CHALLENGES IN EUROPEAN AEROSPACE
5TH CEAS AIR & SPACE CONFERENCE

OVERALL VIEW OF THE EUROPEAN COLLABORATION IN AERONAUTICS RESEARCH WITHIN GARTEUR

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ABSTRACT

This paper provides an overview of collaboration in aeronautics between European countries as continually stimulated by the *Group for Aeronautical Research and Technology in Europe* (GARTEUR) over the last forty years. The mission of GARTEUR, its organisation and principles, as well as its fields of activities are set out. The scope of scientific and technical research performed within GARTEUR is highlighted through examples of projects from the various topics covered by GARTEUR. Conclusions and perspectives for future cooperation are addressed.

1 INTRODUCTION

The *Group for Aeronautical Research and Technology in EURope* (GARTEUR) is the only framework for both civil and military R&T collaboration in the field of aeronautics in Europe. GARTEUR 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, human resources and facilities in aeronautical research and technology. Formed in 1973 by three nations, GARTEUR today involves seven nations with major research and test capabilities in aeronautics through a Memorandum of Understanding.

GARTEUR focuses on collaborative civilian, dual-use or defence research topics mainly aimed at long-term R&T that are essential to ensure sustained European Aeronautical Industry competitiveness. GARTEUR is considered as a unique European forum of aeronautical experts from Academia, Research Establishments and Industry mainly functioning in a bottom-up approach and according to the principle of an overall balance of benefits between the member countries.

As regards communication GARTEUR regularly presents its organisation, provides the latest achievements obtained through its activities and outlines its orientations [1] [2] [3] [4]. In 2004 GARTEUR received the ICAS Von Kármán Award for International Co-operation in Aeronautics "to honour all persons who contributed in the spirit of Theodore von Kármán's vision on cross-border co-operation among scientists and engineers" [5].

The main purposes of the paper are to:
- set out the missions and principles of GARTEUR and its way to carry out joint research work,
- present the GARTEUR organisation and the rules of cooperation of the various groups;

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- explain its position on the European aeronautical R&T scene and its interactions with other European actors like EREA (association of *European Research Establishments in Aeronautics*), EU and EDA programs and initiatives,
- review current activities in the field of "Aerodynamics", "Aviation Security", "Flight Mechanics, Systems & Integration", "Helicopters" and "Structures & Materials";
- provide examples of recent success stories.

Conclusions and indications on future GARTEUR activities and orientations are drawn at the end.

2 MISSION AND OBJECTIVES OF GARTEUR

The mission of GARTEUR is to mobilize, 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 purpose of strengthening collaboration between European countries with major research capabilities and government funded programs.

GARTEUR also aims at continuously stimulating achievements 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 at all levels of the organisation.

GARTEUR adopts the principle of operation that an overall balance of benefits between the member countries is pursued. However, the possibility of bilateral cooperation between member countries continues to exist. Another operating principle is that major decisions in the organisation have to be taken by unanimity of participating countries.
Participation of industry is sought at senior advisory level in both the planning and execution of programs. Organisations from non-GARTEUR countries can participate in specific research activities after a specific agreement.

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.

3 ORGANISATION

GARTEUR is organised at three main levels (Figure 1).

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

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representatives from national research establishments, industry and academia. Currently, five GoRs manage GARTEUR research activities:

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

Action Groups (AGs) compose 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 and through industry participation in the Action Groups.

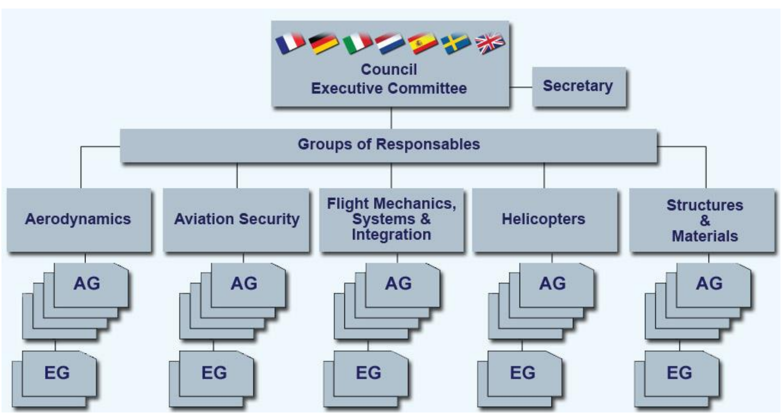

Figure 1: GARTEUR organisational diagram

4 GARTEUR AND THE INTERNATIONAL AERONAUTICAL R&T SCENE

As a unique forum of aeronautical experts from Academia, Research Establishments and Industry fostering research initiatives for the benefits of all the member countries, obviously the GARTEUR actions are aimed to support the European aeronautical community. Hence, GARTEUR directly or indirectly interacts with other entities or fora, such as the *European Union*, the *Association of European Research Establishments in Aeronautics* (EREA), the *European Defense Agency* (EDA), the *Advisory Council for Aviation Research and Innovation in Europe* (ACARE) and the core team of the EU funded *AirTN* projects, for which GARTEUR was the initiator. In particular the Air Transport Network, *AirTN NextGen*, a CSA (Coordination and Support Action) funded under FP7, creates a platform of networking and communication between regional, national and governmental organizations supporting research and innovation in the EU Member States and Associated Countries to the EU Framework Program in the field

