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THE GROUP OF RESPONSABLES "ROTORCRAFT (RC-GOR)": AN OVERVIEW OF ACTIVITIES AND SUCCESS STORIES

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Abstract

The paper provides an overview of the activities carried out by the GARTEUR Group of Responsables dedicated to Rotorcraft configurations. Unlike the other GoRs, which are all dedicated to disciplines, this GoR is related to the rotorcraft platform and an overview of it is described in the paper. Some historical highlights are provided, which show evidence of some of the successful events in the more than forty years of activities of this GoR.

Keywords: GARTEUR, Rotorcraft, Group of Responsables, Historical review

1. Introduction

The *Group for Aeronautical Research and Technology in EURope* – GARTEUR was created in 1973 by France, Germany and United Kingdom. The Netherlands joined the group in 1977 and in 1981 this membership was formally institutionalized by the signature of a Memorandum of Understanding among the governments of the participating nations. The current membership of seven countries was gradually reached in the next decade: in 1991 it was the turn of Sweden, followed in 1996 by Spain and finally by Italy in 2000.

The objectives of GARTEUR are many. It mainly aims at strengthening the collaboration between European nations with major aeronautic capabilities and industry, for both civil and military applications, to increase the competitiveness of European industry. GARTEUR acts to extract the best long-term innovative Research & Technology from upstream research and pull it through for applications in industry. It also aims at providing a platform and network for scientists to pool technology and knowledge to develop ideas and concepts in various aeronautics areas. Based on this, GARTEUR aims at initiating proofs of concept and demonstrations through GARTEUR and other fora such as Framework programmes of the EU for final application by industry.

GARTEUR is organized as a three-level structure [1] which is shown in Figure 1. The first level is represented by the Council which is composed of representatives of each member country who constitute the national delegations. These representatives come from Ministries and Research Establishments. An Executive Committee (XC) and a GARTEUR Secretary assist the Council. The XC is composed of one member from each national delegation. The second level is formed by the Groups of Responsables (GoR) that act as scientific management bodies. The GoRs are composed of representatives from national research establishments, industry and academia.

GARTEUR research activities are currently managed by five GoRs in the fields of Aerodynamics (AD); Aviation Security (AS); Flight Mechanics (FM), Rotorcraft (RC), and Structures and Materials (SM). The third level is represented by the Action Groups (AGs). 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 GoRs and investigated for collaboration feasibility by Exploratory Groups (EGs). If an Exploratory Group establishes an agreed proposal, an Action Group (AG) is launched. A GARTEUR AG needs participation from at least three GARTEUR countries and has a typical duration in time of three years.

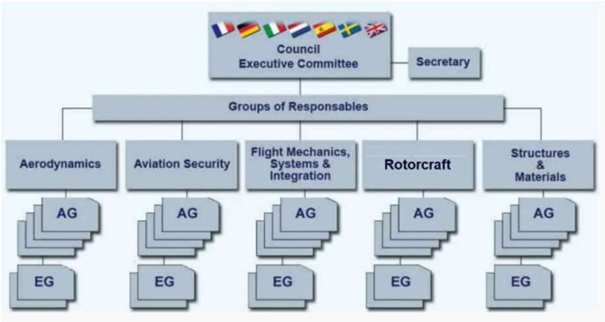

Figure 1 –GARTEUR organization structure [1]

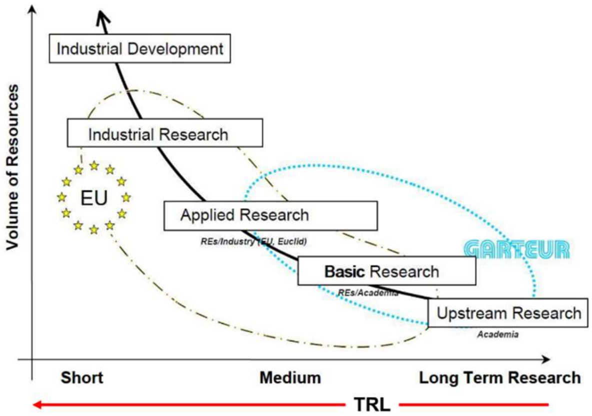

Figure 2 –GARTEUR's perimeter of activities

The activities promoted by GARTEUR span from the upstream to applied medium to long-term research, characterized by a low Technology Readiness Level (TRL) from 1 to 3, Figure 2, and are self-funded by the participating organizations. Although this aspect might represent a deterrent condition for the participation in the AG projects, it is however worth highlighting that in many circumstances this is an extremely important step toward the creation of the necessary expertise which is then spent in funded projects. Indeed, GARTEUR does not contrast other funded initiatives but, rather, helps putting the basis for a fruitful participation in them. As such, GARTEUR can also have the important educational aspect to prepare young researchers before entering the competitive world of the operative work. A demonstration of this statement is the large numbers of scientific publications, Master and PhD theses which relate to activities carried out in GARTEUR.

The present paper focuses on the description of the main characteristics of the Rotorcraft GoR (RC-GoR), its objectives and future trends. Section 2 explains why the activities of the RC-GoR are platform-related rather than discipline-related like all the GoRs. Section 3 describes the structure and the management aspects of the RC-GoR, while section 4 illustrates its main objectives. Some historical highlights are provided in section 5, and section 6 illustrates what the future holds. Some conclusions are described at the end of the paper.

