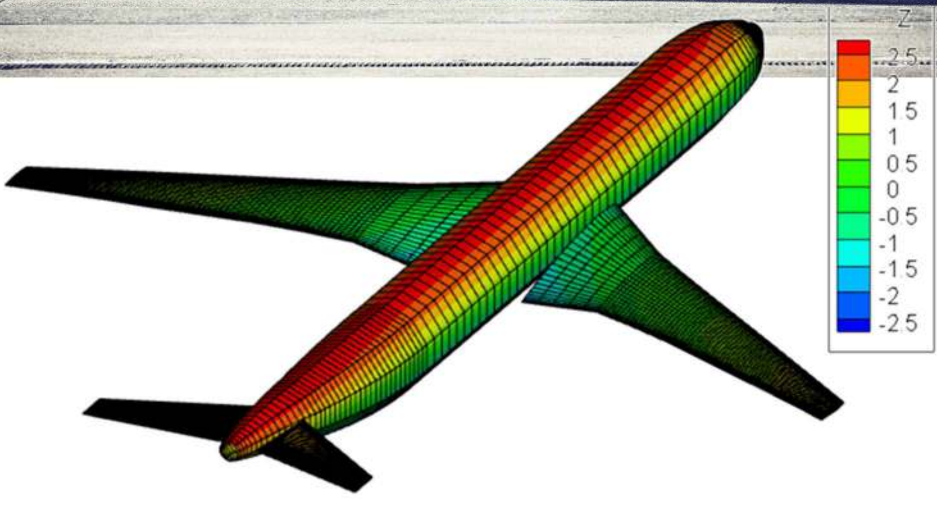
GARTEUR

ANNUAL REPORT 2019



GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

Front cover image: Stock image. Panel model used to tune the wing structure for 10% tip deflection for worst-case gust (AG52 GoR AD)

Back cover image: Stock image

GARTEUR ANNUAL REPORT 2019

Table of Contents

1 INTRODUCTION

During 2019 GARTEUR members have paved the way to consolidate technical work as well as managerial tasks, to keep a major role in coordination of research on basic technologies in Aeronautical Development in Europe, both for defence and civil applications.

2019 has been the second year of the Spanish Chairmanship of GARTEUR Council. During this year many initiatives started during 2018 to enhance the performance of Group, as well as those already put in its way by previous work, have been completed or have seen an adequate progress in order to align with the objectives marked in the beginning of this term. However this is a continuous effort that is required to be sustained for the upcoming years to overcome an increasing number of challenges in this competitive world.

After the SWOT performed in the C65 meeting, a positioning exercise was done, followed by a first draft on an action plan which will be the base of a comprehensive Strategic Plan.

The technology and research mainstreams identified during the last year (38 topics, classified by "Military", "Artificial Intelligence, Big Data and Uncertainty quantification", "Breakthrough", "Certification / Standardization", "Security" and "Multidisciplinary") will help to structure an updated Roadmap, being a recommendation tool for the GoRs to address research of GARTEUR interest, while increasing the inter-GoR collaboration and a decision making tool for the Council. GARTEUR shall be dynamic enough to respond to research demands from the defense and industry. One example of this is the continuous increase of the UAV aspects around defense and security which are going to be covered by GARTEUR.

In 2019, the GARTEUR GoRs had 12 Action Groups and 6 Exploratory Groups active, consolidating the technical research nature of GARTEUR.

During the period we have seen important changes both at European and National levels and also in the political as well as in economic arena. Elections for European Parliament, and subsequent changes in the Commission, are setting a new management in those subjects of our direct concern in Aeronautics. Changes at national level have also rendered their toll in facilitating, or the opposite, the normal pace of our duties.

Also new, and not so new, huge challenges have arisen or been reinforced during the period. Brexit and Global Commerce struggles are no longer far concerns, but direct threats for the wellbeing of citizens, including those from all our respective countries. All these will surely affect our working framework and expectations for the future. GARTEUR shall be adapted to this challenging environment.

