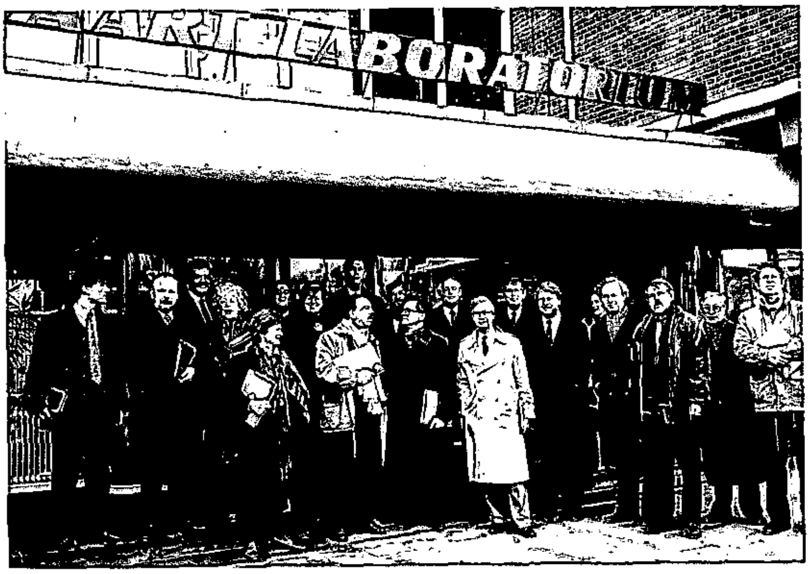
The specific design and implementation of the integrated navigation system proved to perform well within the constraints of the dynamics of the Metro II aircraft.

Fig 6 - Performance of Navigation Filter. The GPS was jammed approximately 50 per cent of the time. Both the TRN and the GPS were INS-aided



Internal and External Relations

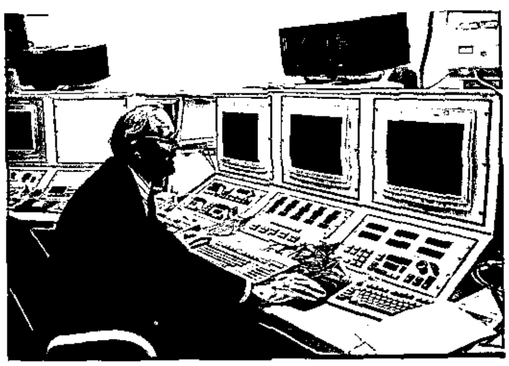
NLR received many visitors over the past year. NLR participated in several Airshows and other events and organized many excursions to NLR.



Members of the Permanent Committees for Economic Affairs, Defence, Transport and Science Policy of the Second Chamber of Parliament (Tweede Kamer)

Visitors from the Netherlands

- Members of the Permanent Committees for Economic Affairs, Defence, Transport and Science Policy of the Second Chamber of Parliament (Tweede Kamer), who paid a visit to both of NLR's establishments.
- A delegation of the Royal Netherlands Navy, Aircraft Technology Office.
- Dr. J.E. Andriessen, Minister of Economic Affairs, who visited NLR Amsterdam, NLR Noordoostpolder and DNW.
- Ir. A.J. van Liere, ir. J.P.F. de Koning and drs.ing. P.J. Blok, members of the Board of the Netherlands Agency for Air Traffic Control (LVB).
- Ir. R. Uijlenhoet and ir.drs. H.N. Smits, directors of Amsterdam Airport Schiphol (NVLS).
- Dr. J.A. van Kemenade, Royal Commissioner in the Province of Noord-Holland.



Dr. J.E. Andriessen, Minister of Economic Affairs, in the modernized control room of the High Speed Wind Tunnel (HST)

Foreign Visitors

- Mr. H.J. Allgeier, director DGXII of the European Union, who visited both of NLR's establishments.
- Dr. R.N. Tyte of the UK Defence Research Agency.
- Mr. Mitsuko Migaki, head Navigation Section of the Electronic Navigation Research Institute, Tokyo, Japan.
- Staff of Federal Aviation Administration and of the Universal Navigation Corporation of the USA.
- Dr. W. Harris, NASA Associate Administrator for Aeronautics, accompanied by Ms. L. Parker, NASA International Relations Specialist.

- Mr. Gon Xinghni, First Secretary of the Chinese Embassy and Mr. Ye Caiwan, Commercial Councillor, who visited both establishments, accompanied by mr. N.L. Schenkman of NIVR.
- Air Commodore M. McMahon of the Indian Embassy in Paris, who visited the Amsterdam laboratory and the Hangar used by NLR at Schiphol.
- Prof. C. Golia, Chairman of the Board of Centro Italiano Ricerche Aerospaziale (CIRA), who visited both Establishments.

Excursions

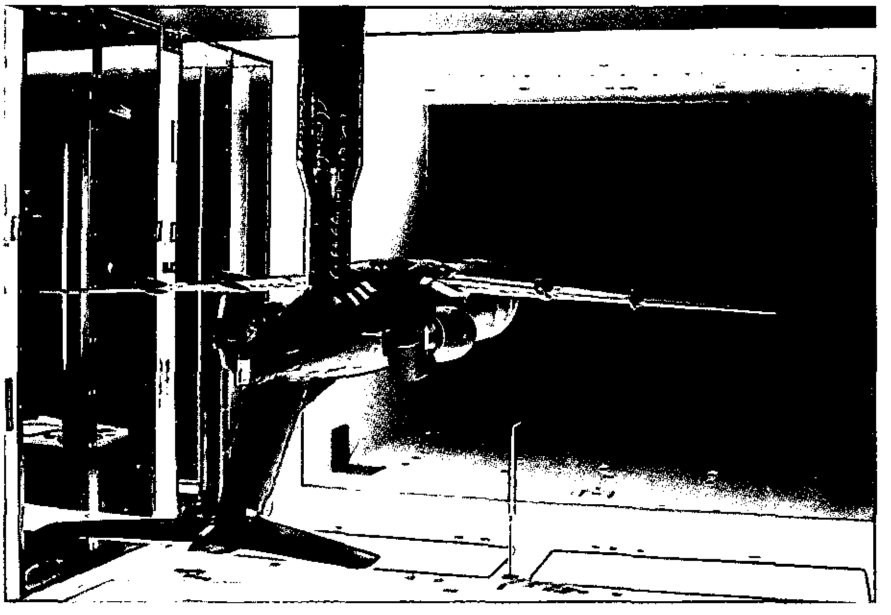
- Physics teachers of Dutch Colleges of Agriculture.
- Members of the Student Society 'Gewis' of the Eindhoven University of Technology.
- Members of the Physics-Mathematics faculty societies of the Groningen State University.
- Members of the Flevoland branch of the Stadswerk society of council civil servants.
- Students of Information Technology of the Gelderland College.
- Members of the Supervising and Management Boards of Scania.
- Engineers of Touw Infra Consult B.V.
- Members of the study society Isaac Newton of Twente University.
- Members of the study society A-ESkwadraat of the Utrecht State University.
- Students of the Rijswijk College.
- Students Information Technology of the Eindhoven College.
- Students of the Institute for Hydro and Gas Dynamics of Trondheim, Norway.
- Students of the Dutch Car Engineering School.
- Students of Information Technology, members of the study society 'Thalia' of the Catholic University of Nijmegen.
- Students of the Leiden Instrument Maker School.
- Members of the Society of Surveyors (VVL).
- Students of the Groningen College, Technical Section.
- Students Mechanical Engineering of the Delft University of Technology.
- Students of the Fachhochschule Hamburg.
- Students Avionics of the Delft University of Technology.
- Members of Euroavia, European students of Aerospace.
- Students of the Fachhochschule Offenburg.
- Students Electrical Engineering of the Haarlem College.