2. Why a GoR dedicated to rotorcraft?

Unlike all the other GoRs, which concentrate their investigations to monodisciplinary topics, the RC-GoR promotes multidisciplinary research activities that are platform-based. In particular, it concentrates the research efforts on the rotary-wing aircraft, known as rotorcraft. The reason for it lies in the need to tackle with technological and operational problems of this category of aircraft which require specific competences in the rotary-wing field for their investigation. To help understand these peculiarities, a brief description of what a rotorcraft is and how it works is provided.

A rotorcraft is an aircraft that generates the lifting, propulsive and control forces by the rotation of a set of aerodynamics surfaces, named blades, around a shaft. This set of blades, together with all the connections (hinges) to the shaft and the various mechanical linkages, takes the name of rotor, a complex but fundamental component of a rotorcraft. Thanks to this peculiarity, a rotorcraft, unlike the fixed-wing aircraft, does not need a translational velocity to fly and is capable of many flight operations that are almost precluded to or inefficiently performed by fixed-wing aircraft, such as pure vertical take-off and landing, hovering flight, and, more generally, to operate in confined areas, in the proximity to the ground and obstacles man-made or natural. These unique capabilities allow the helicopters to be employed in several operations and missions for civil and military applications such as: emergency medical services, rescue operations, patrolling, firefighting, law enforcement operations, commuting flight toward oil & gas platforms, ship landings, large wind turbine maintenance operation, VIP and governmental authorities transportation. In addition, with recent transportation trends - specifically, entrusted to multirotor configurations - air taxis and package/parcel services in urban and/or rural areas.

However, all these peculiarities do not come without a cost. Actually, just because of these outstanding capabilities, the rotorcraft is an extremely complex machine: it is hard to study, theoretically and experimentally; it is hard to manufacture and to pilot; it is noisy and relatively slow; it is expensive; it poses serious safety aspects to be carefully addressed, and certification issues, especially when referring to the new eVTOL configurations. A characteristic of rotorcraft design 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.

Despite that the basic flight physics are the same for both fixed- and rotary-wing aircraft, there are several phenomenological and technological aspects that are present in a rotorcraft which may be of moderate importance, or even absent, in an aeroplane. The aerodynamics of a rotorcraft is always unsteady and the simplifying assumption of steady flow can seldom be made. This unsteadiness produces phenomena which do not exist or have limited importance in the fixed-wing configurations, such as the dissymmetry of lift, the dynamic stall or even the reverse flow on some parts of the rotor blades. The aerodynamics is always interactional: the wake generated by the rotors resides in the proximity to the aircraft, thus generating unsteady loads and altering the performance characteristics of the various components of the vehicle, Figure 3.

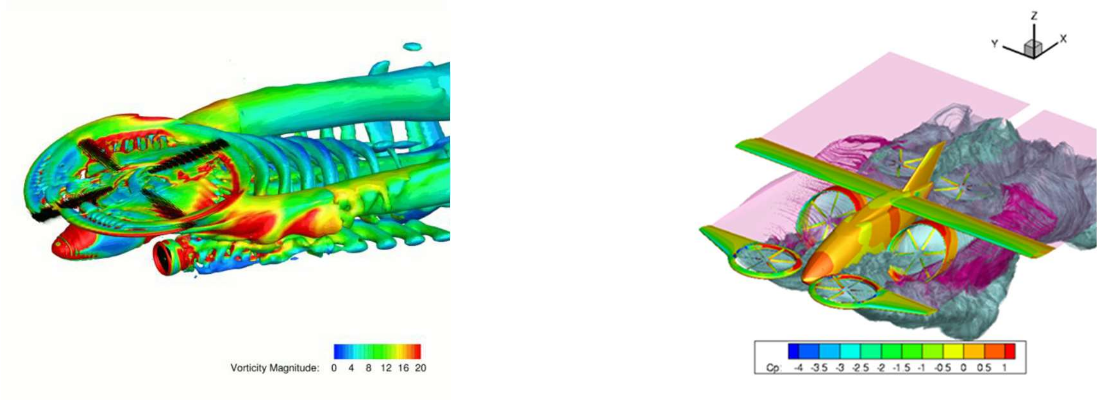

Figure 3 – The complex wake systems generated by a compound helicopter (left - Univ. Glasgow) and by a multirotor configuration (right – CIRA). Numerical simulations

Even when a “simple” monodisciplinary aerodynamic investigation is required on an isolated rotor, it cannot disregard the so-called trim conditions, i.e. the amount of blade pitch control and the resulting blade flapping and lead-lag displacements, and the rotor disk attitude, which define an equilibrium condition of the rotor, and which are provided by structural dynamics/flight mechanics calculations. The fuselage, even in the most streamlined shape, and the rotor hub can generate highly separated flows that must be suitably accounted for and modelled (on some helicopters the main rotor, including the hub, and the fuselage are responsible for almost 70% of the total drag of the entire aircraft). The unsteady aerodynamic loads are transmitted to the whole aircraft thus generating strong aeroelastic issues, mainly to the blades, and vibratory loads which penalize passengers’ comfort and stress not only the structures but also the pilot, increasing their workload. The unsteady aerodynamic loads also generate noise. It is well known that helicopters are noisy, and this is an aspect that can hamper its acceptance by the civil and military community. Unlike fixed-wing aircraft, the most annoying component of noise is the low-frequency tonal one produced by the main rotor. Broadband noise, which is an important component of the noise generated by an aeroplane, has a secondary importance on the classical helicopter configuration. However, recent investigations show that for multirotor eVTOL configurations the broadband component is also equally important. The GNC characteristics are complex. As a rotorcraft is inherently statically or dynamically unstable, particularly in hover, the operations accomplished by a rotorcraft need a specific pilot involvement (pilot in the loop) who is continuously required to provide the feedback control to stabilize the aircraft. This leads to a large amount of pilot workload and may require the design and integration of a stability augmentation system to help stabilize the rotorcraft. Emergency landing maneuvers, such as an autorotation, must be able to completed safely by the pilot and are an important safety design issues that are not present on a fixed-wing aircraft and also pose important certification challenges.