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of Aviation. The aim is to stimulate transnational cooperation in the aviation field for RTD and innovation, research infrastructure related activities and education related activities.

Although GARTEUR is a European organisation, its actions are not limited to Europe. Representatives of GARTEUR Council and AG/EG participants are often involved in NATO groups and/or interact with their scientific community to contribute to the development of the knowledge in the aeronautic field. Indeed, the researchers are encouraged to publish their results in conference and scientific journals. Furthermore, a lot of AG projects are presented on the GARTEUR website [6] and a lot of final reports are available too.

5 REVIEW OF CURRENT WORKING GROUPS

Examples of recent, current or upcoming working groups in the field of Aerodynamics, Aviation Security, Flight Mechanics Systems & Integration, Helicopters and Structure & Materials are given in the following paragraphs. A review of studies is also presented on the GARTEUR website [6] or in GARTEUR Annual Reports [7].

5.1 Aerodynamics

The Group of Responsables for Aerodynamics (GoR AD) initiates and organises basic and applied research in aerodynamics, often coupled to other disciplines. Whilst in general term aerodynamics makes up the majority of the research done within the GoR, some of work has a significant amount of multi-disciplinary content such as aero-thermodynamics, aero-acoustics, aero-elasticity, aerodynamic shape optimization, aerodynamics coupled to flight mechanics and aerodynamic systems integration.

In general terms the work consists of both computational and experiment aspects with the emphasis on the provision of data to validate the computational approaches. In addition the experimental activity has resulted in improvement of measurement techniques, and further understanding of basic flow physics in a number of areas. Numerical studies sometimes give insight to the mechanisms of basic flow and in other cases are used to analyse integrated aerodynamic features of aerial vehicles.

Funding for GARTEUR activities is relatively small and in general, is insufficient to support entirely, new research. In most cases the GARTEUR AG activities are combined with activities funded through other routes, such as EU, STO (NATO Science and Technology Organisation), or National aeronautical research programs. Research initiated in GoR-AD programs sometimes leads to an EU proposals or compliment concurrent EU program content. Also the content of GoR AD can be cross sectorial in covering both Civil and Military interests.

As illustrated on Figure 2 activities carried out within GoR AD range from CFD computations of the flow around high lift devices [8] (Figure 2a) to the prediction of transition in hypersonic flows (Figure 2b). Other recent topics of interest are hybrid RANS/LES computations for a UAV Configuration (Figure 2c), fundamental experimental studies of intake design parameters (Figure 2d) and CFD assessment of the aerodynamic behaviours of two significantly different countermeasures: chaff and flares (Figures 2d and 2e).

To further illustrate the activities performed within GoR AD the purpose of Action Group AD/AG-45 ("Application of CFD to predict high "g" loads" [9]) consisted in CFD assessment activity of European state-of-the-art RANS suites to tackle the load envelope of a civilian aircraft. This Action Group focused on the high G loads encountered at high lift and high Mach number and also on the modelling of control

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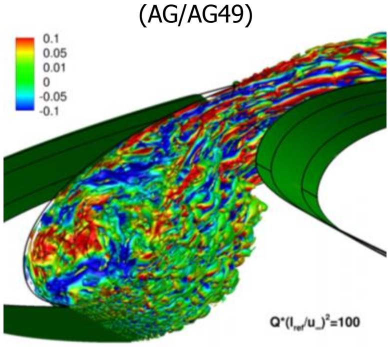
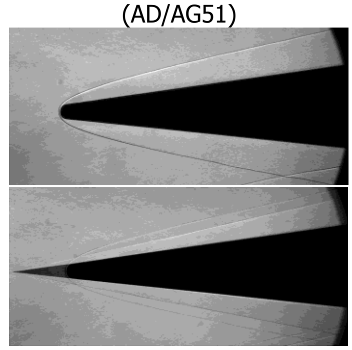
surfaces. The CFD exercises are backed up by the HiReTT half model experiments featuring a civilian aircraft wing in clean configuration and with control surfaces. Key aerodynamic issues occurring in high "g" conditions are the detached flows (on the wing and the control surfaces) and the effects of the wing flexibility. Modelling this flow physics requires the user to tackle the meshing of geometries with control devices, the turbulence modelling with detached flows and also the CFD-CSA coupling.