As part of that Chairmanship and Council envision to the period, it was expected to empower the relationship with other organizations like EASA and EREA finding synergies and collaboration in mutual interests). In this way, three actions can be highlighted. In one hand Mr. ISAMBERT Emmanuel (EASA) presented new research projects (under EPAS, European Plan for Aviation Safety) that are interesting to GARTEUR. In the other, an EREA-GARTEUR meeting was held in Bucharest during Aerodays event, and one of the actions of that meeting was informing GARTEUR Council regarding EREA Future Sky Themes and informing EREA Future Sky Board regarding GARTEUR activities. This exchange was performed by Mr. Philippe Beaumier during C67 and EREA Future Sky Board meeting 2019/03 respectively.

In the European Research Arena, Horizon Europe Programme is now approaching (to start in 2021) with €100 billion for research and innovation, and the competitiveness is more and more demanding, now including Defence Funds for collaborative efforts. Opportunities shall rise and they also disappear promptly if collaboration streams are not well prepared.

We keep believing GARTEUR is of paramount importance to foster European countries partnership and collaboration to generate the first germ of the required innovative solutions which eventually will fill in the existing gap in the European programmes in regards of low-to-medium TRLs.

The GARTEUR Council, as the driving body of all that work, has to keep supporting the different technical levels with the authority it may represents. Ministries, Defence Staffs, Research Institutes and all those involved here, have to be in the core of the impulse of technical activity. All participants are heartily encouraged to be as much active in GARTEUR as they can by providing resources or clearing out the way for the technical work to run smoothly.

2 EXECUTIVE SUMMARY

The GARTEUR Annual Report 2019 provides a summary of the main managerial actions of the Council, and the scientific and technological progress made by the five Groups of Responsables (GoRs). The GoRs constitute the main bodies for establishing research priorities in the technology areas covered by GARTEUR: aerodynamics, structures and materials, helicopters, flight mechanics and systems integration, and security.

Chapter 3 of this report provides a summary of Council activities. Section 4 reports on the European aeronautical R&T environment by highlighting the importance of Horizon 2020, Flightpath 2050 and the Strategic Research and Innovation Agenda (SRIA) to civil aviation. Great steps have been taken to streamline aeronautical research in Europe and 2019 saw the mid-term review of H2020 which has aided in the preparatory talks for the H2020 successor programme FP9 to be entitled “Horizon Europe”.

Developments in military aeronautical strategy within Europe are also discussed with information provided on the European Defence Action Plan and Fund, the military perspective on the Single European Sky programme and the benefits that may be available to aeronautic development from EU funded defence research. The close involvement of GARTEUR members with ACARE is also described.

The GARTEUR scientific and technical activities are reported in Chapter 5, with each of the five GoRs presenting a summary of their work during 2019. This document is accompanied by the Annexes to the Annual Report 2019 in which the GoRs present a more detailed account of their activities. The Annexes can be downloaded in digital format via GARTEUR website. Information on the GARTEUR roadmaps can be found in Chapter 6.

3 GARTEUR COUNCIL

3.1 Chairmanship and membership

2019 was the second year of the Spanish Chairmanship. During 2019 the Chairman of the Council was Bartolomé Marqués, INTA's Director for Aeronautical Systems, with Francisco Muñoz, head of INTA's Aeronautical Innovation and Systems Engineering Centre, as chairman of the Executive Committee. Jose Vicente García served as GARTEUR secretary during 2019.

3.2 GARTEUR Council meetings

GARTEUR Council meetings occur twice a year, with the main Council meeting being preceded by a meeting of the Executive Committee (XC). During the XC the GoR Chairs and XC members meet to discuss the agenda for the Council meeting, reviewing and proposing outstanding actions, shaping the discussion topics in detail, and preparing proposals to the Council.

The Council meetings consist of representatives from the national delegations with the GoR chairs. These meetings provide a vital opportunity for the GoR chairs to inform the Council on the research being undertaken by their Action Groups and Exploratory Groups and to introduce potential new areas of interest.