The numerical simulations of rotary-wing components and configurations are much more demanding than those carried out on fixed-wing geometries. Limiting the description to the aerodynamic simulations, the reasons are basically twofold: on the one hand the numerical schemes, the turbulence models, the mesh generation techniques that are well suited for the fixed-wing aerodynamics may be insufficient or inadequate when applied to rotary-wing geometries. A simple example is constituted by the requirement to model rotating geometries in a non-inertial frame of reference, which requires the need to generate dynamic meshes or to account for the centrifugal and Coriolis effects in the turbulence models and in the numerical schemes. On the other hand, the recent interests of fixed-wing aerodynamicists are more addressed to methodologies of a degree of sophistication and complexity, such as the application of LES or even DNS methods, which are currently beyond the capabilities of rotary-wing solvers, because of the higher phenomenological complexity of the rotary-wing to be simulated.

Experimental activity on rotary-wing configurations is extremely demanding because complex and expensive wind tunnel models (see Figure 5) composed of fixed and rotating parts must be designed and manufactured. In addition, measurement techniques require suitable instrumentation to be installed on the rotating blades, and systems for the transmission of the acquired measurement.

Figure 4 – The complex, densely instrumented tilt-rotor model manufactured by NLR (left); its installation in the ONERA S1MA wind tunnel (right). NICETRIP project [2].

Rotorcraft are slow aircraft because of phenomenological limitations (dynamic stall on the retreating blade region and compressibility effects on the advancing blade region of the main rotor) that make the achievement of a forward flight velocity comparable to fixed-wing aircraft impossible. They also operate at a relatively low altitude making them particularly vulnerable to atmospheric agents (snow, ice, rain, gusty winds). The (partial) solution to the problem is offered by different rotary-wing configurations such as tilt-rotors, compound helicopters and co-axial rotor helicopters. However, all these configurations present additional issues to those above illustrated for the helicopters. They refer to the complexity of the rotor+wing aerodynamics, noise, controllability and tilting mechanism for the tilt-rotor; to the rotor-wing interactional aerodynamics and controllability for compound helicopters; to the issues of rotor hub drag and mechanical complexity increase because of the mutual proximity of the coaxial rotors.

All these aspects, and many more, require the involvement of teams of rotary-wing experts with skills created during years of education and working on rotorcraft topics.

Finally, it is also worth highlighting that the above described main characteristics of rotorcraft are such that this category of vehicles cannot be employed for very-long range flights nor for volume of passengers typical of the airplane commercial flights. For this reason, the rotorcraft market is much smaller than that of the fixed-wing one (in 2021, the global helicopter market was USD 45.21 billion worth vs the USD 128.31 billion of the global commercial aircraft market). As a matter of fact, the rotorcraft R&D community, especially the European one, is rather small with lower resources with respect to the fixed-wing world.

3. Structure and management of the Rotorcraft GoR

The membership of the RC-GoR sees the participation of the European countries hosting a rotorcraft industry: France, Germany, Italy and United Kingdom, plus the participation of The Netherlands. The members are representative of industries, research centres, universities and governmental agencies. The chairmanship is rotating and is held by each member for two years. Usually, the vice chairman takes over the role of chairman at the end of the two years. The updated list of the RC GoR is illustrated in Table 1. Mr. Antonio Visingardi of CIRA (I) is the chairman currently in charge (July 1st, 2021 until June 30th, 2023). Vice chairman is Prof. Mark White of the University of Liverpool (UK).

Chairman		
Antonio Visingardi	CIRA	Italy
Vice-Chairman		
Mark White	Univ. Liverpool	United Kingdom
Members		
Rainer Heger	Airbus Helicopters (D & F)	Germany
Klausdieter Pahlke	DLR	Germany
Barbara Ohlenforst	NLR	The Netherlands
Arnaud Le Pape	ONERA	France
Observer		
Richard Markiewicz	DSTL	United Kingdom

Table 1 – The RC GoR membership

Generally speaking the rotorcraft community in Europe is rather small. In fact, most RC-GoR members are at the same time deeply involved in the preparation of proposals for EU projects so that automatically there are close relations between GARTEUR research activities and EU projects.

In the Clean Sky 2 Joint Technology Initiative and especially for Fast Rotorcraft IADP, the RC-GoR members were active in Calls for Proposals. In the view of the RC-GoR, this aspect is advantageous for all, GARTEUR and EU, industry and research establishments. In practice, the EGs are used both for the generation of proposals for continued GARTEUR activity within an AG, normally at a relatively low level of effort, to analyse the state of the art for new topics, and to define the framework and specification of further common research programmes, including EU proposals. In general, these activities are complementary, with some EU projects based on earlier GARTEUR research, and GARTEUR AG benefitting from the outcome of EU funded activities. This applies in particular by using extensive wind tunnel and flight test databases, as well as any kind of valuable validation data.