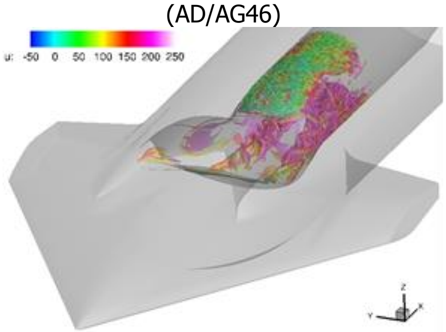
a) ZDES computation of a 3-element aerofoil (AG/AG49)



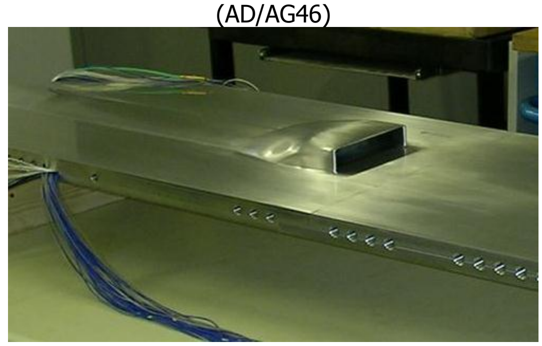
b) Transition in hypersonic flows for sharp and blunt cones (AD/AG51)



c) CFD computations for a UAV configuration (AD/AG46)



d) Experimental parametric study of intake design (AD/AG46)



e) Countermeasure aerodynamics - Use of flares to distract the enemy radar (AD/AG55)

f) Countermeasure aerodynamics - Simulation of chaff concentration transport (AD/AG55)

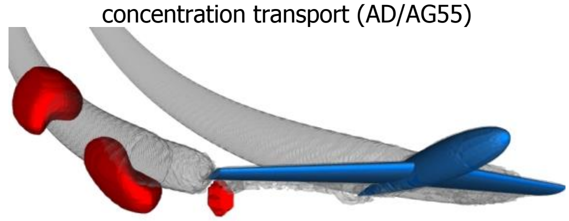


Figure 2: Illustrations for the GoR Aerodynamics

Other examples of activities covered by GoR AD are Action Groups concerning highly integrated subsonic air intakes [2] [10] [11] [12] [13] [14] [15]. The major objective of GARTEUR Action Group AD/AG-46 "Highly Integrated Subsonic Air Intakes" was to apply DES methods at the forefront of innovative subsonic intake design and to evaluate their capabilities to accurately simulate unsteady internal flow fields (Figure 2c). A comprehensive set of experimental data for highly integrated subsonic air intakes had been identified to validate unsteady numerical simulations in this field of research. Further areas of

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research within AD/AG-46 were computational predictions and experimental studies of dynamic intake distortion in complex flow fields due to S-shaped compactness of intake integration, flow separation effects due to challenging intake entry design, intake entry shaping, intake internal flow control, as well as boundary layer control and diversion for diverterless intakes.

5.2 Aviation Security

Security has become a key issue in aeronautics in view of the increasing number of threats against aviation security in the last few decades. In particular the *International Civil Aviation Organisation* (ICAO), the *International Air Transport Association* (IATA) and the *European Commission* (EC) have made efforts to avert upcoming danger to civil and commercial aviation. For this reason and regarding the EU requirements of the Challenge 4 "Ensuring safety and security" established by ACARE [16] the GARTEUR Council launched a specific Group of Responsables in the field of "Aviation Security" in March 2014. In the aeronautic community the development of autonomous vehicles and related technologies as well as the growth of cybersecurity technologies are becoming increasingly important topics [16]. For this reason a Group of Responsables on Aviation Security (GoR AS) was created in March 2014. The GoR AS pursues to do research in the Aviation Security field dealing with both military and civil R&T.

Four major R&T domains, illustrated on the logo of the Aviation Security GoR (Figure 3), have been identified by the Group of Responsables:

- Cybersecurity:

Airspace operators (both commercial and military) wish to make use of new communications capabilities to support their missions, develop new cost efficient operations and maintenance procedures, and offer new revenue producing services. These intentions can only be realised by moving more information on and off the aircraft on a regular basis. The latest aircraft therefore rely on interconnected systems which extend off the aircraft to ground-based systems run by airlines, airports and Aviation Service providers of various types. With the continual and rapid integration of new technologies, the aviation industry keeps expanding, changing, and becoming increasingly connected.
The introduction of new technologies and interconnection of systems also introduce new vulnerabilities. Without the appropriate cyber-security measures in place, the air transport system may be at risk. More attention is therefore due to this complex problem.