The Council meetings also offer the member states an opportunity to provide updates and developments at national level in R&T activities and investments in civil and defence aeronautics. The multidisciplinary nature of the Council meetings provides excellent opportunities for dynamic collaboration and exchange of expertise and varied perspectives.

Meetings:

- XC162 – 12th February 2019, NLR, Amsterdam (The Netherlands)
- C66 – 3rd and 4th April 2019, INTA, Torrejón de Ardoz (Madrid)
- XC163 – 18th September 2019, DLR, Bonn (The Netherlands)
- C67 – 17th and 18th October 2019, Ministère de la Défense Balard, Paris (France)

3.2.1 XC162

The first XC meeting of 2019 was held in The Netherlands, hosted by NLR in its facilities at Amsterdam on the 12th February. The primary purpose of the meeting was to review the Action Plan and the Strategic Plan initiated during 2018.

The possibility of setting up a GARTEUR Graduate Program was discussed, with the opportunity of fostering participation of both young and senior researchers, and tie them to societal challenges.

It is reminded the importance of increasing Garteur presence of the XC members in GoR meetings and symposiums, to help in the Garteur positioning (dissemination actions).

Three Action Groups were proposed for the Garteur Award of Excellence:

From HC GoR:

- HC/AG-22 “Forces on obstacles in rotor wake”.

From AD GoR:

- AD/AG-51 “Effect of laminar / turbulent transition in hypersonic flows”.
- AD/AG52 “Surrogate-based global optimization methods in preliminary aerodynamic design”.

3.2.2 C66

The first Council meeting of 2019, C66, was held in Torrejón de Ardoz (Madrid), at INTA facilities, on the 3rd and 4th April. During the meeting it was reinforced the necessity of defining a clear line of action in order to cope with the challenges to come. This means the definition of a Strategic Plan that, jointly with a related and consistent roadmap, shall constitute the guidelines to follow in the near to medium future work. For achieving these objectives is important the participation of all players at all levels of the organization.

The meeting covered the discussions around the importance of UAV (Unmanned Aircraft Vehicles) Research, and therefore it shall be covered within Garteur. It was decided that XC should prepare a presentation around UAV thematics including possible line of actions that could be considered in the FM GoR.

It was decided, after the review of XC considering the related criteria, the Garteur Award of Excellence went to AD/AG52 “Surrogate-based global optimization methods in preliminary aerodynamic design”.

Moreover the progress of the Strategic Plan was presented (please see Chapter 3.3).

3.2.3 XC163

The XC163 meeting was held in Bonn, in the DLR facilities on 18th September 2019. The main topic of the discussion was reviewing the outcomes from C66 around:

- Refine the "Raw Action Plan" established in the Workshop
- Mission & Vision. Gather and consolidate data from survey and Workshop.
- GARTEUR Graduate Program.
- Presentation around UAV thematics and GARTEUR possible actions
- GoR FM Relaunch.
- Revitalize the GoR SM.

3.2.4 C67

The C67 meeting was held Ministère de la Défense Balard, Paris on 17th and 18th October 2019.

Francisco Muñoz presented the UAV thematic in GARTEUR (Attachment 2). The latest version of that presentation has been agreed during the pre-Council meeting.

Francisco Muñoz outlined the preliminaries and context of this initiative. This was originally initiated with a proposal from the French delegation, and the opening of the related action to consider the topic and provide some material around this subject in next Council meeting (in this case the current C67 meeting).

It was highlighted how wide the scope is, and therefore proposed 2 approaches and concrete orientations (possible topics to be addressed):

- Bottom-up
    - Explore technology needs in UAV field. Short to medium term. Long term.
    - GoRs to analyse and propose a short list of ideas to develop at GARTEUR level.
- Top-down
    - Selection of needs to fulfil (at operational, technology or system level).
    - Decide about a work structure to cope with the challenge (incl. decisions about GoR orientation).
    - Decide about a few pilot projects.