4. Main objectives of the RC-GoR

4.1 RC-GoR overview

The RC-GoR supports the advancement of civil and defence-related rotorcraft technology in European research establishments, universities and industries through collaborative research activities, and through identification of future projects for collaborative research.

The RC-GoR initiates, organizes and monitors basic and applied, computational and experimental multidisciplinary research in the following areas and in the context of application to rotorcraft vehicles and systems technology.

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 Virtual Engineering using numerical tools based on low-order (analytical, BEM) to high-order (CFD) methods, validated with relevant tests campaigns;
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines, more electric rotorcraft ...);
- Increase security and safety:
    - Security studies, UAVs, advanced technologies for surveillance, rescue and recovery;
    - Flight mechanics, flight procedures, human factors, new commands and control technologies;
    - Increase crashworthiness, ballistic protection, …;
- Better integrate rotorcraft into the traffic (ATM, external noise, flight procedures, requirements/regulations);
- Tackle environmental issues:
    - Greening, pollution;
    - Noise (external, internal);
- Progress in pioneering: breakthrough capabilities.

Technical disciplines include, but are not limited to, aerodynamics, aeroelasticity including stability, structural dynamics and vibration, flight mechanics, control and handling qualities, vehicle design synthesis and optimization, 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.

The RC-GoR, wherever practicable, informs, seeks specialist advice and participation where appropriate, and interacts with activities in other GARTEUR GoRs.

4.2 RC-GoR activities

The members of the RC-GoR represent the major national research centres and helicopter manufacturers in the European Union involved in civil and military rotorcraft related research. Currently, it is noticeable that the two European helicopter manufacturers represent more than 60% of the civil helicopters delivered worldwide.

This 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 establishing collaborative research programmes, at a non-competitive level, to the benefit of the European rotorcraft community, including both governmental and industrial interests. In addition, the RC-GoR represents a unique forum within Europe for the interaction of the research establishments and industry, for the exchange of knowledge and understanding in the field of rotorcraft research and technology. An increasing number of University teams are associated with the activities of the AGs. Since 2011 the University of Liverpool has been an active member of the RC-GoR. The RC-GoR is a kernel for ideas for new research projects and supported the preparation of several EU proposals, even if the number of helicopter dedicated projects within H2020 has significantly been reduced compared to previous framework programmes. Figure 5 illustrates the relation between many of the AGs promoted by the HC-GoR and the European funded research projects in 25 years starting from the '90s. The RC GoR is currently concerned by the fact that rotorcraft topics are not included in the working program for Clean Aviation and that opportunities of a European project dedicated to rotorcraft in Horizon Europe are limited.

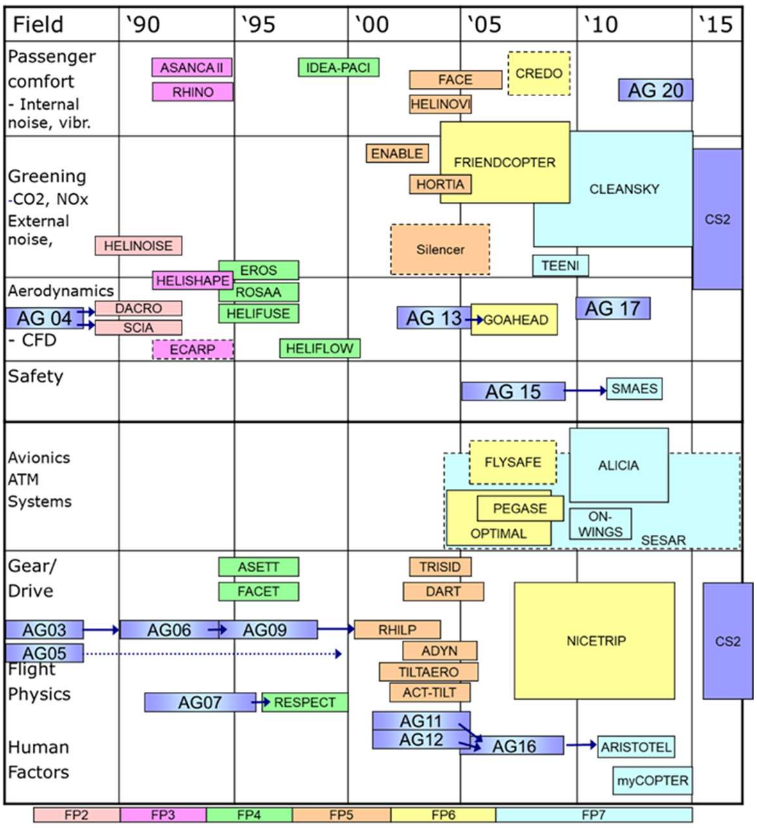

Figure 5 – Relation between HC/AGs and EU projects (EU program overview by Eric Lecomte EC)

A particular area of success in past work 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, and for acoustics. This modelling capability has underpinned improvements across the field of rotorcraft performance, enhancing both military and civil market competitiveness, as well as safety for all users. There is no question that the availability of high quality, well-validated modelling tools is essential to the effective design and development of competitive rotorcraft and it may fairly be claimed that in supporting the creation of such tools over many years, GARTEUR has significantly contributed to place the European industry in the favourable position that it holds in the world market-place today.

In addition, as rotorcraft require multidisciplinary studies, the AGs discuss and exchange tools with other AGs (for example from FM, AS, AD and SM domains).