- CBE (Chemical, Biological and Explosive) detection:

Both, the criminal and the accidental release of chemical, biological and explosive (CBE) substances represent a threat to civil security, especially at public places like airports. Laser based standoff methods offer promising possibilities for early detection and identification of hazardous CBE substances at a distance. People and luggage can be screened nearly instantaneously in a harmless way without any further disturbance of the passengers and by maintaining their integrity. In case of crisis management discrete and reliable detection methods allow for an immediate initiating of counter measures and thereby reduce the threat for people in general and first responders in particular.

- Dazzling:

Recent events have shown that laser can be used to dazzle persons or optronic systems. In order to protect pilots from such attacks, laser radiation present on an aircraft has to be detected and to be reported to the pilots to make them aware of the threat and to prepare protection measures.

- Malevolent use of RPAS:

Remotely Piloted Aircraft Systems and/or Unmanned Aerial Systems (RPAS/UAS) are expected to become a reality in the airspace within the coming years thanks to their (imminent) integration into non

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segregated airspace (thanks, among others, to EU roadmap). This will open the airspace not only to security applications but also to a wide number of particular, private, leisure and commercial ones.
Many small and low cost systems (some hundred Euros) such as autonomous model aircraft or micro/mini RPAS/UAS are currently being flown in cities and/or in open environments and will exponentially thrive within this context. Recent events have shown malevolent use of RPAS. So, more effort in prevention has to be done to ensure the protection of aviation activities regarding this threat.

The current work of this newly created GoR on Aviation Security is to define Exploratory Groups for each of these R&T domains and subsequently to come up with proposals for Action Groups, as usually done in the other GoRs.
On the other hand a position paper of the GARTEUR community on the Aviation Security topic is expected in the second half of 2015.

Figure 3: Illustrations for the GoR Aviation Security

5.3 Flight Mechanics, Systems and Integration

The Group of Responsables for Flight Mechanics, Systems and Integration (GoR FM) is active in the field of flight systems technology in general.
The GoR-FM is responsible for all research and development subjects concerning a chain starting from the air vehicles and their flight mechanics, concerning embedded sensors, actuators, systems and information technology, cockpits, ground control and human integration issues, with reference to automation for both inhabited and uninhabited aircraft. This GoR is in charge of subjects concerning flight guidance, air traffic control, integration of remotely piloted systems in the air spaces, sensor technology and systems, and human factors (Figure 4).

An example of activities covered by GoR FM concerns the current demand of increasing autonomy in multiple Unmanned Air Vehicles [18] (FM/AG-18). The wider use of UAVs for Military, Civilian and Commercial applications is dependent on obtaining the optimum partnership between the human supervisor and the system. Communications between the supervisor and the system should be reduced as far as possible and be at high levels of abstraction with the majority of activity carried out with a minimum of human intervention. Given adequate autonomy, communications between the human supervisor and the vehicle can be minimised being necessary only where critical decisions are required. Moreover, it is clear that the more challenging applications with only a small number of human supervisors available to operate more than one UAV will create a distributed control problem. Work carried out by the GARTEUR nations has led to the conclusion that unprecedented autonomy levels will be required and world-wide research in the area is very active examining a range of methods for achieving autonomy. Since it is difficult to identify where investment is needed to rapidly mature the most promising contenders, the Action Group FM/AG-18 was designed to aid this process and the aim of the

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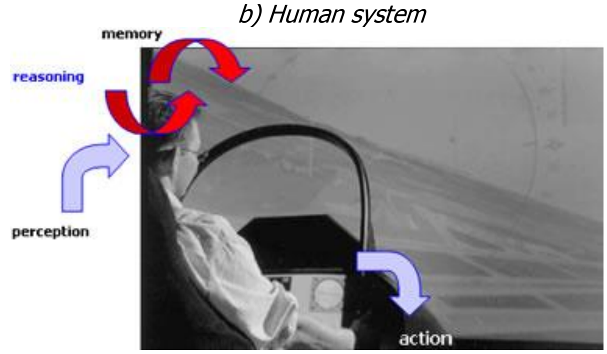
work was the collection, implementation and systematic categorisation of machine based reasoning and artificial cognition approaches applicable to facilitate co-operation between UAVs and other assets with reduced human intervention. Those other assets include other UAVs, manned assets and human operators performing supervisory control.

The GoR FM is also interested in flexible aircraft modeling methodologies (FM/AG-19, Figure 4e). The aim of this AG was to define a way of working for the integrated modelling activities, in order to generate an integrated aerodynamic and aeroelastic model to be used in the flight control laws design of advanced flight control system.

