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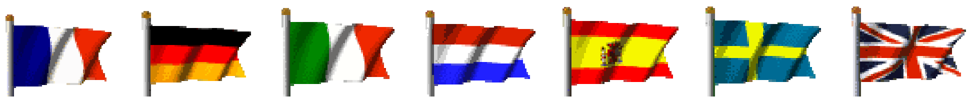
NLR-TP-2004-284



GARTEUR: 30 YEARS OF EUROPEAN COLLABORATION IN AERONAUTICS RESEARCH

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This report has been based on a paper presented at ICAS 2004 - 24th Congress of the International Council of the Aeronautical Sciences, in Yokohama, Japan, 29 August - 3 September 2004.

Customer:	National Aerospace Laboratory NLR
Working Plan number:	---
Owner:	National Aerospace Laboratory NLR
Division:	Aerospace Vehicles
Distribution:	Unlimited
Classification title:	Unclassified
	July 2004

Approved by author:	Approved by project manager:	Approved by project managing department:
i/o BO 16/7	16/7	BO 16/7

Summary

This paper presents an overview of collaboration in aeronautics between European countries as stimulated continuously by the Group for Aeronautical Research and Technology in Europe (GARTEUR) over the last thirty years. Its mission, operating principles and organisation, as well as its fields of scientific and technical activities are exposed. The scope of research performed within GARTEUR is highlighted in terms of a selected number of projects from the various disciplines covered by GARTEUR. Conclusions and points of interest for future operation of GARTEUR are addressed.

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Keywords: *aerodynamics, structures & materials, helicopters, flight mechanics, systems & integration*

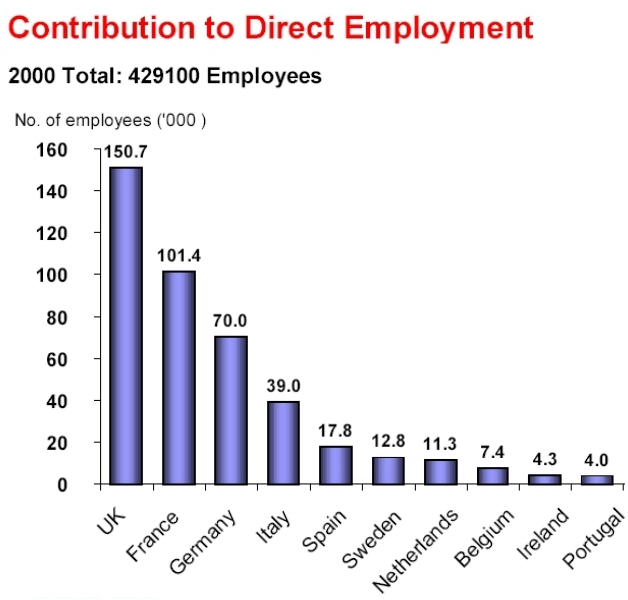
Abstract

This paper presents an overview of collaboration in aeronautics between European countries as stimulated continuously by the Group for Aeronautical Research and Technology in Europe (GARTEUR) over the last thirty years. Its mission, operating principles and organisation, as well as its fields of scientific and technical activities are exposed. The scope of research performed within GARTEUR is highlighted in terms of a selected number of projects from the various disciplines covered by GARTEUR. Conclusions and points of interest for future operation of GARTEUR are addressed.

1 Introduction

GARTEUR (Group for Aeronautical Research and Technology in Europe) is a government-to-government agreement between France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom to mobilise their scientific and technical skills, their human resources and facilities in aeronautics for the purpose of strengthening collaboration between European countries.

The GARTEUR objective is to improve the competitiveness of aerospace industries by performing high quality, precompetitive research in the field of aeronautics by research establishments, industry and academia. Subjects of investigation cover civil as well as military Research & Technology (R&T), and provide for synergies and mutual benefits to the GARTEUR member countries. The GARTEUR nations are also the seven European Union countries with the largest direct employment in the aerospace business, as can be seen in the figure below from the statistical survey by the European Association of Aerospace Industries (AECMA) for the year 2000.



Direct employment in aerospace companies, taken from the statistical survey by AECMA for 2000

GARTEUR identifies the best of European long term innovative R&T, both in terms of upstream research performed nationally at universities, as well as in terms of basic R&T performed at research institutes. GARTEUR aims at the readiness of this R&T outcome for applications in industry. Within GARTEUR, emerging technologies relevant to industry are matured. Subsequently, technology readiness is presented by GARTEUR (and other bodies such as EUCLID "European Co-operation on the Long-term In Defence" and the Framework Programmes of the EU "European Union") to qualify these technologies for application by industry. Some proposals submitted to the Framework Programmes of the EU are based on activities of GARTEUR Action Groups.

The European context is of great importance for GARTEUR because of the more recently developed EU environment promoting co-ordinated aeronautics R&T. There exists a permanent mutual influence between this EU environment and GARTEUR.

The objective of this paper is to present the GARTEUR organisation, to highlight its technical activities and to identify the factors that have led to the success of the GARTEUR organisation over the last thirty years. Conclusions are drawn at the end.

2 The GARTEUR organisation

This section provides background information on GARTEUR, its mission and operating principles, and organisation.

2.1 Origin of GARTEUR

Airbus was established in 1970 after its first aircraft, the A300B, was launched at the 1969 Paris airshow. In 1973, GARTEUR was formed, as it became clear that only through co-operation, would European R&T activities become competitive in the global playing field. The initiative to strengthen R&T activities was taken by the governments of France, Germany and the United Kingdom. The Netherlands joined the GARTEUR in 1977, followed by Sweden in 1991, Spain in 1996 and Italy in 2000. The collaboration is based on a Memorandum of Understanding between these seven European Nations with major research and test capabilities in aeronautics.