The RC-GoR is used as a forum for briefings by members on their organisations' activities and for discussion of new ideas which may be mature for collaboration. The RC-GoR also considers other collaborative initiatives within Europe, bringing mutual understanding and co-ordination and hence contributing to best use of scarce resources. For instance, the RC-GoR is maintaining an awareness of the range of EU Technology Programmes.

5. A Brief History of the RC-GoR

The birth of a Group of Responsables dedicated to rotorcraft has a very precise date and place: February 11th 1980 at Farnborough (UK). That day, a first meeting to justify a GARTEUR AG concerning helicopter's fuselage drag was held. At the meeting it was decided to apply the test results of the DFVLR/MBB fuselage research model for GARTEUR use. However, it was only more than one year later, on November 20th 1981, that the clearence for the use of these data for GARTUR purposes was given. Consequently, the kick-off meeting of the first AG was held on December 4th, 1981 in Paris.

Members of this first AG were: Mr. G. Polz (MBB – now Airbus Helicopters), chairman; Mr. J. Amstberg (DFVLR, now DLR - D); Dr. E.C. Maskell (RAE- now DSTL – UK); Mr. J.J. Philippe (ONERA – F); Mr. A. Vuillet (Aerospatiale Helicopters – now Airbus Helicopters – F), and Mr. F. Wilson (Westland Helicopters – now Leonardo Helicopters – UK).

The test cases for numerical simulations were agreed and experimental data were transferred to all AG members. Nevertheless,the latter operation was significantly delayed by problems involving the different computer systems (!) and was completed only in Spring 1983.

The reason for such an AG was motivated by the awareness that the fuselage drag prediction poses serious simulations issues due to the massive and complex flow separation produced by the bluff shape of the fuselage afterbody. The numerical simulations were carried out by using potential methodologies coupled, when possible, to semi-empirical models to account for the parasitic drag, being the methodologies Euler-based or the Navier-Stokes solvers in an earlier stage of development and hence not suitable at the moment of the AG activities, Figure 6. The reccomendations for future work suggested that investigations on a more slender fuselage shape would be required and that the theoretical studies of the wake modelling should be increased.

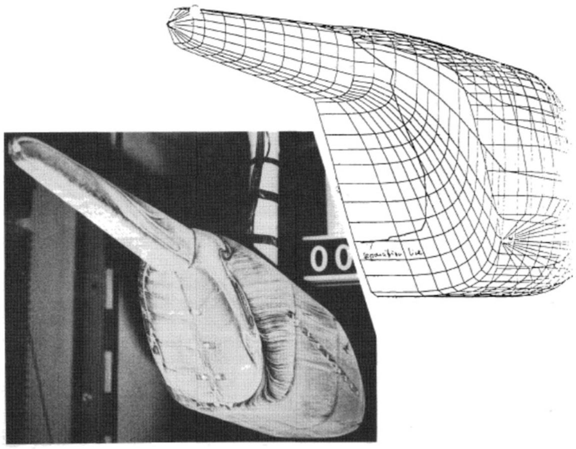

Figure 6 – Some results of the AG-01

It is interesting to notice that at the end of the project, in 1985, the final document specifically reads that it was prepared "*under the auspices of Responsables for Aerodynamics of GARTEUR*" because the activity was still considered as concern of the Aerodynamic GoR. The full autonomy was reached starting from the AG-02 launched in 1982, and the new-born GoR was named the *Helicopter Group of Responsables (HC-GoR)*.

From the first AG project to date, 26 AGs have been launched dealing with the many disciplinary aspects of the rotorcraft, from helicopters, to fast rotorcraft to the recent multirotor VTOLs. Figure 7 shows the distribution of the investigated topics per discipline.