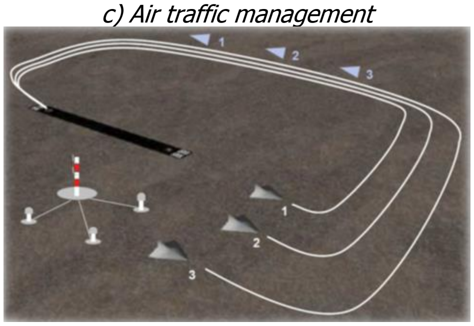
Concerning future activities in the GoR for Flight Mechanics, Systems and Integration, two Exploratory Groups, resulting from conclusions of European projects, have been initiated. The first one concerns a "Non-linear flexible civil aircraft control methods evaluation benchmark" (FM/EG-28), whereas the second one concerns the "Trajectory Verification & Validation Methods: formal, automatic control and geometric methods" (FM/EG-29) and is related to the EDA/EREA project E4U (EREA for UAS).

a) Flight desk

b) Human system



c) Air traffic management



d) ONERA SV4 vertical wind tunnel and associated dynamic simulation test benches

e) Flexible Aircraft Modeling Methodologies (FM/AG-19)

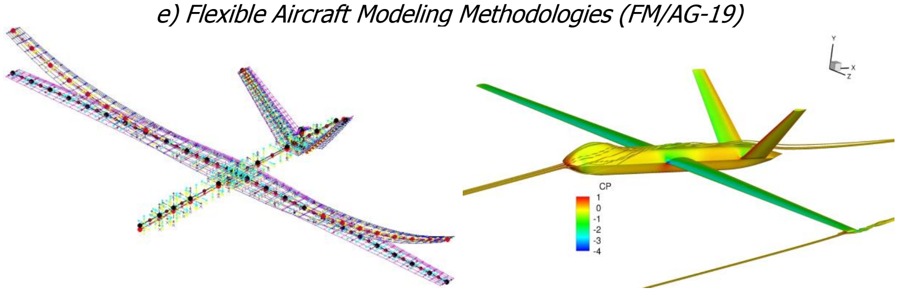


Figure 4: Illustrations for the GoR Flight Mechanics, Systems and Integration

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5.4 Helicopters

The Group of Responsables for Helicopters (GoR HC) initiates, organises and monitors basic and applied, computational and experimental multidisciplinary research in relation with rotorcraft (helicopters and tilt rotor aircraft) vehicles and systems technology (Figure 5).

The field for exploration, analysis and defining requirements is wide. It covers knowledge of basic phenomena of the whole rotorcraft platform in order to:

- Decrease costs (development and operation) through CFD and comprehensive calculation tools, validated with relevant tests campaigns;
- Increase operational efficiency (speed, range, payload, all weather capability, highly efficient engines...);
- Increase security and safety (crashworthiness, ballistic protection…);
- Tackle environmental issues (emissions, noise);
- Integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations);
- Progress in pioneering: breakthrough capabilities.

Technical disciplines include, but are not limited to, aerodynamics, aeroelastics including stability, structural dynamics and vibration, flight mechanics, control and handling qualities, vehicle design synthesis and optimisation, crew station and human factors, internal and external acoustics and environmental impact, flight testing, and simulation techniques and facilities for ground-based testing and simulation specific to rotorcraft.
A characteristic of helicopter and tilt rotor matters is the need for a multidisciplinary approach due to the high level of interaction between the various technical disciplines for tackling the various issues for rotorcraft improvement.
The GoR HC, wherever practicable, informs, seeks specialist advice and participation where appropriate, and interacts with activities in other GARTEUR Groups of Responsables.

Figure 5: Illustrations for the GoR Helicopters

The members of GoR for Helicopters represent the major national research centres and helicopter manufacturers in the European Union involved in civilian and military rotorcraft related research. The membership enables the GoR to act as a highly effective forum in its primary function of promoting collaborative research through Exploratory Groups and Action Groups. It has been successful in setting up collaborative research programs to the benefit of the European rotorcraft community, including both governmental and industrial interests.

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A particular area of success has been the development and validation of modelling capabilities for rotor aeromechanics, for rotorcraft flight mechanics and simulation, for vibration prediction and management and crashworthiness. This modelling capability has underpinned improvements across the field of rotorcraft performance, enhancing both military and civilian market competitiveness, as well as safety for all users.