Exhibitions

- NLR participated in the international exhibition 'Internoise 1993' at Leuven, Belgium.
- During an ATC Conference at Maastricht, demonstrations showing NARSIM were held in co-operation with the Netherlands Department of Civil Aviation.
- During the ITC-Symposium 'International Symposium on Operationalization of Remote Sensing' at Enschede, photographs of activities of NLR were exhibited.
- NLR's defence activities were shown on panels during a workshop on Radar Cress Section Determination organized by FEL - TNO and NLR in The Hague.
- For the third time, NLR took part in ITEC (International Training Conference and Exhibition), held in London/Wembley. In the NISP (Netherlands Industrial Simulator Platform) stand, NLR showed its simulation facilities in a video film and a slide show.
- NLR contributed to a display of the Gas Turbine Association (VGT) during the ASME Conference and Exhibition at Cincinatti, USA.

Events

- Well-attended New Year receptions for the staff, held in the Amsterdam and Noordoostpolder sites.
- The annual lunch of members of the Works Council with members of the NLR Board.
- A meeting of the Steering Committee for the Project Helicopter Training Simulators.
- A meeting of representatives of EPAF (European Participating Air Forces) countries.
- A meeting at the start of the High Performance Computing Project, a co-operation with NEC.
- The seventh ISNaS Symposium.
- A one-week course for students of the Royal Military Academy (KMA).
- A three-day meeting on the Aerospace Programme for Education, Research and Technology attended by a delegation from Indonesia.
- A two-day meeting of the Management Board of the Programme for Harmonized Air Traffic Management in Eurocontrol.
- The first meeting of the AGARD Flight Mode Panel 'Flight Test Editorial Committee', held in Amsterdam.
- An NLR-NEC Workshop, held in Amsterdam.
- Meetings at Amsterdam and Noordoostpolder for acquainting new employees with activities and procedures.
- A symposium on Operations Research and Active Air Defence, in which the Royal Netherlands Air Force showed great interest.



Fokker 70 model for tests in ground effect in the Low Speed Wind Tunnel (LST)

6 Scientific Committee NLR/NIVR

The Scientific Committee provided advice:
- To the Board of the Foundation NLR, on:
  - the results of the work NLR carried out under the programme for basic research and development of facilities (EW) of NLR;
  - the preliminary Work Plan for 1994;
  - the programme for basic research and development of facilities for 1995;
- To the Boards of Directors of NLR and NIVR, on:
  - the results of the work carried out by NLR in 1992 under the 'General Research Programme with a view to aircraft development in the near future' (ARP) of NIVR;
  - the reports NLR submitted to the Committee to be considered for suitability as scientific publications.
- To the Board of NIVR, on:
  - the subjects qualifying for a contract of NIVR in the framework of the ARP in 1993 or 1994.

Composition of the Scientific Committee

The composition of the Scientific has not been changed in 1993. It is given in the list below.

Composition of the Subcommittees

Three new members were appointed in the subcommittees:
- Prof.dr.ir. F.T.M. Nieuwstadt, in the Subcommittee for Aerodynamics;
- Prof.dr. S. van der Zwaag, in the Subcommittee for Structures and Materials;
- Major E.R.A. van Kleef, in the Subcommittee for Flying Qualities and Flight Operations.

No memberships were terminated. The compositions of the subcommittees are given below.

The annual report of the Scientific Committee contains the following concluding remarks:

'In 1993 the taking over of Fokker by DASA of Germany was effected. The consequences, including those for NLR, are expected to appear only in the course of time. The recovery of the world aircraft market has not yet begun. Partly because of that, large-scale reorganizations in the aircraft industry were the order of the day. The Dutch industry was not spared. A certain crisis exists in the space sector as well. In this mainly government-controlled market, public funding is under severe pressure. The future of manned spaceflight has become most uncertain.

In spite of these worrying tendencies, in 1993 NLR has again appeared capable of carrying out research in aerospace technology in a sufficient amount and satisfactorily. This is also illustrated by the large number of reports that were submitted to the Scientific Committee. The majority of these reports belongs to proceedings of international congresses, allowing the conclusion that the work NLR carries out is well thought of internationally.

The Scientific Committee has expressed its approval of the Work Plan for 1994. The volume of the contracts of 1993 has remained impressive, but has led to reductions in the work carried out under NLR's research programme in some areas. Because of this the risk exists that the dedication of personnel to specific ares becomes too small to keep and extend relevant knowledge. Now of all times the attention should be aimed at preparing for the future, and at NLR the research programme must provide a solid basis. The above considerations apply to 1994 also, since the amount of contract work is expected to remain at a high level.

The modernization of the HST was energetically carried through, especially in view of the financial limitations. The tunnel seems to be taking in a superior position after the second phase to be carried out yet. The construction of the National Simulation Facility also is going well. Finally, preparations are being made for making serviceable the new research aircraft, the Citation II, that is operated jointly with the Delft University of Technology.