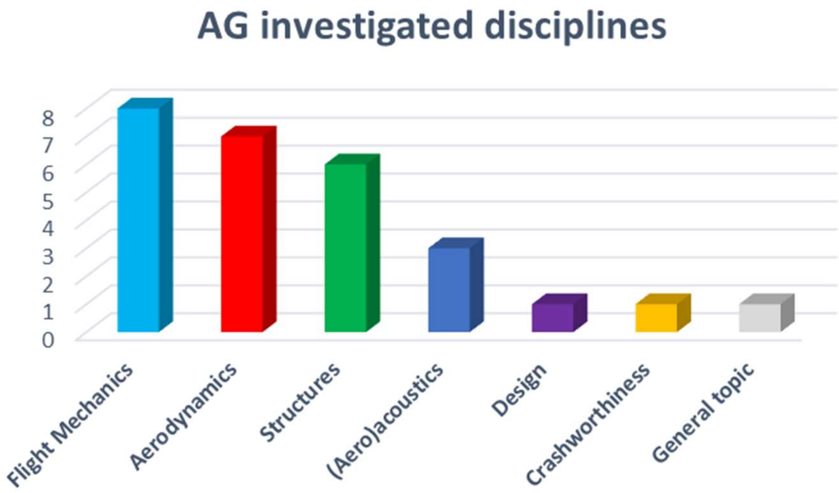

Figure 7 – The disciplines investigated in the Rotorcraft AGs

Until approximately the last five years the majority of the AGs have investigated topics almost exclusively related to helicopters or of general application to all rotorcraft. An exception was represented by the early studies of the defined advanced rotorcraft, today better identified as fast rotorcraft, such as tilt-rotors and compound helicopters. Actually, it is a fortuitous circumstance that the first AG launched by the HC-GoR, AG-02 [3], was related to a sort of opinion poll, based upon questionnaire replies from organisations representing a significant proportion of the major civil helicopter users, but including only a limited input from military users, to acquire opinions about alternative configurations to helicopters to overcome the operational limits of this aircraft. A need was foreseen for advanced rotorcraft in civil transport and long range search and rescue operations. Advanced rotorcraft were deeemed not required for external load, public service, agricultural and civil utility operations. The limited data obtained from military users indicated that these operators often require features which are of little interest to commercial operators. AG-02 was carried out during three years from 1982 to 1985. In accordance with the recommendations of the AG-02, another AG, AG-05 [4] was launched to perform a technical analysis in order to assess the applicability of the various possible configurations of advanced rotorcraft to the operational and missions that were drawn by the survey completed in AG-02. The tilt-rotor and the compound helicopter were selected as the most promising types of advanced rotorcraft. The main conclusions drawn in the final document, dated 1987, indicated that the tilt-rotor owned the most favourable efficiency and potential compared to the compound helicopter. It is also thanks to the outcomes of these two action groups that a long series of European-funded reserach projects related to the tilt-rotor was launched several years later, starting from the end of the 90s with the projects ACT-TILT, ADYN, DART, RHILP, TILTAERO, TRISYD, and NICETRIP, and which still continue today in the framework of the CleanSky 2.

From the end of the first decade of the new millenium, the research activities of the HC-GoR were also addressed to aspects not directly linked to the aircraft but rather to its interaction with the surrounding environment during specific flight missions. The exclusive capabilities of a rotorcraft to operate in hover or to fly in confined areas make this aircraft able to operate in the proximity to the ground and obstacles. This pecularity triggered the interest of the HC-GoR members towards the investigation of a helicopter in ground effect, AG-17 [5] from 2008 to 2012, Figure 8; of the forces generated on the rotorcraft and on the surrounding obstacles as well, AG-22 [6] from the end of 2014 to 2017, Figure 9 and Figure 10; of the flight of a helicopter inside a large wind turbine wake system, AG-23 [7] from the end of 2015 to 2018, Figure 11, Figure 12 and Figure 13.

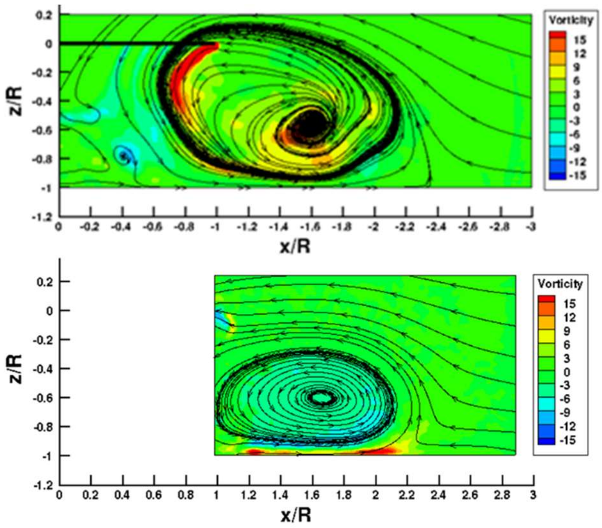

Figure 8 – Helicopter in IGE forward flight. Flow field vorticity. CIRA simulations (top) vs Univ. Glasgow experimental results (bottom)

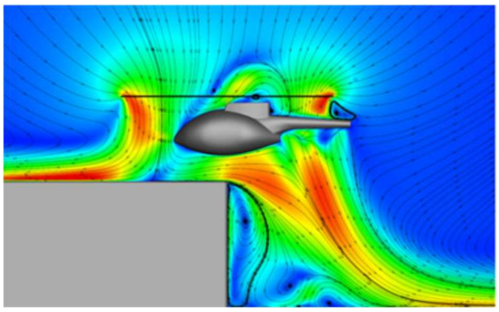

Figure 9 – Politecnico di Milano RANS simulations of a hovering helicopter in the proximity to an obstacle

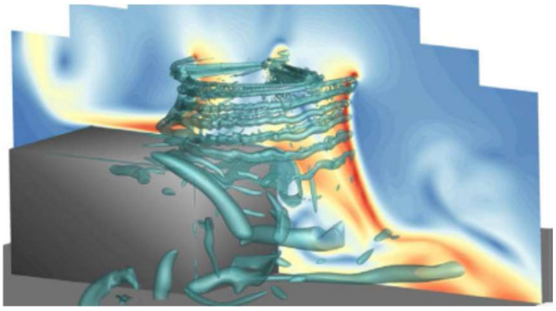

Figure 10 – ONERA RANS simulations of a hovering helicopter in the proximity to an obstacle

Figure 11 – Wind turbine scenario in the DLR helicopter simulations facility

Figure 12 – NLR Helicopter Pilot Station and NREL5 wind turbine wake

Figure 13 – Wind turbine scenario in the Univ. Liverpool simulator

The acquired experimental database and the numerical investigations highlighted the strong interactions occurring between the aircraft and the surounding obstacles, which produce significant changes in the performance of the first and non negligible loads on the latter.

All these projects benefitted from a strong cooperation among the members who put at disposal several numerical tools for the simulations, ranging from flight mechanics tools to panel methods to the sophisticated Navier-Stokes solvers, and numerous low-budget wind tunnel test campaigns aimed at generating the necessary database for the numerical validation. AG-22 turned out to be particularly prolific in publications, more than 30, which continue to grow, Master and PhD theses. The paper produced by the consortium to show the main outcomes of the project was awarded in 2018 the European Rotorcraft Forum Chairman’s award for having the best paper with a focus on international Cooperation at the 43rd European Rotorcraft Forum [8].