The Council agreed that the UAV topic should be addressed by the FM GoR, as a first choice, with the support of the other GoRs.

During this meeting Mr. ISAMBERT Emmanuel (EASA) presented new research projects (under EPAS, European Plan for Aviation Safety) that are interesting to GARTEUR:

- Sandwich composites structure
- Single Pilot Operations
- Cybersecurity research
- Cabin air quality

3.3 Council initiatives

During 2019, the Council progressed with the Spanish Chairmanship initiatives defined in 2018. As a summary, we can highlight:

Line of action 1. Consolidate initiatives from previous periods.

This line included:

- Setting up a GoR on Aviation Security

A new Exploratory Group for GoR AS was setup in 2019: "Identification, Modelling And Management Of Cyber Attacks To Drones".

- Identification of main steams of research.

According to the main streams identified in Garteur Council C65, we derived the following technologies, and what relevant GoR applies in the Council C66.

TOPIC	RELATED TECHNOLOGIES	GoR
MILITARY	Missile	All
	HUMS	HC, FM

	Unmanned Which Challenges?	All
	UAV as a weapon	All
	Countermeasures	AD, AS, SM
	Hybrid propulsion	FM, HC
	Stealth	SM
	High velocity weapons	AD
	Emerging weapons (i.e laser)	TBD
	Material scatter	SM
	Human Factors issues / training for complex automation	HC, FM
ARTIFICIAL INTELLIGENCE BIG DATA UNCERTAINTY QUANTIFICATION	Situation awareness	FM
	Deep learning with safety & security data	AS
	SHM	SM
	Uncertainty quantification, from mean to quantile	All
	Certification by analysis	HC, AD, SM
	Big Data for Maintenance	HC, FM
	Big Data for aviation development	HC, FM
BREAKTHROUGH	Digital Twin. Industry 4.0	SM
	Unconventional Configurations. Blimps & other configurations.	All
	Near orbital flight	SM, FM, AD

	Quantum computing (to be aware)	All
	Bionic structures	SM
	Define breakthrough as a continuous activity	All
	Climate change. Decrease of market (Aviation).	All
	eVTOL / Urban Air Mobility	HC, AS, FM
CERTIFICATION / STANDARDIZATION	Standard to assure Safety & Security harmonization. Harmonization by Design.	AS
	Virtual testing & certification	All
	UAV and uncertainty quantification	FM
	Standard flexibility to adapt to innovative technologies	All
	Dynamic Risk Assessment	AS
	Detect & Avoid	HC, FM, AS
	Ice Adhesion. Ice effects.	SM, AD
SECURITY	Honey pot feeding A.I to face emerging threats	AS
	UAV, laser, emerging threats, Urban security (from UAV)	AS
	Intrusion Detection Systems	AS
	Data protection mechanism for risk data sharing & data mining	AS
MULTIDISCIPLINARY	System of systems (i.e collaborative flight)	All

Table 1. Technologies main streams.

Line of action 2. New impulse.

This line included:

- Review of all GoRs. Identification of main needs/obstacles. Support.

The review of the GoRs was performed trying to identify the best practices that could be shared between them.

- Positioning.

The positioning exercise was performed. It included how Garteur should be positioned taking into account civil / military and low / high TRL axis.

- Roadmapping effort.

Roadmapping is pending, however main trends have been identified.

Line of action 3. Organizational issues.

- Meetings. Structure. Frequency. Confluence at different levels (XC, GoR, AGs, Interdisciplinary)

Analysis of meeting attendance has been done.

- Reporting and dissemination. Reach.

A new AG report template has been elaborated. Initial ideas for a future GARTEUR Graduate program has been defined.

- Website. Social Networks.

Website redesign has been completed and Twitter and Linkedin accounts have been setup.

- Archive and custody.

The Garteur archive has been encrypted to ensure security in case of being stolen. New files to improve organization (i.e list of AG reports) have been created.