The GARTEUR focus is on research topics aimed at long term R&T because this is considered essential to assure sustained competitiveness of the European aerospace industries. Subjects of interest within the GARTEUR programme are not restricted to particular application areas. The GARTEUR scope is wide and covers civil, defence and dual use applications. As such, it is one of the few mechanisms in Europe that allow for transfer of aeronautical technology between the military and civil fields.

It offers a unique forum to aeronautical experts from research establishments, industry and academia. GARTEUR interacts with other bodies, such as the European Union, the Association of European Research Establishments in Aeronautics (EREA), the Aerospace and Defence Industries Association of Europe (ASD) and the Western European Armaments Group (WEAG).

2.2 Mission and principles

The mission of GARTEUR is to mobilise, for the mutual benefit of the GARTEUR member countries, their scientific and technical skills, human resources and facilities in the field of aeronautical research and technology for the purposes of strengthening collaboration between European countries with major research capabilities and government funded programmes.

GARTEUR also aims at continuously stimulating advances in the aeronautical sciences and at pursuing topics of application-oriented research in order to maintain and strengthen the competitiveness of the European aerospace industry by concentrating existing resources in an efficient manner and seeking to avoid duplication of work.

These objectives are accomplished by performing joint research work in fields suitable for collaboration and within research groups specifically established for this purpose. Technology gaps and facility needs are identified and effective ways are recommended to the member countries to jointly overcome such shortcomings. Finally, scientific and technical information is exchanged among the GARTEUR member countries.

GARTEUR adopts the principle of operation that an overall balance of benefits between the member countries is pursued. However, the possibility of bilateral co-operation between the member countries continues to exist. Another principle is that major decisions in the organisation have to be taken by unanimity of the member countries.

Participation of industry is sought at senior advisory level in both the planning and execution of programmes. A flexible approach is taken towards participation of non-GARTEUR countries and organisations in the programmes.

Full safeguarding of intellectual property rights is obtained through compliance with a set of agreed written regulations. In addition, all participants work according to a set of security regulations.

2.3 Organisation

GARTEUR is organised at three main levels.

The highest level is the Council composed of representatives of each member country who constitute the national delegations. These representatives come from all relevant Ministries and Research Establishments. An Executive Committee (XC) assists the Council. This XC is composed of one member from each national delegation, and a Secretary.

The second highest level is formed by the Groups of Responsables (GoR) that act as scientific management bodies. They also represent the think-tank of GARTEUR. The GoRs are composed of representatives from national research establishments, industry and academia. Currently, four GoRs manage GARTEUR research activities:

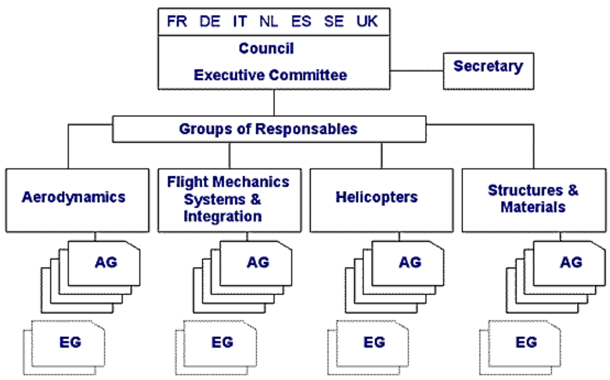
- Aerodynamics (AD);
- Flight Mechanics, Systems and Integration (FM);
- Helicopters (HC);
- Structures and Materials (SM).

In the early nineties, a Group of Responsables for Propulsion Technology (PT) has been operational for a number of years; however, this GoR has been discontinued.

Action Groups (AGs) form the third level of GARTEUR. AGs are the technical expert bodies that formulate the GARTEUR research programme and execute the research work. Potential research areas and subjects are identified by the Groups of Responsables and investigated for collaboration feasibility by Exploratory Groups (EGs). If an Exploratory Group establishes an agreed proposal, an Action Group is launched. A GARTEUR AG needs participation from at least three GARTEUR countries.

The GARTEUR operating principals provide for participation by organisations from non-GARTEUR countries in GARTEUR technical activities, under a special procedure subject to approval by the Council.

GARTEUR has interfaces with the European aeronautical industry through Industrial Points of Contact in the Groups of Responsables, through industry participation in the Action Groups, and through the Industrial Management Group (IMG[4]). IMG[4] is a committee within the Aerospace and Defence Industries Association of Europe (ASD) that is involved in the R&T activities performed in the Framework Programmes of the EU.



GARTEUR organisational diagram

GARTEUR is an independent organisation without permanent secretariat and headquarters. The co-ordination of GARTEUR and the information centre of GARTEUR reside with the Chairman of the XC and the GARTEUR Secretary. The seven GARTEUR nations take their turn in fulfilling the functions of the

Chairmanship of the Council and its XC, and the Secretariat for periods of two consecutive years.

The necessary resources are made available by the governments of the member countries or by the participating organisations on the basis of balanced contributions.

3 GARTEUR statistics

Up to the end of 2003, 97 Action Groups have been active within GARTEUR. Average participation per individual AG from organisations such as research establishments (REs), industrial companies, academia and other entities (governmental organisations) amounts to 8.5 participating organisations per AG, see the table below. This level of participation ranges from 6 to 11 organisations per AG, depending on the particular GoR under consideration. The field of aerodynamics contained the largest number of Action Groups (39); this is also reflected in the distribution of the total number of participating organisations over the various research areas although the total number for the GoR(SM) comes close.