Scientific Committee

Prof.dr.ir. P.J. Zandbergen, *chairman*
Prof.ir. C.J. Hoogendoorn
Prof.dr. T. de Jong
Prof.ir. P. Jongenburger
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. F.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

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

Subcommmittee for Applied Mathematics and Information Technology

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

Subcommittee for Flying Qualities and Flight Operations

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

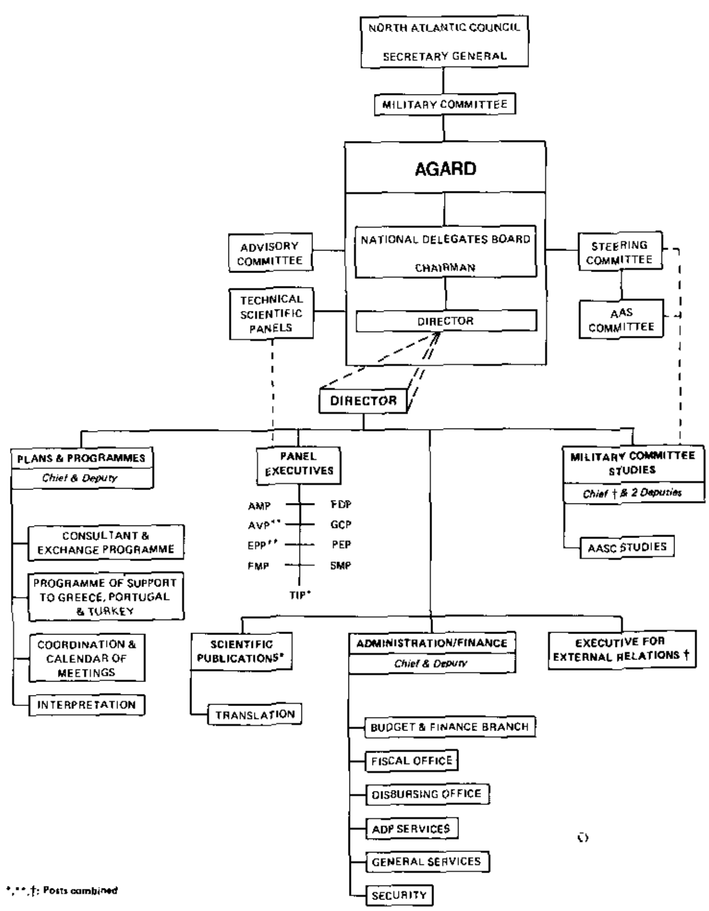
International Co-operation

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

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;
- 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

Panel meetings/symposia

AGARD symposia are technical meetings concerned with subjects of relatively general interest within specific fields. In 1993, eighteen symposia have been organized, two 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 1993, five Lecture Series have been organized, none 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 1993, three Special Courses have been organized, none of them in the Netherlands.

Support programmes

The following numbers of support programmes were active in 1993:

Greece - 25
Portugal - 28
Turkey - 32

The Netherlands actively participated as supporting nation in six programmes.

Consultants programme

In 1993 a total of 85 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 1993 two studies commenced, AAS-39 and AAS-40.

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.

Netherlands Delegation to AGARD

The Netherlands Delegation consists of:

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

DNW was well occupied for contract testing. Large efforts were spent for the updating of test systems and auxiliary equipment.

The Board of DNW at the end of 1993

Dr.rer.publ. J. Blum, *Chairman*	DLR
J. van Houwelingen, *Vice-chairman*	NLR
Drs. G.M. van Aardenne	Netherlands Agency for Aerospace Programs (NIVR)
Min.Rat R. Schreiber	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 of the Netherlands (RLD)
Secretary: Dipl.Volksw. A. Dick	DNW

The Advisory Committee

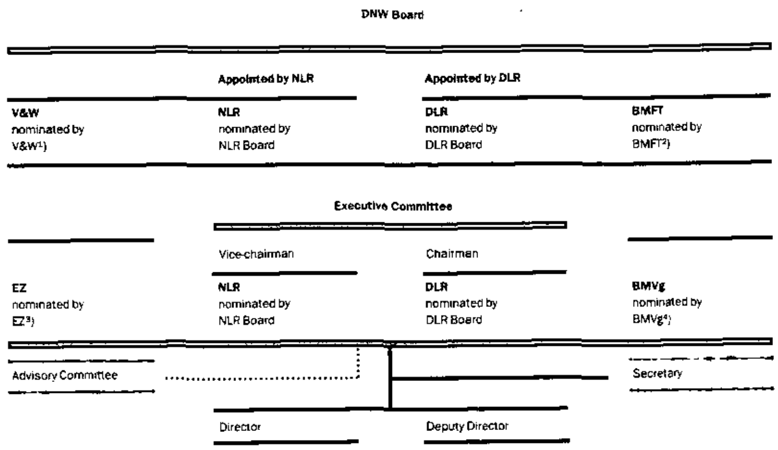
The Advisory Committee, providing support to the Board, and representing the aerospace industry and research establishments:

Dipl.-Ing. O. Friedrich, *Chairman*	Panavia Aircraft GmbH
Dipl.-Ing. J. Thomas	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
Dipl.-Ing. K. Buchholz	Deutsche Aerospace Dornier
Prof.Dr.-Ing. F. Thomas	DLR
Ir. F. Holwerda	Fokker Aircraft
Y. Richard	Eurocopter

Secretary: Ir.J.C.A. van Ditshuizen, DNW*

*Mr. Van Ditshuizen left the DNW to join the European Transonic Windtunnel (ETW) as of 1 September 1993; his task as secretary to the Advisory Committee was transferred to Dr.-Ing. D. Eckert.

The Board and the Advisory Committee had one joint meeting.



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)

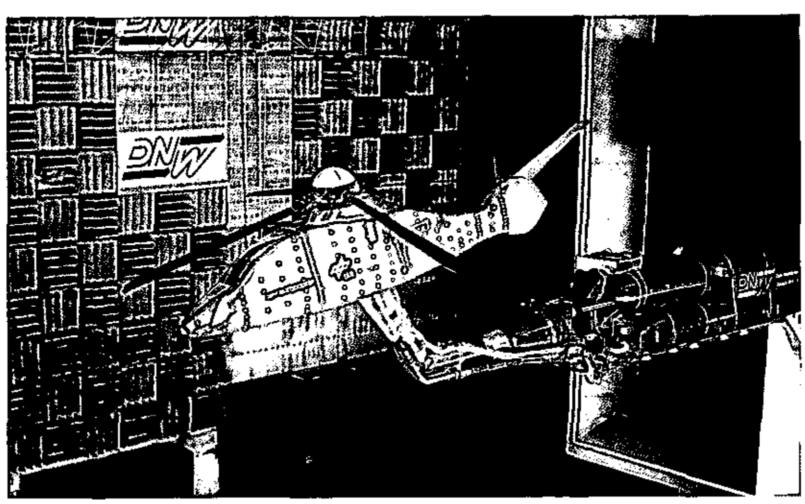
Organization diagram of the Foundation German-Dutch Wind Tunnel