Line of action 4. Specific initiatives: Development of a Strategic Plan.

- SWOT

A SWOT analysis was performed during the C65 meeting (with preliminary survey inputs). This exercise was fruitful to understand the current health of Garteur.

- GARTEUR self-assessment.

A survey covering all the aspects of Garteur was performed with results from 17 participants. Following this, during C66, a workshop was performed.

- Action plan

During C66 workshop, a preliminary action plan was established.

- KPIs

A preliminary set of KPIs was identified in order to be able to measure and consequently improve the overall organization of GARTEUR. This shall be refined, completed and tested.

- Mission & Vision statement

The updated mission and a vision statement are still in progress and it will be continued by The Netherlands Chairmanship.

3.4 GARTEUR website

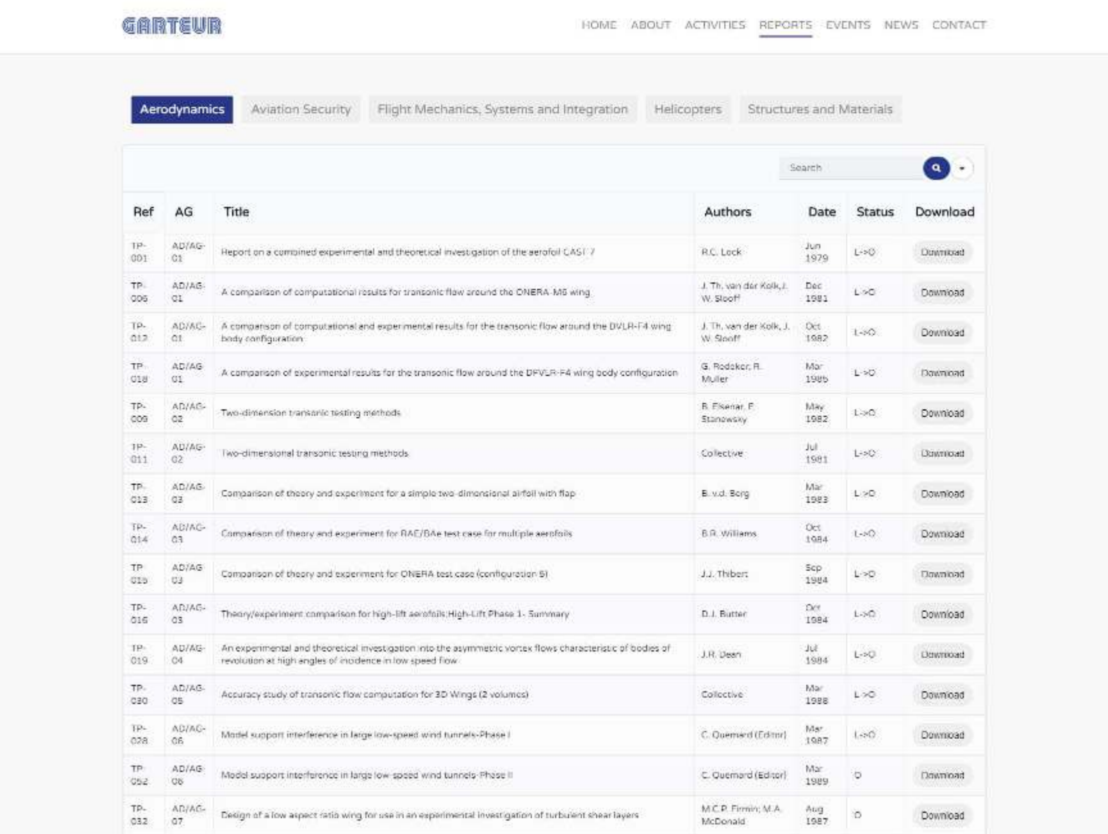
The GARTEUR website is accessible at www.garteur.org and provides information on the mission, principles and background of GARTEUR, along with access to information and reports from the five GoRs. Contact details and information on how to be involved in GARTEUR research are also provided, along with links to the national strategic documents of the GARTEUR countries.