An example of GoR HC activities is the HC/AG-17 which concerned helicopter wakes models in the presence of ground obstacles [20] [21] [22] (Figure 6). It is well known that the wake trailed from the blades of a rotor has a significant influence on many aspects of the performance and dynamics of a rotorcraft. At low forward speeds, the wake released by one blade travels close to the incoming blades. This can lead to high levels of vibration and an uncomfortable flight, as well as noise. At high speeds, blade/wake interactions can exacerbate the problems with aerodynamic stall and compressibility. The work performed within HC/AG-17 addressed the interaction between the wake dynamics and ground obstacles, such as the ground itself, buildings or super-structures that are close enough to the helicopter to affect the flow recirculation. The core objectives of the Action Group were to review the current status of methods of modelling wake interaction with ground obstacles, and, if necessary to identify the feasibility of modifying existing methods to allow wake/ground obstacles to be modelled. Other objectives were to examine and identify existing databases for the purposes of validation, and to perform a series of experimental investigations for data gathering allowing each partner organisation to correlate and improve the respective analytical models. Results were published during two ERF conferences [21] [22].

a) Multi-vortex rings rotor model *b) Rotor assembly for wind tunnel tests (Glasgow Univ.)*

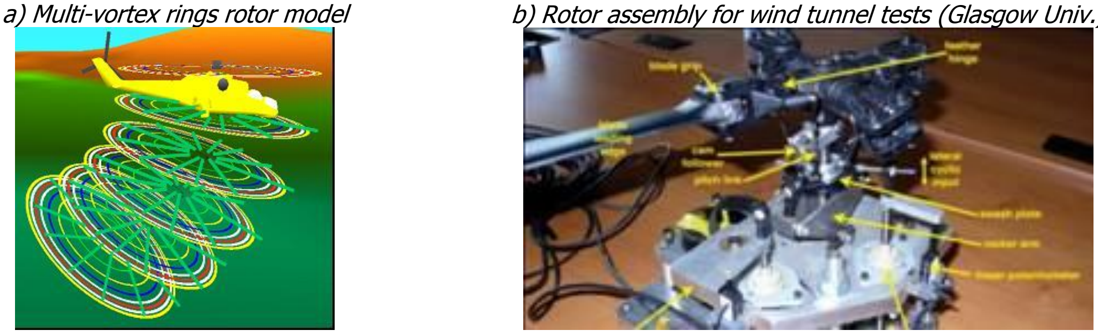

Figure 6: Illustrations for the HC/AG-17 on Helicopter Rotor Wakes in Presence of Ground Obstacles

Another example of GoR HC activities is the Action Group on "Methods for Improvement of Structural Dynamic Finite Element Models using In-flight Test Data" (HC/AG-19) [23] (Figure 7). The main purpose of this AG was to explore methods and procedures for improving Finite Element Models (FEM) through the use of in-flight dynamic data. Indeed for the foreseeable future it is expected that validated FEM will be the major tool for improving the dynamic characteristics of the helicopter structural design. It is therefore of great importance that the procedure of validating and updating FEM with such in-flight data is robust, rigorous and effective in delivering the best finite element model. The working group has assessed the methodology with respect to evaluating vibration measurements from flight tests where effects of aerodynamic and rotating machinery affect the vehicle response.

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Figure 7: Illustrations for the HC/AG-19 on Improvement of Structural Dynamic FEM using In-flight Test Data

An example of current studies concerns HC/AG-20 "Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction". Activities of this Action Group are to apply different types of simulation methods to design and optimize composite trim panels, to validate numerical approaches by tests, to apply different types of experimental techniques to characterize composite trim panel acoustic radiating in both a standardized test set-up and a generic helicopter cabin, and to develop test procedures to separate correlated and uncorrelated acoustic sources in cabin.

5.5 Structures and Material

Structural and material research in aeronautics strives to reduce structural weight, improve safety and reliability, keep operation cost low, reduce environmental impact and improve passenger comfort. In many cases the research tasks are strongly interconnected so that an optimum design can only be reached through balanced improvements in all fields. The Group of Responsables for Structures and Material (GoR SM) is active in initiating and organising aeronautics oriented research on structures, structural dynamics, acoustics and materials in general. Materials oriented research is related to material systems primarily for the airframe but also for the landing gear and the engines; it includes specific aspects of polymers, metals and various composite systems. Structural research is devoted to computational mechanics, loads and design methodology. Research on structural dynamics involves vibrations, response to shock and impact loading, aeroelasticity, acoustic response and adaptive vibration suppression.

The activities within the Action Groups of the GoR SM cover several aspects of new technologies, new structural concepts and new design and verification criteria. Recent and current work is devoted to high velocity impact, damage management of composite structures for cost effective life extensive service, damage growth in composites. Topics of interest also include fatigue and damage tolerance assessment of hybrid structures, damage repair in composite and metal structures, and sizing of aircraft structures subjected to dynamic loading.