The Board of Directors

The Board of Directors of the DNW consisted of
Prof.Dr.-Ing. H.U. Meier (DLR), *Director;*
Ir. A.H. Runge (NLR), *Deputy Director.*

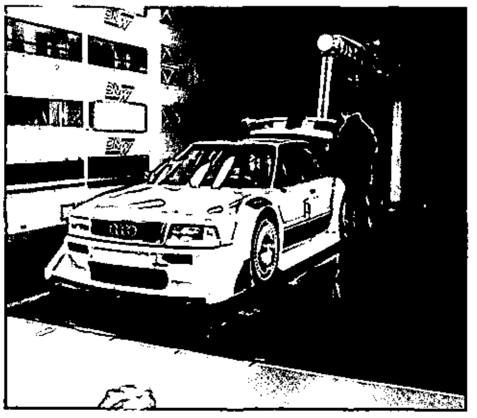
In 1993 some 1000 hours were spent on contract testing, of which about 200 hours were used for the automotive industry. Aircraft testing comprised ten entries covering:

- refinement of several Airbus configurations;
- semi-span model tests on a commuter type aircraft;
- engine installation optimization on a two-propeller commuter aircraft;
- engine airframe interference studies on an aircraft with two high-bypass ratio fans;
- *performance tests on a model of a counter-rotating high-bypass ratio fan* engine;
- stability and performance tests on three models of helicopters equipped with high-performance rotor systems.

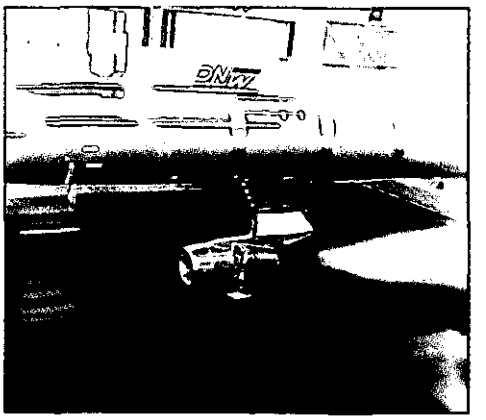


Force tests in the open test section on a model of a helicopter equipped with a high-performance rotor

For the automotive industry twelve test campaigns were executed, ten of which concerned passenger cars and two concerned full-sized lorries. The complexity of these tests and the diversity of problem areas has steadily increased. Ground simulation is becoming almost a standard requirement, and tests on interior noise levels, car body deformation, internal flows and cooler efficiency get increasing weights in the programmes.



A sports car being prepared for a test run over the moving belt ground plane



Thrust-reverser test on an isolated model propulsion unit over the moving belt ground plane

To support the increasing demand on testing capabilities, DNW in close co-operation with the parent institutes NLR and DLR has carried out a three-year programme for updating the installations, concluded by the end of 1993. Under this programme an electronic scanning pressure measurement system has been acquired and integrated in a modernized data acquisition and reduction system, and a system for the acquisition and analysis of dynamic data has been purchased. This latter system is also fully operational and, although still used off-line, has demonstrated its potential in several contract tests.

A further impulse for the improvement of the testing capabilities was given by the parent institutes, supporting the continuation of the work for the improvement of the compressed air system and the construction of a support platform for testing cars under improved operational conditions as well as large semi-span models.

7.3 The European Transonic Windtunnel (ETW)

On behalf of the Netherlands, NLR is a 7% shareholder in the European Transonic Windtunnel GmbH, established in 1988. The main event of the year 1993 was the official Inauguration of the ETW on 8 June 1993. This important milestone was attended, among others, by Mrs. J.R.H. Maij-Weggen, Minister of Transport.

On 1 July 1993 the commissioning and calibration of the facility was started; these activities will continue until mid-1994, when the initial operation will be started.

At the end of 1993 the membership of the Supervisory Board was as follows:

France	IGA G. Dorey	(ONERA)	
	IGA J. Chéret	(DRET/SDCE)	
	ICA E. Lisack	(DPAC)	
Germany	Dr.-Ing. H. Hertrich	(BMFT)	
	Dr.rer.publ. J. Blum	(DLR)	
	Dr.-Ing. O. Lawaczeck	(DLR)	
United Kingdom	S.I. Charik	(DTI)	
	Dr. G.T. Coleman	(DRA)	
	Dr. D.S. Woodward	(DRA)	
The Netherlands	Ir. H.N. Wolleswinkel	(V&W)	
	J. van Houwelingen	(NLR)	
	Dr.ir. B.M. Spee	(NLR)	*Chairman*

As planned, the members of Board of Directors responsible for the construction of the ETW left the company in 1993. Per 1 October 1993 the Supervisory Board appointed Mr. T.B. Saunders (UK) as Managing Director Operation. Mr. Saunders is assisted by:

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

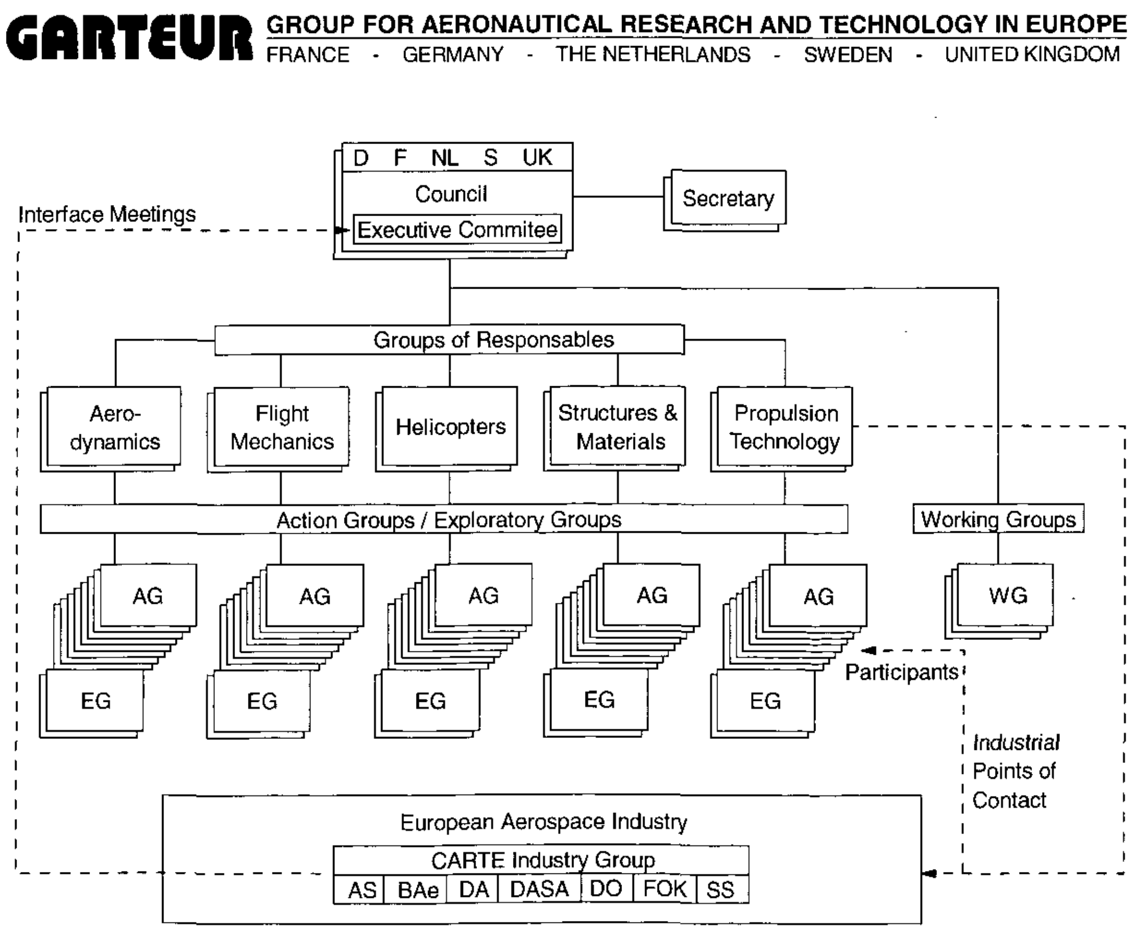
7.4 GARTEUR

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. If the subject

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



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.

Organisation

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

Composition GARTEUR Council and Executive Committee

France

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

Germany

Dr.-Ing. H. Hertrich	(BMFT)
Prof.Dr. W. Kröll	(DLR)
Dr. K.O. Pfeiffer	(DLR) *)
Prof. F. Thomas	(DLR)

United Kingdom

M.J. Earwicker	(DRA)
S.I. Charik	(DTI)
Dr. G.T. Coleman	(DRA)
Dr. C. Mace	(MOD)
Dr. R.H. Warren	(DRA)
P.G. Wilby	(DRA) *)

Sweden

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

The Netherlands

J. van Houwelingen	(NLR)
Prof.ir. F.J. Abbink	(NLR) *)
Dr.ir. B.M. Spee	(NLR)

*) member of the Executive Committee

During 1993, IGA Bouchet held the chairmanship of the Council. Dr. Pfeiffer held the chairmanship of the Executive Council for the years 1992 and 1993. The Secretary of GARTEUR for the period 1992-1993 was Mr. G. Gruber (DLR).

NLR Participation

NLR participates in all five Groups of Responsables.

At the end of 1993, twenty-five Action Groups were active; NLR participates in all of these 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 (BPPT) 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 main 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 "Integrated 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) respectively, also took part in the projects; ISARD was successfully completed in September 1991.

With the same participants an interim Programme for Education, Research and Technology (APERT) was started in the beginning of 1992, planned to last two years. As in the foregoing projects, NLR and BPPT are the co-ordinating bodies for APERT, which is sponsored by Fokker and NLR on the Dutch side and by IPTN and LAGG on the Indonesian side. The programme is supported by both Governments, which was upheld by the signing of a MoU by the Ministers B.J. Habibie and J.M.M. Ritzen in September 1992, among other things aiming at the development of a plan for long term co-operation on the basis of equal partnership and mutual interest.

APERT

The co-operation under APERT covers:

I	Project Bandung:	continuation of the integrated support of ITB by TUD.
II	Project Serpong:	continuation of the integrated support of ILST operation by NLR.
III	Project Joint Research:	Definition, preparation and execution of joint research programmes.

During the Plenary Programme Meeting (PPM), held at NLR in Amsterdam on 7 April, it was agreed to extend APERT with one year (1994). Furthermore, the Terms of Reference for the Working Group on Aerospace Technology were approved and the members appointed.

The Projects

After a start in 1992 a very ambitious activity plan was developed and carried out in Project Bandung during 1993. Most of the activities planned in Project Serpong were completed at the end of the year. Three different projects were developed under Project Joint Research; execution started in the course of the year.

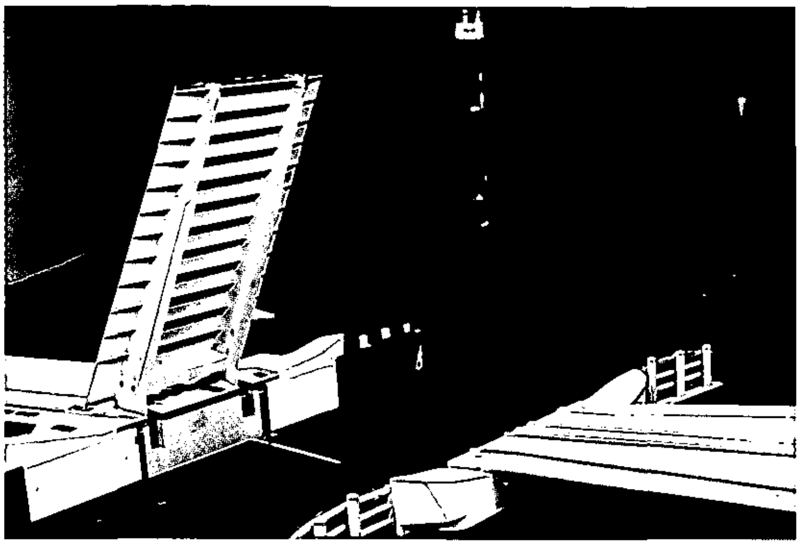
Future co-operation

In December the first meeting of the APERT Joint Working Group on Aerospace Technology was held in Jakarta, during which the principles of co-operation, the scope of activities and some financial principles were established for a long term co-operation to start in 1995.