On GARTEUR scale, research establishment and industry participation is fairly of the same size; but in GoR(SM) work the number of industrial participants is substantially larger than RE participants, while the opposite applies for the GoR(AD) and GoR(FM). The FM Action Groups feature a relatively large number of academic participants.

Average number of participating organisations per Action Group

	Group of Responsables (number of Action Groups)					
Kind of participant	**AD (39)**	**FM (14)**	**HC (14)**	**SM (28)**	**PT (2)**	**Total (97)**
RE	177	66	45	103	8	399
Industry	107	33	35	154	10	339
University	5	26	7	22	1	61
Other	13	4	2	11	3	33
Total	**302**	**129**	**89**	**290**	**22**	**832**
Average per AG	**8**	**9**	**6**	**10**	**11**	**8.5**

Status December 2003

This distribution of activities over the research areas is also reflected in the amounts of man-years spent, as shown in the second table. Resources spent in Action Groups have been recorded from 1989; in the past 15 years 402 man-years have been invested in GARTEUR research.

Number of man-years spent in AGs (from 1989)

	GoR					
	AD	**FM**	**HC**	**SM**	**PT**	**Total**
Man-years	**167**	**85**	**30**	**114**	**6**	**402**

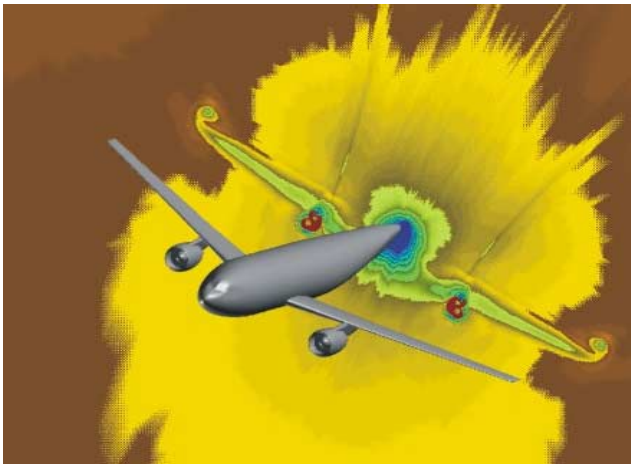
Status December 2003

4 Fields of scientific and technical activities

This section presents an overview of the activities that are executed in the Action Groups that operate under supervision of the four Groups of Responsables in GARTEUR.

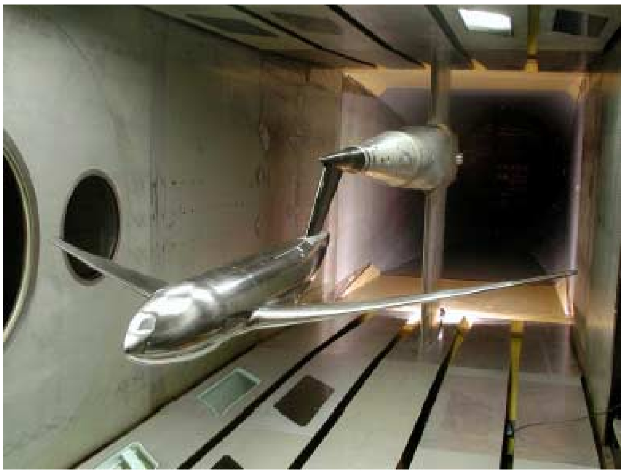
4.1 GoR for Aerodynamics, GoR(AD)

The GoR(AD) is active in initiating and organising basic and applied research in aerodynamics and aerothermodynamics. The first discipline is a cornerstone of aeronautics that determines the shape of the aircraft. The latter is closely related to space operations and flight through the earth’s atmosphere at very high speeds, and is also required for exploring wing-icing phenomena.



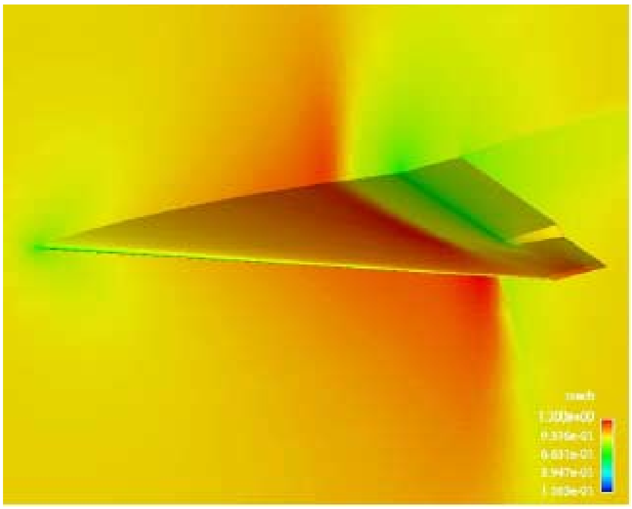
Environmental issues are of great concern in aeronautics for civil aircraft, and advanced aerodynamic design has a significant impact on fuel consumption and the noise of aircraft. For military aircraft, the requirements of stealthy operation require new aircraft shapes to be considered and these shapes must be aerodynamically effective.