AG projects related to the internal and external acoustics are only concentrated in the most recent years. Two main reasons can be identified. The first one lies in the fact that numerous European research project were already funded on the topic in the '90s and during the first half of the 2000s. It is worth mentioning projects like HELINOISE, HELISHAPE, HELINOVI and ADYN, which however investigated only the tonal component of the aeroacoustics of isolated rotors or proprotors. No investigations of the broadband noise and of the scattering effects were carried out. The second reason stands in the growing awareness matured during the recent years that quieter rotorcraft are more easily accepted by the civil and military communities, especially when considering the innovative multirotor configurations. The first AG that investigated the internal acoustics of a fuselage was the AG-20 in the period 2012-2016. The AG investigated numerically and experimentally the adoption of passive acoustic solutions, such as the trim panels, to control the acoustics of a helicopter cabin. Regarding the external acoustics, the AG-24 [9] examined, in the period 2015-half 2019, the main rotor noise propagation in the presence of a fuselage. The activity established an experimental acoustic database and prediction design tools for main and tail rotor noise in the presence of a fuselage, and also included the main/tail rotor interactions, Figure 14.

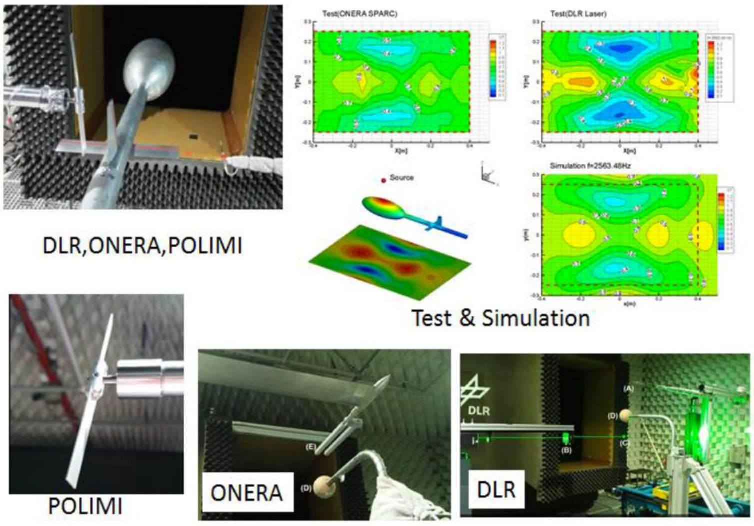

Figure 14 – Numerical and experimental activities in AG-24

Currently, there are two AGs running. AG-25, started in September 2019, aims at investigating both numerically/experimentally the aerodynamics of rotor/rotor wakes interactions. These kind of interactions occur on fast rotorcraft, but could also appear in UAVs or eVTOL concepts. The importance of this activity is in the fact that these interactions may have significant impact on vibrations, and aerodynamic performances, especially, but not exclusively at low speed. Experimental databases related to this phenomenon are scarce since high speed helicopter concepts developed by industry are confidential, and there is low indistrial interest in investing such wake aerodynamic phenomena. In addition, the use of sophisticated CFD tools, able to capture the details of this phenomenology, are too expensive. Therefore, the need for cost effective, yet accurate, approaches and for cost effective wind tunnel test campaigns to produce publically experimental databases motivated the formation of this AG, Figure 15.

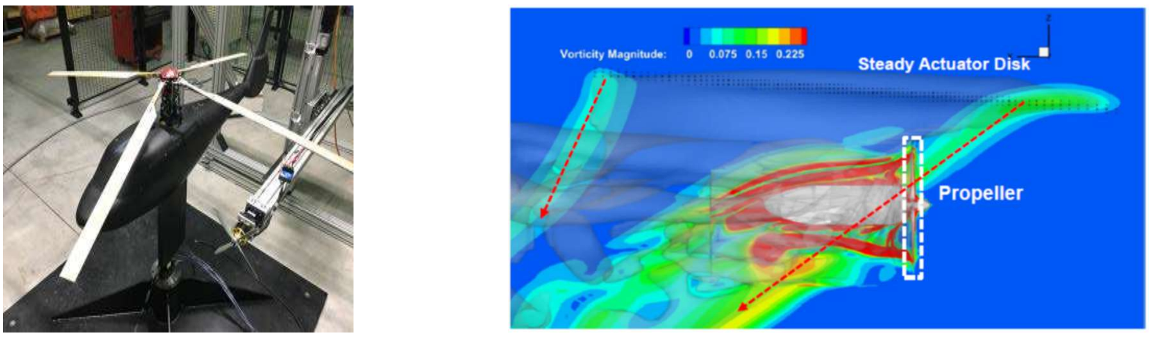

Figure 15 – AG-25: ONERA wind tunnel test set-up (left); Univ. Glasgow CFD simulation (right)

During the years, the research and technological advancements in the rotorcraft field not only have seen significant improvements in the existing rotary wing configurations but have also allowed the birth of completely new archtectures, such as the mutlirotor VTOLs, which dffer substantially from the typical main rotor-tail rotor one of a helicopter. For this reason, the HC-GoR members deemed more appropriate to change the name of the GoR to *Rotorcraft Group of Responsables (RC-GoR)*. This new denomination was approved by the Council and replaced the old one starting from January 1st 2021.