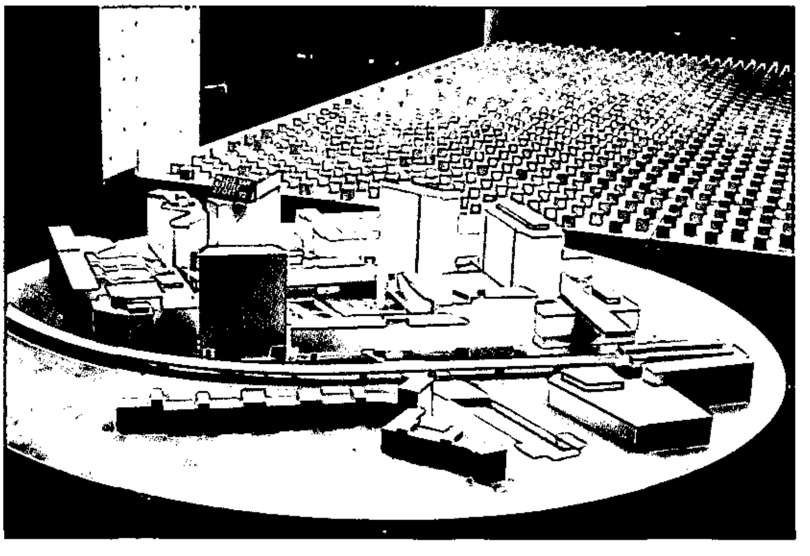
Other activities

Under the umbrella agreement between IPTN and NLR, signed on 30 June 1988, running contracts were continued and new ones prepared.

The Low Speed Wind Tunnel (LST) used in non-aerospace testing



Model of Erasmus bridge for Rotterdam in the Low Speed Wind Tunnel (LST)



Model of the Paleis van Justitie (Hall of Justice) and surrounding buildings in The Hague, in the Low Speed Wind Tunnel (LST)

Appendices

1 Publications

In 1993, NLR produced a total of 592 reports, including unpublished reports on contract research and on calibrations and tests of equipment. The reports listed below were released for publication.

TP 89191 U
Validation experiments with an ethernet model using the simulation tool "PROMISE"
Wedzinga, G.

TP 90198 U
A flight test program differential GPS for approach guidance
Driel, N. van; Krijn, R.

TP 90247 U
CFD-based drag prediction; state-of-the-art, theory, prospects
Vooren, J. van der; Slooff, J.W.

TP 90376 U
Supercomputing has to be part of an organization-wide automation concept
Loeve, W.

TP 91142 U
Fractographic and microstructural analysis of fatigue crack growth in Ti-6 Al-4V fan disc forgings
Wanhill, R.J.H.; Looije, C.E.W.

TP 91249 U
Fracture toughness and crack resistance of damage tolerant and high strength Al-Li alloys
(Paper presented at the "Sixth Aluminium-Lithium Conference", Garmisch-Partenkirchen, Germany, October 1991)
Wanhill, R.J.H.; Schra, L.; Hart, W.G. 't

TP 91446 U
Flight simulator evaluation of advanced MLS procedures
Erkelens, L.J.J.; Dronkelaar, J.H. van

TP 91471 U
Numerical simulation of leading-edge vortex flow
(Publication on the occasion of the retirement of Prof.dr.ir. Steketee, Professor in Theoretical Aerodynamics of the Faculty of Aerospace Engineering of the Delft University of Technology, Delft, The Netherlands)
Hoeijmakers, H.W.M.

TP 91476 U (V2)
WISPER and WISPERX Final definition of two standardised fatigue loading sequences for wind turbine blades
Have, A.A. ten

TP 91489 U
Aircraft simulation and pilot proficiency: from surrogate flying towards effective training
Jorna, P.G.A.M.; Kleef, E.R.A.; Boer, W.P. de

TP 92020 U
A stochastic control approach to flight path monitoring
Doorn, B.A. van; Blom, H.A.P.

TP 92042 U
A review of the status and capabilities of NAVSTAR GPS
Driel, N. van

TP 92062 U
The deterministic power-spectral-density-method for linear systems
Noback, R.

TP 92081 U
Numerical simulation of a condensor in two-phase heat transport systems - a feasibility study
Berg, J.I. van den; Dam, A.A. ten

TP 92113 U
Real-time and the NLR aerodynamic facilities
Draai, R.K. van der

TP 92114 U
The deterministic power-spectral-density method
Noback, R.

TP 92134 U
The MACS-TSA applied in the ISO and SAX spacecraft projects
Sonnenschein, F.J.; Keppel, D.

TP 92139 U
Grid adaption in computational aerodynamics
Hagmeijer, R.; Cock, K.M.J. de

TP 92151 U
Flight testing of GPS and GPS-aided systems
Pietersen, O.B.M.; Peters, M.A.G.; Driel, N. van

TP 92156 U
Development of a method to predict transonic limit cycle oscillation characteristics of fighter aircraft (continued)
Meijer, J.J.; Cunningham Jr., A.M.

TP 92158 U
In-flight tailload measurements
Gelder, P.A. van

TP 92160 U
Engineering of systems for application of scientific computing in industry
Loeve, W.

TP 92163 U
Prospects of time-linearized unsteady calculation methods for exponentially diverging motions in aeroelasticity
Hounjet, M.H.L.; Eussen, B.J.G.

TP 92167 U
Gravity dependence of pressure drop and heat transfer in straight two-phase heat transport system condenser ducts
Delil, A.A.M.

TP 92174 U
Multi-sensor data fusion and the use of artificial intelligence
Zuidgeest, R.G.

TP 92183 U
Investigation of the bond strength of a discrete skin-stiffener interface
Thuis, H.G.S.J.; Wiggenraad, J.F.M.

TP 92184 U
Determination of acceleration field parameters with linear accelerometers
Vreeburg, J.P.B.

TP 92185 U
A survey on Schiphol airport of the contamination of wing leading edges of three different aircraft types under operating conditions
Elsenaar, A.; Haasnoot, H.N.

TP 92190 U
The design of a system of codes for industrial calculations of flows around aircraft and other complex aerodynamic configurations
Boerstoel, J.W.; Spekreijse, S.P.; Vitagliano, P.L.

TP 92193 U
Status and prospects for aluminium-lithium alloys in aircraft structures
Wanhill, R.J.H.

TP 92202 U
Uitslag enquete surfnet3-security
Klaasse, A.A.C.

TP 92210 U
Understanding and development of a prediction method of transonic limit cycle oscillation characteristics of fighter aircraft
Meijer, J.J.; Cunningham Jr., A.M.