The GoR(AD) remit covers aerodynamics, aeroacoustics and aeroelasticity. This GoR is active in experimental and theoretical fields of aerodynamics to contribute to the development of methods and procedures. Work in experimental areas is performed to obtain data for the validation of numerical methods. Measurement techniques are developed and refined to increase accuracy and speed of experimental investigations. Numerical studies give insight into the mechanisms of basic flow phenomena.



Aérospatiale AS-28 model in DNW-HST High Speed Wind Tunnel test-section, from AD(AG) on 'Transonic wing/body code validation experiment'

Current GoR(AD) projects are for example on ***Time-accurate methods*** to obtain better understanding of the advantages and disadvantages of various methods for the computation of unsteady flow and specification of possible improvements. Another AG is aimed at ***RANS code validation for transonic wing-body*** to assess the capabilities of CFD codes solving the Reynolds-Averaged Navier-Stokes equations for the computation of detailed flow features and aerodynamic forces and moments for attached and separated flows.



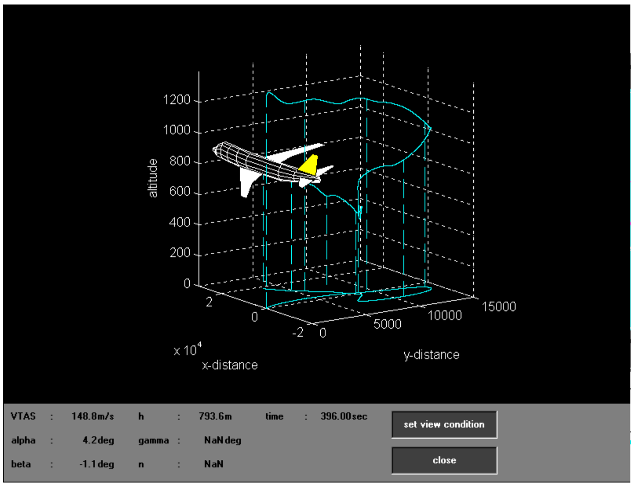
Mach number distribution over a delta wing at $M_\infty = 0.97$, $Re = 19\times10^6$, • = 0º, from AD(AG) on 'Time-accurate methods'

4.2 GoR for Flight Mechanics, Systems and Integration, GoR(FM)

The GoR(FM) is active in the field of air vehicle systems technology in general, including but not limited to safety, avionics systems, certification, multidisciplinary design aspects, performance, and stability & control. Flight testing technologies as well as flight simulations are tools that require further research. Apart from flight mechanics, the GoR(FM) is also responsible for subjects concerning flight guidance, air traffic control, sensor technology and systems, and human factors.

Flight-deck illustration

Current GoR(FM) AGs are on ***Autonomy in UAVs*** to develop and compare autonomous planning and decision making techniques to enable a number of UAVs, of pre-specified dynamics and sensor fit, to co-operate in a highly uncertain environment in order to achieve a goal that has no unique solution. Another one covers ***Pilot-in-the-Loop-Oscillations - analysis and test techniques for their prevention*** to develop and evaluate novel methods for phase compensation and stability analysis of fixed wing aircraft handling qualities with special focus on aircraft-pilot coupling phenomena.



EL AL flight 1862 recovery scenario simulation, from FM(EG) on 'Fault tolerant control'

4.3 GoR for Helicopters, GoR(HC)

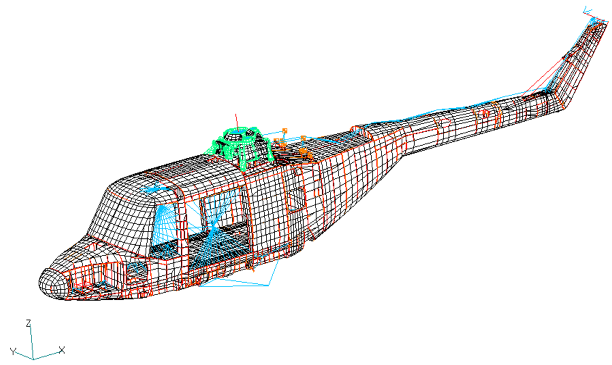
The GoR(HC) is active to facilitate the advancement of civil and military rotorcraft technology in Europe through collaborative research programmes and information exchange.

Benefits to rotorcraft are being sought from advances in technology to obtain an extension of the flight envelope and performance, to increase safety and survivability, to increase public acceptance by paying attention to environmental issues, to

Rotor test rig and experimental rotor in QinetiQ 5 Metre Wind Tunnel, from HC(AG) on 'Validation of rotor blade / hub load synthesis techniques'

increase crew and passenger comfort, and to focus on cost, affordability and time-to-market.

Interests of the GoR(HC) cover the full range of appropriate technical disciplines including aerodynamics, aeroelastics, flight mechanics, handling and control, flight tests and simulation, human factors, and internal and external acoustics.



Refined finite element model of a Lynx helicopter, from HC(AG) on 'Method for the refinement of structural dynamic finite element models'

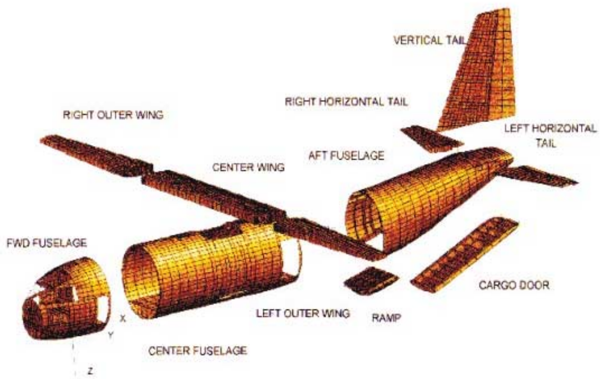
Current GoR(HC) projects are on:
Helicopter yaw axis handling qualities modelling to improve the modelling of yaw axis handling qualities, with special attention to the Dutch roll damping, lateral dynamic response and directional control in quartering flight out-of-ground-effect, on:
Validation of rotor blade / hub load synthesis techniques to validate various hub load synthesis techniques such that ‘measured’ rotor centre loads can be derived with confidence from measured blade parameters with the aim to understand and compute dynamic hub loads, and on:
Method for the refinement of structural-dynamics finite element models to explore methods and procedures for the improvement of finite element models through the use of dynamic testing.