The activities on high velocity impact are aimed to the increase of safety of aircraft structures and to the reduction of design and certification costs by improving numerical approaches for simulation of bird strike on pre-stressed structures and by predicting damage caused by impact from foreign objects (Figure 8). Emphasis is put on novel/hybrid materials and structures with complex geometries.

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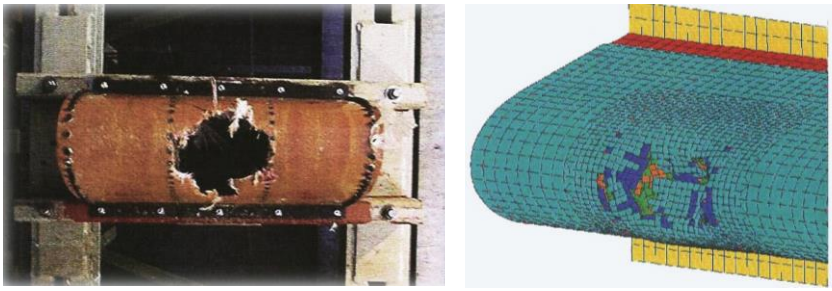

Figure 8: Illustrations for the GoR Structures and Materials on computational modelling of bird strike and experimental validation, from SM/AG-24 on "Bird strikes"

As an example of the recent studies carried out within GoR SM the Action Group SM/AG32 dedicated to the "Damage Growth in Composites" [24] was based on the emerging needs related to the composites usage in aerospace applications. The main objective of this AG was the development of integrated numerical and experimental methodologies capable to take into account the presence of damage and its evolution in composite structures from the early phases of design up to the detailed FEM analysis and verification phase. Results expected from these integrated methodologies are the improvement of composite components performances by optimising the weight according to damage tolerant design philosophies and the enhancement of the allowables by modifying the safety concepts and criteria thus decreasing or removing the safety factors related to the presence of damage.

Another example of the current studies carried out within GoR SM is the Action Group SM/AG34 dedicated to "Damage Repair with Composites" [25]. The raison for this study is that the structure of aircraft in service will obtain various types of damage e.g. from impact loading. It is therefore important to have effective repair methods. Damages caused by impact are generally much more severe in composite structures than in metals structures. The main objective of this AG based on emerging needs related to the composites usage in aerospace applications is the definition of effective repair techniques both for civilian and military aircraft structures through the development of numerical and experimental methodologies. This objective addresses the following issues: repair criteria, design of patches and repair strategies, analysis of the repair, manufacturing and test, repair strategies and technology, effective repair methods (Figure 9).

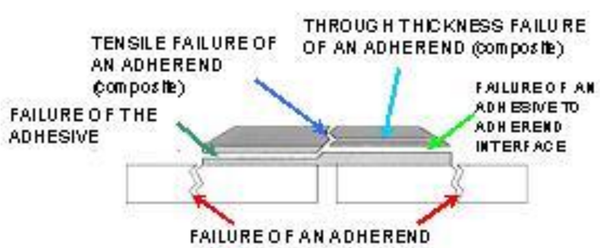

Figure 9: Failure modes in adhesively bonded repair to be analysed within SM/AG32

A major challenge in the fatigue analysis and subsequent fatigue testing of hybrid structures originates from the differences in deriving fatigue spectra for metal and composites and incorporation of required environmental load factors for composites. For example elimination of peak loads in the spectrum for metals is conservative as crack retardation is prevented whereas for composites this is not conservative. An example of GoR SM activities is the SM/AG-35 which concerned "Fatigue and damage tolerance

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assessment of hybrid structures". This Action Group should result in establishing a joint "best practice" approach for full scale testing of hybrid airframe structural components.

New topics of interest have been discussed in the GoR SM. Specific topics such as "Bonded and bolted joints" and "Additive Layer Manufacturing" have been considered as possible future Actions Groups.

Although specific topics of GoR SM vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas on future activities. In several cases the results of the collaboration have led to research proposals which have been submitted successfully to the EC to be granted by the Framework Programmes and to EDA to be granted by MoD's. Furthermore, some collaborations have formed the basis of relevant national programmes. Besides strengthening links between EREA members, the collaborative research programme satisfies a primary industry requirement and for this reason participation of industry in AGs is particularly valuable.

6 EXAMPLES OF SUCCESS STORIES

The joint European knowledge in Aerodynamics, Flight Mechanics, Helicopters, and Structures & Materials has largely been built up over the past decades through national efforts coordinated via GARTEUR Action Groups [5]. This statement is clearly pointed out by strong links between GARTEUR AGs/EGs and European projects since the early 1990's as illustrated in the following examples in Aerodynamics, Flight Mechanics, Helicopters as well as Structures and Materials.