For the use of the GoRs, the site is also used as a repository for minutes and other documents. During 2019 the website was regularly updated by the secretary.

Moreover, during 2019, the redesign of the website, which was started in 2018 has been finished, providing more features and new modern look, performance and security boost and legal compliance by means of:

- Use of a Content Management System (Wordpress) which allows to update the content easier than with the current website.
- Use cookie consent widget and legal pages in order to be fully GDPR compliant.
- Use 2FA (two-factor authentication) in order to ensure security of the website.
- Use SSL encryption to ensure the communication with the website is fully encrypted.
- Use proper SEO (Search Engine Optimization) to increase GARTEUR awareness on web search engines.
- Mobile devices friendly.

Figure 1. GARTEUR new website (www.garteur.org).



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Ref	AG	Title	Authors	Date	Status	Download
TP-001	AD/AG-01	Report on a combined experimental and theoretical investigation of the aerofoil CAST 7	R.C. Lock	Jun 1979	L->O	Download
TP-006	AD/AG-01	A comparison of computational results for transonic flow around the ONERA-M6 wing	J. Th. van der Kolk, J. W. Slooff	Dec 1981	L->O	Download
TP-012	AD/AG-01	A comparison of computational and experimental results for the transonic flow around the DVLR-F4 wing body configuration	J. Th. van der Kolk, J. W. Slooff	Oct 1982	L->O	Download
TP-018	AD/AG-01	A comparison of experimental results for the transonic flow around the DFVLR-F4 wing body configuration	G. Redeker, R. Muller	Mar 1985	L->O	Download
TP-009	AD/AG-02	Two-dimension transonic testing methods	B. Elsenar, E. Stanewsky	May 1982	L->O	Download
TP-011	AD/AG-02	Two-dimensional transonic testing methods	Collective	Jul 1981	L->O	Download
TP-013	AD/AG-03	Comparison of theory and experiment for a simple two-dimensional airfoil with flap	B. v.d. Berg	Mar 1983	L->O	Download
TP-014	AD/AG-03	Comparison of theory and experiment for RAE/BAe test case for multiple aerofoils	B.R. Williams	Oct 1984	L->O	Download
TP-015	AD/AG-03	Comparison of theory and experiment for ONERA test case (configuration 5)	J.J. Thibert	Sep 1984	L->O	Download
TP-016	AD/AG-03	Theory/experiment comparison for high-lift aerofoils:High-Lift Phase 1- Summary	D.J. Butter	Oct 1984	L->O	Download
TP-019	AD/AG-04	An experimental and theoretical investigation into the asymmetric vortex flows characteristic of bodies of revolution at high angles of incidence in low speed flow	J.R. Dean	Jul 1984	L->O	Download
TP-030	AD/AG-05	Accuracy study of transonic flow computation for 3D Wings (2 volumes)	Collective	Mar 1988	L->O	Download
TP-028	AD/AG-06	Model support interference in large low-speed wind tunnels-Phase I	C. Quemard (Editor)	Mar 1987	L->O	Download
TP-052	AD/AG-06	Model support interference in large low-speed wind tunnels-Phase II	C. Quemard (Editor)	Mar 1989	O	Download
TP-032	AD/AG-07	Design of a low aspect ratio wing for use in an experimental investigation of turbulent shear layers	M.C.P. Firmin; M.A. McDonald	Aug 1987	O	Download

Figure 2. Improved public reports management.

3.5 GARTEUR certificates

In 2019 GARTEUR certificates were awarded to past members of the Council, GoR chairs, industrial points of contact (IPoC) and secretaries, in recognition and appreciation of services rendered to GARTEUR.

France		
Philippe Beaumier	GoR HC Chair	ONERA
Spain		
Bartolomé Marqués	Member of the Council	INTA
The Netherlands		
Carlo Mekes	Member of the Council	Ministry of Defence of The Netherlands
Sweden		
Martin Hagström	GoR FM Chair	FOI

Table 2. Awardees of GARTEUR Certificates in 2019.