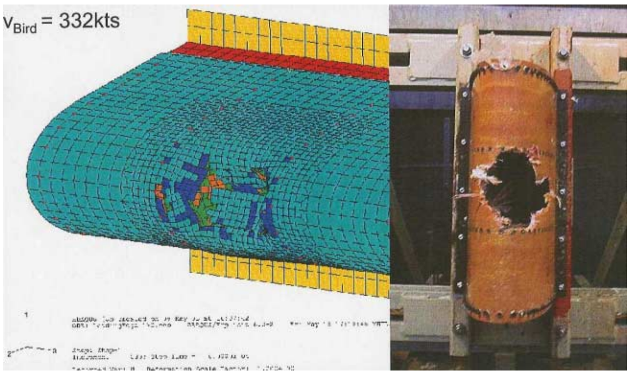
4.4 GoR for Structures and Materials, GoR(SM)

The GoR(SM) is active in initiating and organising aeronautics-oriented research on structures, structural dynamics and materials.

Structural research is devoted to computational mechanics, loads and design methodology. Research on structural dynamics involves vibrations, responses to shock and impact load, aeroelasticity, acoustic response and adaptive vibration suppression.

Materials-oriented research is related to material systems, primarily for the airframe but also for the landing gear and the aero-engines. It includes specific aspects of polymers, metals and various composite systems. The group is active in theoretical and experimental fields of structures and materials to assist in the development and improvement of methods and procedures. Of great importance is the mutual stimulation of alternative scientific approaches. Experiments give new insights into the mechanisms of structural behaviour that can initiate better models. Theoretical work provides advancement in analytical and numerical procedures to investigate the models. Finally, the results must be verified and validated by suitable experiments or trials.





Computational modelling of bird strike and experimental validation, from SM(AG) on ‘Bird strikes’

Current GoR(SM) projects are on:
Fractographic aspects of fatigue failure in complex composite laminates and structures to extend earlier findings on fractographic features of complex laminates and structures; these include woven and non-crimped fabrics that are being used with increased frequency for the manufacture of components, and on:
Impact damage and repair of composite structures; this project aims to develop and validate methods that are able to characterise real impact damage in composite structures, and aims to investigate bonded repairs in terms of durability of under fatigue loading.

5 Technical highlights

This section presents highlights from a number of Action Groups. Two projects are described in terms of objectives and results from each of the four areas of research (AD, FM, HC, and SM).

5.1 Aerodynamics highlights

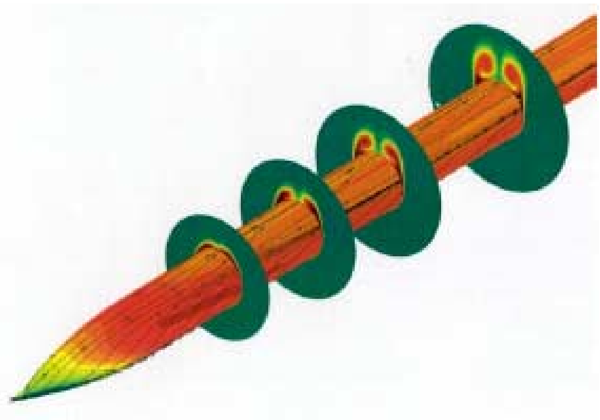
The Action Group on ***Navier-Stokes calculations of the supersonic flow about slender configurations*** was set up with the main objective to investigate CFD applications for supersonic flows around generic missile configurations. These flows feature dominant phenomena such as flow separation from smooth surfaces and the formation of vortices, especially at high incidence, which need to be modelled accurately in order to compute vortex lift, induced rolling moment and other vortex/airframe interactions.

In this Action Group, Navier-Stokes methods have been validated for generic configurations for which reliable experimental data were available. The objective of the Action Group was to verify using these detailed experimental data that the codes were able to capture the mentioned flow phenomena for missile configurations. Particular attention has been paid to the accuracy of the codes, their efficiency and their robustness.

Three generic test cases have been defined for which extensive experimental data were available. Two of the test cases are isolated body configurations. The first one is an ogive-cylinder in a laminar flow (see [1]), and the second one is also an ogive-cylinder but in a turbulent flow (see [2]). The third test case, that is more representative for realistic missile geometries, is a cruciform wing-body configuration (see [3]).

For the first test case, an ogive-cylinder in laminar flow, the computational results show good correspondence with the experimental data with relation to the overall forces and the vortical flow topology.

This holds to a lesser extent for turbulent flow where significant discrepancies appear. This results from an inadequate description of the vortex structure (even if it looks correct, see the figure below), and this is in particular evident at application of the standard Baldwin-Lomax turbulence model, but also for the k-ε and k-ω turbulence models. Nevertheless, improved solutions to the flow field equations have been obtained by manipulation of the turbulence models, knowing that the reason for the discrepancies is an excess of turbulent viscosity in the vicinity of the vortices.