Aerodynamics
Numbers of EU-projects are quoted as important contributors to the wing design on modern European aircraft types such as Airbus A380 and Dassault Falcon 7X. GARTEUR activities on High Lift Aerodynamics were carried out within six Action Groups from 1981 to 2014 with participation of Research Establishments and industries. The joint European knowledge in High Lift Aerodynamics, applied on modern European aircraft types, has been built up over the past decades through national efforts coordinated via GARTEUR Action Groups and continued in European projects funded via Framework Programmes (EUROLIFT I & II, DESIREH, SADE, ATAAC and GO4HYBRID projects) and through Clean Sky JTI-SFWA/GRA. This illustrates coordinated efforts between GARTEUR nations, strong connections between GARTEUR and EU activities, long time scales from basic research to application and the impact of lower TRL research on future projects.
Furthermore, the European knowledge in Missile Aerodynamics, and especially in numerical simulation, is developed presently with the support of three recent GARTEUR groups [26] [27] [28] for the development of Meteor which is the new generation Beyond Visual Range Air-to-Air Missile system that will revolutionize air-to-air combat in the 21st century. It can be noticed that there is no other organisation in Europe where such a collective effort is done for the specific topics of Missile Aerodynamics.
Additionally the aerodynamic integration of intakes into the airframe of UAVs assuring high performance and minimized aerodynamic drag is of vital importance for innovative vehicle configurations. Several GARTEUR Action Groups have addressed research areas within the field of intake aerodynamics [10] [11] [12] [29] with enhanced emphasis on dynamics simulations of internal flow fields applying hybrid RANS/LES methods [30]. They essentially contributed to prepare the groundwork for engine/intake compatibility assessment with accuracy levels meeting industrial demands. Mid-term prospects for fulfilling these requirements and for successfully applying these methods for project oriented work are considered most promising.

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Flight Mechanics

The analysis of the recent activities points out that the EDA project NICE (Nonlinear Innovative Control designs and Evaluation, 2010-2012) was supported in a first time by the FM/AG17 (Nonlinear Analysis and Synthesis Techniques for Aircraft Control). The outputs of this EDA project are currently assessed in an exploratory group (FM/EG28) on the topic "Non-linear Control Aircraft benchmark".
In the civilian domain, the AG activities on "Fault Tolerant Control" are the basis of the currently EU-FP7 project RECONFIGURE (Reconfiguration of aircraft systems for safety & upset recovery, 2013-2015).

Helicopters

The links between EU projects and GARTEUR HC/AGs exists from the early 1990's. During the FP7 period, the HC/AG16 (Rigid body and aeroelastic rotorcraft-pilot-coupling – predictions tools and means of prevention) achieved to improve the physical understanding of both rigid body and aero elastic Rotorcraft Pilot Coupling (RPC) by developing procedures and validating appropriate prediction methods during simulator experiments. Guidelines and criteria have been defined to prevent or suppress critical RPC incidents in the future. The results of this work have been successfully published in 27 scientific papers and were used in the EU-FP7 project ARISTOTEL on "Aircraft and Rotorcraft Pilot Couplings / Tools and Techniques for Alleviation and Detection", which is just finished.

Structures and Materials

The pioneering research activities on damage mechanics, damage tolerance and bolted joints in composites started within GARTEUR and were later followed by more application oriented projects within EU FP4 and FP5 as well as within WEAG (Western European Armament Group – predecessor of EDA). The activities of the European projects DAMOCLES were pursued in the SM/AG31 on the damage management of composite structures. All the activities are conducted at a low TRL and it can be noticed that there is no other organisation in Europe where such a collective effort is done for this topic.

7 CONCLUSIONS AND FUTURE PROJECTS

GARTEUR is a multinational organisation that performs high quality, collaborative, pre-competitive research in the field of aeronautics by research establishments, industry and academia. It offers the only framework in Europe to bring civilian and military R&T together and therefore delivers added value through the operation of jointly supported research programs in line with the programs conducted in other European frameworks.

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. For that reason, it is essential to preserve the close relations with industry in civilian and defence environments and consequently the enhancement of industrial participation at GoR level is always encouraged.

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. For this reason and regarding the EU requirements of the Challenge 4 "Ensuring safety and security" [16] established by ACARE, the GARTEUR Council launched a specific Group of Responsables in the field of "Aviation Security" in March 2014. Tasks concerning Remotely Piloted Aircraft Systems and Cybersecurity are suggested among identified actions. Furthermore a position paper of the GARTEUR community on this topic is expected in the second half of 2015.

Moreover, future GARTEUR strategy aims to strengthen the longer term element of the research programme to ensure that synergy between civilian and military R&T is maintained.

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