TP 92217 U
Grid adaptation for problems in computational fluid dynamics
Hagmeijer, R.; Cock, K.M.J. de

TP 92221 U
Time-step enlargement and optimal smoothing in Runge-Kutta time-integration algorithms by implicit and explicit smoothing
Linders, R.C.A.

TP 92222 U
Eigenvalue analysis of the convergence behaviour of an Euler method
Cazemier, W.; Berg, J.I. van den; Veldman, A.E.P.

TP 92230 U
Software design of a multi-block, multi-zone Navier-Stokes solver
Vogels, M.E.S.

TP 92233 U
Software engineering and software management in a distributed unix environment
Jong, S. de; Baalbergen, E.H.

TP 92243 U
Multi-sensor data fusion in a distributed environment, Architectural solutions
Zuidgeest, R.G.

TP 92244 U
Hera training facility concept
Pronk, C.N.A.; Prins, J.J.M.; Dupont, J.L.; Simkens, P.; e.a.

TP 92248 U
Numerical investigation into high-angle-of-attack leading-edge vortex flow
Berg, J.I. van den; Hoeijmakers, H.W.M.; Sytsma, H.A.

TP 92252 U
Experiments and theoretical considerations regarding the allowable roughness height in laminar flow
Bruin, A.C. de

TP 92253 U
The experimental flight management system: An air traffic management research tool
Brüggen, J.

TP 92256 U
Flight simulator research into advanced MLS approach and departure procedures
Erkelens, L.J.J.; Dronkelaar, J.H. van

TP 92261 U
Aiding the operator in the manual control of a space manipulator
Bos, J.F.T.; Stassen, H.G.; Lunteren, A. van

TP 92268 U
Domain modelling and grid generation for multi-block structured grids with application to aerodynamic and hydrodynamic configurations
Spekreijse, S.P.; Boerstoel, J.W.; Vitagliano, P.L.; Kuijvenhoven

TP 92270 U
Low frame rate video coding for small bandwith real-time multi-media tele-education systems
Algra, T.

TP 92272 U
Development concept for Dutch user support
(IAF paper 92-0711)
Pronk, C.N.A.; Koopman, N.; Hoop, D. de

TP 92281 U
Modal analysis of solar panels using boundary integral equations
Koelink, H.T.; Schippers, H.; Heijstek, J.J.; Derksen, J.J.

TP 92284 U
Development and validation of a linear recursive "order-N" algorithm for the simulation of flexible space manipulator dynamics
Woerkom, P.Th.L.M van; Boer, A. de

TP 92288 U
Comparison of RCS prediction techniques, computations and measurements
Brand, M.G.E.; Ewijk, L.J. van; Klinker, F.; Schippers, H.

TP 92289 U
Turbulence modelling of the shear layers in the trailing edge region of a modern aft-loaded airfoil at incidence
Bruin, A.C. de; Absil, L.H.J.; Passchier, D.M.

TP 92300 U
The development of the NLR ATC research simulator (NARSIM): Design philosophy and potential for ATM research
Have, J.M. ten

TP 92305 U
Corrosion and stress corrosion properties of damage tolerant aluminium lithium sheet materials
(NLR contribution to BREU 3250, task 2)
Schra, L.; Hart, W.G.J. 't

TP 92311 U
Correction of X hot-wire measurements for gradients normal to the plane of the wires
Gooden, J.H.M.

TP 92315 U
Evaluation of 6013-T6 sheet for damage tolerant applications
Hart, W.G.J. 't; Schra, L.

TP 92321 U
Vibrations in engineering structures "a review of model and full-scale test of a cable-stayed bridge and a traffic sign gantry"
Persoon, A.J.

TP 92327 U
Control system design for A&R supported microgravity experiments: An experiment payload control development model
Dieleman, P.

TP 92342 U
The deterministic power-spectral-density-method for nonlinear systems
Noback, R.

TP 92344 U
Certification of helicopter vertical take-off and landing operations: a computer program and an application to the S-76B helicopter
Vodegel, H.J.G.C.; Stevens, J.M.G.F.

TP 92351 U
High-lift system analysis method using unstructured meshes
Cock, K. de

TP 92353 U
Fast and efficient variable-to-fixed-length coding algorithm
Algra, T.

TP 92356 U
Morphodynamics of inter-tidal areas the Dutch Wadden sea
Noorbergen, H.H.S.

TP 92361 U
Calculus of variations applied to 2D multi-point airfoil design
Labrujere, Th.E.; Vooren, J. van den

TP 92371 U
De regeling van het Mach-getal in de hoge snelheidstunnel van het NLR
Bos, J.F.T.; Faasse, P.R.

TP 92386 U
Sampling behavior in a four instrument monitoring task - effects of signal bandwidth and number of events per signal
Bohnen, H.G.M.; Leermakers, M.A.M.; Venemans, P.J.

TP 92408 U
Representations of dynamical systems described by behavioural inequalities
Dam, A.A. ten

TP 92409 U
Sectional prediction of 3D effects for separated flow on rotating blades
Snel, H.; Houwink, R.; Piers, W.J.

TP 92410 U
WISPER and WISPERX: a summary paper describing their backgrounds, derivation and statistics
Have, A.A. ten

TP 92420 U
The modernised HST of NLR
Jaarsma, F.; Smith, J.; Draai, R.K. van der

TP 92426 U
Microgravity fluid science research in Europe
Vreeburg, J.P.B.

TP 92435 L
Informatica bij het NLR
Loeve, W.

TP 92437 U
A preliminary study of fatigue durability in terms of short and long crack growth
Wanhill, R.J.H.

TP 92439 U
Residual strength of damage tolerant aluminium-lithium sheet materials
(NLR contribution to BREU 3250, task 3)
Hart, W.G.J. 't; Schra, L.

TP 92441 U
Application of the new NLR measurement system pharao in unsteady wind tunnel tests on straked delta wings
Boer, R.G. den

TP 92443 U
Euler results of the ISNaS compressible multi-block flow solver
Wagenaar, W.; Vogels, M.E.S.

TP 92445 U
Influence of gust spectrum variations on fatigue crack growth behaviour of damage tolerant aluminium-lithium sheet materials
(NLR contribution to BREU 3250, task 4)
Schra, L.; Wanhill, R.J.H.

TP 92448 U
The approach for the development of simulators at the National Aerospace Laboratory (NLR): two space related examples
Couwenberg, M.J.H.; Dam, A.A. ten; Mans, M.T.G.A.R.

TP 92467 U

Fatigue and residual strength behaviour of Arall3 panels with bonded-on doublers
Hoeven, W. van der

TP 92469 U

The generation of aircraft propeller and fan noise
Schulten, J.B.H.M.