Flow field around the ogive-cylinder at a free stream Mach number of 2 and at 10 degrees incidence

For the body-wing test case, the majority of the computational methods are capable to provide reasonably accurate values of the normal force and pitching moment.

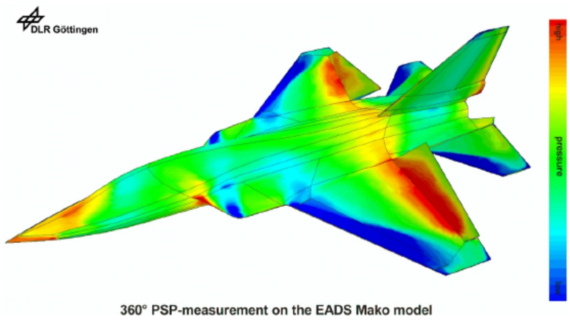
The most important benefits from the work of this Action Group are:

- the high-quality code calibration using detailed experimental data,
- the comprehensive cross-comparison of various CFD methods,
- the improved understanding of the flow physics around a body of revolution at incidence, and
- the identification of the difficulty to properly model flow separation from a smooth surface.

The Action Group ***Pressure Sensitive Paint, phase II*** aimed to measure the quantitative pressure distribution over a complete model surface by application of an optical system (PSP) without disturbances like conventional pressure taps. In this way not only can pressure distributions be measured, but also transition, loads and forces, as well as attachments and re-attachments. The underlying objective is to reduce the number of manufactured models (one equipped with balances, another with pressure taps, etc.) and therefore the design costs as well as wind tunnel occupation time.

This AG has generated some very good examples of pressure measurements on the type of models that are used for routine industrial testing. Different teams have studied various aspects of the pressure paint technique; experience with the application of this technique in various wind tunnels has been exchanged.

In the final report of this Action Group, various applications are shown of the pressure distribution measured on transport-type aircraft configurations and on military aircraft.



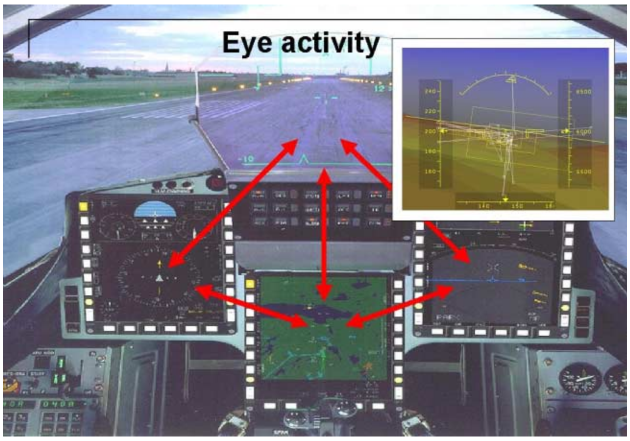
Pressure Sensitive Paint surface pressure distribution; red = high pressure, blue = low pressure

As the figure shows, very detailed pressure information can be obtained over the complete surface and the results can be used to analyse the flow and to estimate the aerodynamic loads. It is expected that the PSP technique will find its place in routine wind tunnel testing (see [4]).

5.2 Flight Mechanics, Systems and Integration highlights

The Action Group ***Mental Workload Measurement*** presented their results, findings and recommendations in the final report of the Action Group, The GARTEUR Handbook of Mental Workload Measurement (see [5]), in September 2003.

The mental workload problems experienced by current and future pilots of fixed and rotary wing aircraft impose a major limiting factor on information processing capabilities and mission performance. Studies on mental workload issues are therefore highly important. However, current workload measurement techniques still need refinement, and since the methods used are not standardised, it is problematic to compare results from different studies.



Display integration exercise

The objectives of the Action Group were to make an inventory of mental workload measurement methods and techniques, to present a methodology to choose between these different measurement methods and, finally, to advise on their use in various operational settings.

In order to be able to recommend suitable measures for different studies, the Action Group has developed Measures Assessment Matrices (MAMs) that assist in the selection of appropriate measures from the workload ‘toolbox’. The final report also describes a number of example studies performed by the Action Group members where issues such as experimental protocol and how to put results in their context are discussed.

Finally, the GARTEUR Handbook produced by this AG describes a number of available approaches to summarise data when several different types of measures have been used in an experiment.

The collaboration within the Action Group has been beneficial to the GARTEUR community, and new contacts between research institutes and industries have been established. The industrial partners have been exposed to the latest measurement and analysis methods. Besides, the GARTEUR Handbook represents a very hands-on guide to the research field.

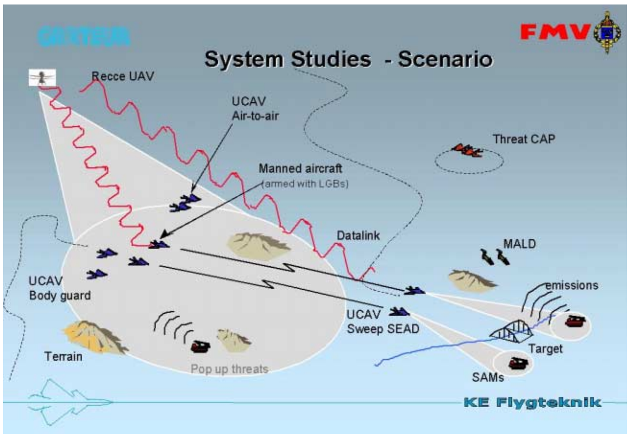
The Action Group ***Autonomy in UAVs*** is the first project in the area of Unmanned Air Vehicles (UAVs) and has gathered great interest from the GARTEUR community, both from research establishments and industry.