AG-26, is the first action group approved by the RC-GoR and is the latest one activated. Its aim is the investigation of the aeroacoustics of multirotor configurations. This AG, set-up in 2022, sees the signficant participation of many partners from many nations, all involved in investigating the noise radiation and propagation (installation effects) of multirotor systems and are developing numerical models for the simulation of noise sources and noise scattering.

Figure 16 – AG-26: Test rigs for experimental activities. DLR (top left); CIRA-UniCusano (top right); PoliMi (bottom)

6. What the future holds

The future of the RC-GoR activities is intimately linked to the technological advancements in the rotorcraft field. Three main areas of investigations can be identified:

- *Improvement of the classical helicopter configurations*. This is a constant objective of the helicopter industry, which aims at increasing the acceptability of this configuration of rotorcraft by reducing on one side the CO_2 and NO_X emissions, the noise generated and the operating costs, and on the other side by increasing its performance, safety and reliability, and its integration in the air traffic system;
- *Fast rotorcraft*. This category of rotorcraft includes tilt-rotors, compound helicopters and coaxial rotors helicopters, which are able to mitigate the main technological limits of the conventional helicopter such as having a lower flight speed, range and operating altitude;
- *eVTOLs*. This recent category represents a disruptive technology, which has opened new scenarios for rotorcraft applications. Triggered by the electrification of flight and by the rapid expansion of multirotor drone configurations, these new rotorcraft represent the means to make the development of Urban/Advanced Air Mobility the new frontier of air transportation in urban and rural areas, fully integrated in the air traffic system in the near future.

According to the “Industry Needs for the Future” identified by Airbus Helicopters, the topics of relevance for future research activities are identified as follows:

- Early noise prediction for:
  - New concepts / new configurations (incl Air taxis in early architecture phase);
  - Rotor-rotor interactions;
  - Rotor installation noise. Ducted rotor / rotor-wing interaction / shading effects;
  - Noise propagation / perception;
- Gust resilience;

- Sense and avoid; sensors and their reliability;
- Vertipads; landing on top of skyscrapers

Two exploratory groups (EGs) are currently active and under examination to be converted to action Groups:

- *RC/EG-40: Gust Resilience of VTOL Aircraft.* The objective is to set-up a team of researchers able to investigate and test the different approaches that might be employed to achieve gust resilience of multirotor vehicles;
- *RC/EG-42: Analysis and Decomposition of the Aerodynamic Force Acting on Rotary Wings*. The technology for drag analysis of CFD solutions of fixed wing configurations has reached a mature stage. Conversely, applications in rotary wing aerodynamics are still very limited, if not absent. However, recent progresses obtained in unsteady flow analysis are promising for both parasite force calculations, and thrust extraction. The objective of this EG is to study the application to rotary wings of aerodynamic force analysis and decomposition methods.

Finally, a list of New Initiatives is discussed and constantly updated by the RC-GoR members. This constitutes a basis for further insights, which could lead to the promotion of ideas to new EGs or to their definitive rejection. The latest list, February 2022, is illustrated in the following:

- Helicopter Icing & De-Icing: extremely important for safer flights in all-weather conditions, an objective to be pursued to reduce the operative costs of rotorcraft;
- Modelling of electric systems for eVTOLs;
- Drone impact on Helicopters (rotating parts): This topic is extremely important for UAM and military applications;
- Human Factor issues and training methods for complex automation in cockpit;
- Pressure Sensitive Paint / Temperature Sensitive Paint for rotors/propellers (drone, e-VTOLS...): innovative means for less expensive experimental measurements on complex geometries in complex flight conditions;
- Perception and public acceptance of UAM and Noise propagation in urban environments (high RPM with high frequency noise): this is a relevant topic for the success of the UAM;
- Installation effect of propeller noise (wing, ducts) in the early design phase.

7. Concluding Remarks

The paper has provided an overview of the activities carried out by the Rotorcraft Group of Responsables in the framework of GARTEUR. The RC-GoR is the expression of the European rotorcraft community, a small yet united one, and aims at supporting the advancement of civil and defence-related rotorcraft technology in European research establishments, universities and industries through collaborative research activities, and through identification of future projects for collaborative research. The areas of concern to rotorcraft are such that their investigations require a multidisciplinary approach, which is carried out by a team of experts specifically skilled on rotorcraft topics. Born in 1981, and during more than forty years of activity, the RC-GoR has promoted numerous Exploratory Groups forming 26 Action Groups in which the various disciplines of a rotorcraft have been theoretically and experimentally investigated. Historical requirements defined the majority of activities devoted to conventional helicopters. However, in recent years there is a growing interest toward fast rotorcraft, and even more toward multirotor configurations that will likely focus the attention of the rotorcraft community in the forthcoming years, especially if UAM is demonstrated to be a viable and successful new concept of air transport. The RC-GoR, despite its small size, has proven over the years to be a successful group which has had, and is having, the capabilities to promote activities in which the cooperation, despite the lack of funding, has been very successful producing many experimental databases employed to validate the numerical tools applied and improved during the life cycle of the AGs. In many occasions, the expertise matured in GARTEUR has been profitably put at disposal of follow-on funded research projects. Last but not least, RC-GoR has produced a large number of publications and theses which have enabled students and young researchers to train on the job and to acquire the necessary expertise that will allow them to successfully contribute to the rotorcraft research of the future.

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10. Copyright Statement

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