TP 92481 U

Smart – a simulation for multi-radar analysis for realistic traffic
Hogendoorn, R.A.K.; Heerema, F.J.; Sauer, P.

TP 92521 U

Aspects of the modelling and numerical simulation of leading-edge vortex flow
Hoeijmakers, H.W.M.

TP 92524 U

A residual correction method applied to 2D multi-point airfoil design and 3D single-point wing design
Labrujère, Th.E.; Vooren, J. van der

TP 93019 U

The influence of trigger configurations and laminate structure on the failure mode of composite crush cylinders
(Paper presented at the "7th International Conference on Composite Structures (ICCS-6)", University of Paisley, Scotland, 5–7 July 1993)
Thuis, H.G.S.J.; Metz, V.H.

TP 93020 U

Acquiring tail load spectra from in-flight measurements
(Paper presented at the "34th AIAA Structures, Structural Dynamics and Materials Conference", La Jolla (CA), USA, 19–22 April 1993)
Gelder, P.A. van

TP 93034 U

Spectral analysis of heart rate and psychological state: a review of its validity as a workload index
(Published in the "Journal Biological Psychology, 1992")
Jorna, P.G.A.M.

TP 93039 U

Development of a structure relevant specimen for damage tolerance studies
(Paper presented at the "9th International Conference on Composite Materials (ICCM-9)", Madrid, Spain, 12–16 July 1993)
Labonte, S.; Wiggenraad, J.F.

TP 93046 U

Experimental validation of a wind turbine aerodynamic noise prediction code
(Paper presented at the "European Community Wind Energy Conference and Exhibition", Lübeck-Travemünde, Germany, 8–12 March 1993)
Dassen, A.G.M.

TP 93047 U

Fame: a forest assessment and monitoring environment scenario
(Paper presented at the "International Symposium 'Operationalization of Remote Sensing'", ITC, Enschede, 19–23 April 1993)
Looyen, W.J.; Zeppenfeldt, F.O.; Venema, J.C.; Burg, G. van de

TP 93069 U

End-to-end delay reduction in narrow bandwidth real-time multimedia tele-education applications
(Paper presented at the "EOS/SPIE International Symposium on Fiber Optic Networks and Video Communication", Berlin, 5–8 April 1993)
Algra, T.

TP 93082 U

Information system for flow simulation based on the Navier-Stokes equations
Vectorization of a multi-block Navier-Stokes solver
(Paper presented at the "Negende supercomputer gebruikersdag", Amsterdam, 17 December 1992)
Mourik, P.A. van

TP 93086 U

Flight simulation fatigue crack growth testing of aluminium alloys: specific issues and guidelines
(Published in the "International Journal of Fatigue")
Wanhill, R.J.H.

TP 93086 U

Flight simulation fatigue crack growth testing of aluminium alloys: specific issues and guidelines
(Published in the "International Journal of Fatigue")
Wanhill, R.J.H.

TP 93094 U

Systematic error estimation in multisensor fusion systems
(Paper presented at the "SPIE Conference 'Signal and Data Processing of Small Targets', Orlando, USA, 12–16 April 1993)
Doorn, B.A. van; Blom, H.A.P.

TP 93100 U

Multitemporal analysis of a braiding river (the advanced study of 1992)
(Paper presented at the International Symposium "Operationalization of Remote Sensing", ITC, Enschede, 19–23 April 1993)
Noorbergen, H.H.S.

TP 93151 U

Advanced materials in gasturbine engines
Kool, G.A.

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	Flygtekniska Försöksanstalten (Aeronautical Research Institute of Sweden)
FSS	Fokker Space & Systems
GARTEUR	Group for Aeronautical Research and Technology in Europe
GPS	Global Positioning System
HSA	Hollandse Signaalapparaten B.V.
HST	Hoge-Snelheids Tunnel (High Speed Wind Tunnel)

ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IEPG	Independent European Programme Group
ILST	Indonesische Lage-Snelheids Tunnel (Indonesian Low Speed Tunnel)
INTA	Instituto Nacional de Técnica 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)

National Aerospace Laboratory NLR

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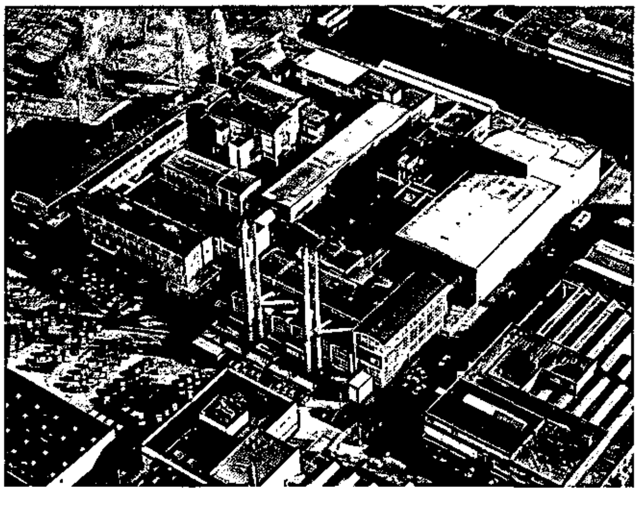
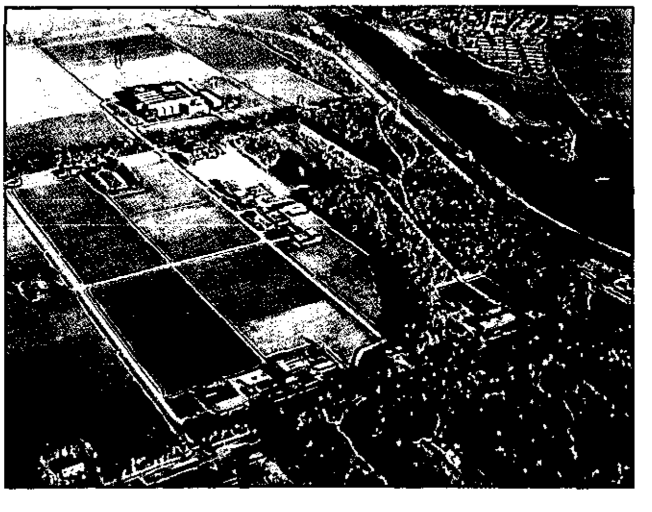


NLR Amsterdam
(Photography: KLM Luchtfotografie)



NLR Noordoostpolder
(Photography: KLM Luchtfotografie)

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