The main aim of this Action Group is the development and comparison of autonomous planning and decision-making techniques to enable a co-operative group of UAVs to achieve a goal that has no unique solution implying that some 'intelligence' is required. The UAVs under study have pre-specified dynamics and sensor fit; they are co-operating in a highly uncertain environment.

The UAVs will be defined in terms of airframe, flight controls, sensors and dynamic characteristics. The characteristics of the co-operating UAVs may be different and factors such as fuel state, weapon load and health (e.g. battle damage) will vary as the mission proceeds and will need to be taken into account by the autonomous planning and decision-making techniques.

The techniques under investigation will enable the group of UAVs to co-operate and change their planning on a mission/navigation level. A highly uncertain environment implies that the group of UAVs will encounter unexpected external events or entities.

Within the aviation industry, human supervisory interaction with complex systems has long been a requirement driven by the need to reduce air vehicle crew levels and workload,



Possible operation scenario

compensate for human frailty and, more recently, the demands imposed on UAVs deployed in many diverse tasks. The development of autonomous planning and decision-making techniques will increase vehicle autonomy, thereby enabling a reduction of the number of operators required, or a reduction of operator workload, as well as a compensation for human frailty.

It is expected that the autonomous planning and decision-making techniques to be developed in this Action Group will find applications in a wide range of other domains.

5.3 Helicopter highlights

The Action Group on ***Helicopter yaw axis handling qualities modelling*** aims to improve the establishment of yaw axis handling qualities. Special attention is given to the Dutch roll damping, lateral dynamic response and directional control in quartering flight out-of-ground-effect. The subject under investigation is of high relevance to industry. The modelling deficiencies in establishing yaw axis handling qualities are noticeable in the area of Dutch roll damping and dynamic response and in the loss of tail rotor efficiency when the helicopter is in low-speed quartering flight conditions.

With the availability of suitable wind tunnel and flight test databases, the Action Group will be able to remove the modelling deficiencies by use of their expertise and modelling (simulation) capabilities.

EH Industries EH-101 Merlin helicopter

The Action Group on ***Validation criteria for helicopter real-time simulation models*** aims to examine the process and criteria used in the validation of helicopter simulators and, where possible, define new criteria, rules and procedures that adequately reflect the range of flight conditions and operational manoeuvres encountered during civil and military flying.

Particular attention has been paid to the assessment of the requirements in JAR-STD-1H on the validation of helicopter simulators, and to the assessment of the requirements and processes by which simulators are tuned to achieve correspondence of the simulation properties with real flight characteristics.

Important conclusions have been drawn on the extent to which modelling can reproduce real-life handling qualities and the acceptability of various tuning methods. Recent experience with the use of the JAR within the simulator community is being assessed.

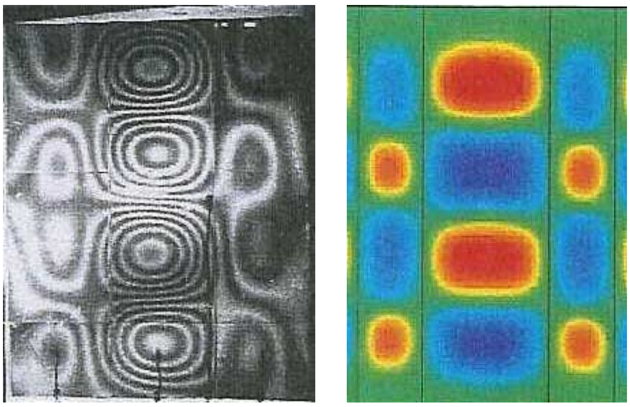
HeliFlight simulator at the University of Liverpool

The activity will be beneficial to the participants in the Action Group by providing the organisations involved in simulator acceptance with a deep understanding of the process and pitfalls of simulator development and acceptance. Aircraft manufacturers will be supplied with the opportunity to market their engineering simulation models to simulator manufacturers. Finally, the possibility will be provided to participants to become involved in the specification of simulator requirements and in the final acceptance testing process.

5.4 Structures and Materials highlights

In order to fully exploit the load carrying capability of structures manufactured from advanced high-strength and high-stiffness material, local buckling can no longer be accepted as a design limit. To explore the region between buckling and collapse phenomena, improved analysis procedures are required. The Action Group ***Post buckling and collapse analysis*** obtained test results for three aircraft-relevant structural components through the use of various numerical analysis packages that have been applied to model the buckling load, the post-buckling behaviour and the final collapse.

The three benchmarks considered have been analysed successfully (see [6], [7], [8]). The group has succeeded in obtaining numerical results that qualitatively correspond very well with the benchmark tests. In most cases the results are also quantitatively in good correspondence with the test results from an engineering point of view.



Moiré pattern of the buckling mode of a compression-loaded, curved, stiffened panel (left); results of the analysis (right)

Efficient and reliable computations and simulations are important to reduce costs in the development of optimised aerospace structures. The benefit of this Action Group is improved knowledge of finite element techniques for the analysis of buckling, post buckling and collapse phenomena that occur in metallic and composite aerospace structures, both in military and civil aircraft.

The group has developed into an active meeting forum for specialists from universities, research institutes, industry and software developers.

The primary objective of the current Action Group ***Impact damage and repair of composite structures*** is:

- to develop and validate methods that are able to characterise real impact damage in composite structures and to study the durability of bonded repairs under fatigue loading.

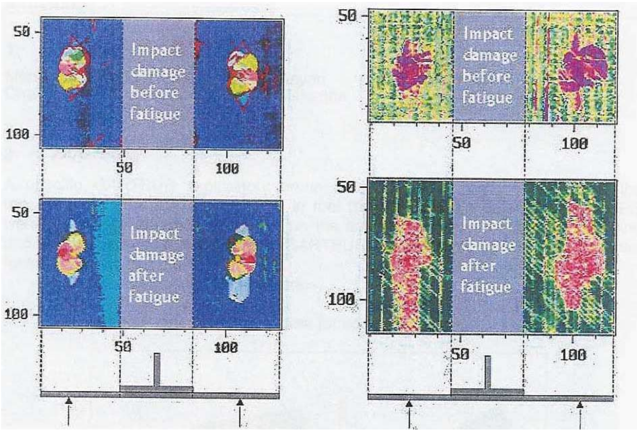
Secondary objectives are:

- to compute impact damage in terms of type, size, geometry and constitutive properties;
- to analyse panels with impact damage;
- to study the durability of bonded repairs to composite structures that are subjected to low energy impact;
- to develop, improve and validate codes for fatigue computation as part of an integrated safety-engineering concept.

Low energy impact is critical for damage tolerance of composite structures (see [9]). It may create superposed delaminations at the layer interfaces and the material is often repaired by bonding. The durability and the efficiency of bonded repair to composite structures subjected to loading (including fatigue loading) become crucial. In recognition of the need to reduce testing costs, this Action Group will develop reliable computational methods for repaired structures.

The group draws on the experience of more than twenty experts from industry, research institutions and universities throughout Europe. Seven different countries provide input. The Action Group offers a greater opportunity for information exchange among specialists than would be obtained at national level only.

The improved understanding gained from involvement in the above-mentioned activities will allow the development of reliable methods for the analysis of repaired structures with the benefit that testing costs can be reduced.



Impact damage growth under fatigue loading

6 Conclusions

GARTEUR is a multinational organisation that performs high quality, collaborative, precompetitive research in the field of aeronautics by research establishments, industry and academia. It offers the only framework in Europe to bring civil and military R&T together and therefore delivers added value through the operation of jointly supported research programmes.

GARTEUR provides a very useful platform and network for scientists from research establishments, industry and academia to pool technology and knowledge in order to develop ideas and concepts in various aeronautical areas, and in the absence of organisations like AGARD this role becomes more significant for GARTEUR.

Although operating effectively in terms of increased competitiveness of aerospace industries, further improvements to GARTEUR's performance and efficiency are continuously pursued in view of the changing aeronautical environment and in order to rise to the occasion of new challenges and unforeseen opportunities. Among a number of proposed adaptations, it is considered important to preserve the close relations with industry in civil and defence environments by enhancing industrial participation at GoR level.

It will also be attempted to increase the direct involvement of universities in basic research issues, as for example in aerodynamics where significant basic research benefits can be foreseen.

Further, it will be explored if 'thematic design concepts' provided by industry could be used to stimulate multidisciplinary activities. At this moment GARTEUR, like many organisations such as NATO-RTO (Research & Technology Organisation) and EUCLID, is split along the lines of traditional disciplines as reflected by the four Groups of Responsables. In recent years, it has become clear that a more interdisciplinary approach is required to achieve specific goals that depend critically on cross-fertilisation of ideas between the various GoRs covering traditional disciplines.

It is therefore the role of these GoRs to cope with the changing environment and to be open to new challenges and unforeseen opportunities. The GoRs will remain to be continuously aware of new developments (e.g. nano-technologies) by scanning activities of universities, research institutes and industries in an outlook role (technology watch).

Moreover, future GARTEUR strategy aims to strengthen the longer term element of the research programme to ensure that synergy between civil and military R&T is maintained, and to include aviation security aspects as part of the research programme.

Last but not least, various actions with relation to the visibility of GARTEUR and communication with the players in the field of aeronautics have been undertaken and will remain to be a point of continued attention of the GARTEUR community. Among them, the successful submission of the proposal for nomination for the *ICAS Von Kármán Award for International Co-operation in Aeronautics 2004* deserves a special remark. The awarding of this prestigious prize should be regarded as a mark of honour to all those persons who contributed to the success of GARTEUR during the last 30 years of European collaboration in aeronautical research.

Acknowledgements

The work that is described here stretches over a long period. Co-operative research efforts, certainly in the advanced research part of the spectrum, do not easily attract large public attention. Still, the work performed under the GARTEUR umbrella has been instrumental in bringing European efforts in this domain forward.

GARTEUR is carried forward by the enthusiasm of the scientists and engineers for whom borders have been removed by the governments participating. This corresponds with Theodore von Kármán's vision that mankind can only progress thanks to young scientists and engineers finding each other over borders. He dedicated his life to the enhancement of understanding and co-operation among scientists of different nations.

In particular, the support to the workers in the Exploratory Groups and Action Groups is crucial in getting GARTEUR to work. Groups of Responsables, the Executive Committee and the Council do stimulate this collaboration at the level of Exploratory Groups and Action Groups. It is thanks to the efforts of all those involved in GARTEUR that this paper could be written.

Special thanks go to the staff who has wrestled with the text in a short timeframe in order to meet the deadline. Thanks are also due to ICAS who have recognised the GARTEUR work and awarded it the prestigious Von Kármán medal.

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