4 THE EUROPEAN AERONAUTICS RTD ENVIRONMENT

This section provides a brief overview of the European aeronautics RTD environment in both civil aeronautics and military aeronautics.

4.1 Civil aeronautics

Civil aeronautics research and technology development (RTD) in Europe is centred around collaborative research calls performed within the Framework Programmes for Research and Innovation. The current Framework Programme, Horizon 2020, is the biggest research and innovation programme in Europe and offers almost €80 billion in grants, loans and incentives over seven years (2013-2020) for researchers, engineers and entrepreneurs in addition to private investments the programme attracts.

Horizon 2020 is funding a considerable number of initiatives that will have a positive impact on Europe by unlocking innovation, providing the funds necessary to encourage and enable scientific and technological breakthroughs. Seen as a key driver of economic growth and job creation, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament

Aeronautical RTD is funded through a specific Aviation programme within the Transport theme as a Societal Challenge and sets out to tackle some of the main environmental challenges attributed to the aeronautical industry including designing and producing cleaner and quieter aircraft, minimising the impact of transport on the environment. Another key focus of Horizon 2020 is aimed at creating better mobility, less congestion and more safety and security.

Within Horizon 2020, Clean Sky 2 is Europe's dedicated aeronautics research programme with a €4bn budget. Clean Sky 2 represents a Joint Technology Initiative (JTI), a Public-Private Partnership (PPP) that brings together industry (including SMEs), academia and research institutions with the European Commission. Its aim is to develop and demonstrate break-through technologies for the civil aircraft market to cut aircraft emissions and noise whilst securing the future competitiveness of Europe's aeronautics industry.

4.1.1 Strategic direction of European R&I

The European Commission's Flightpath 2050 document outlines long-term goals associated with meeting society's needs for more efficient and environmentally friendly air transport, as well as maintaining global leadership for the European aerospace industry. It is therefore a crucial reference document for organisations in Europe and serves as the basis for the research calls within Horizon 2020 and the research projects that GARTEUR chooses to undertake.

Along with the Flightpath 2050 reference document, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) advises the European Commission on all aspects of aviation research and innovation in Europe and in its role as a European Technology Platform (ETP), it has a specific function to develop an industry-focused Strategic Research and Innovation Agenda (SRIA) for action at EU and national levels.

4.1.2 Strategic Research and Innovation Agenda (SRIA)

The SRIA provides a road map for aviation research, development and innovation in Europe and sets out areas of long-term research that support the Flightpath 2050 goals.

Comprised of two volumes, Volume 1 of the SRIA builds on Flightpath 2050, providing additional detail and explanation around the five central research themes;

- Meeting market and societal needs;
- Maintaining and extending industrial leadership;
- Protecting the environment and the energy supply;
- Ensuring safety and security; and
- Prioritising research, testing capabilities and education.

To tackle these challenges, several goals have been fixed (e.g. for Challenge 1: 90% of the travellers within Europe are able to complete their journey door to door within 4 hours). These are described in Volume 1 of the SRIA[1].

The purpose of volume 2 of the SRIA goes beyond this and describes what needs to be done, turning the high-level goals in Flightpath 2050 and Volume 1 of the SRIA into a series of specific and time-bound research and innovation objectives to guide the work of research and innovation teams across Europe.

4.1.3 GARTEUR and ACARE

In addition to its responsibility for developing the SRIA, ACARE plays an integral role in advancing aviation innovation within Europe by developing policy positions on European aviation initiatives and working closely with European Commission officials to ensure that Horizon 2020 funding calls - as well

[1] ACARE - Strategic Research & Innovation Agenda – 2017 Update Volume 1

as calls associated with the Clean Sky 2 and SESAR Joint Undertakings - are closely aligned with the SRIA.

Members of the GARTEUR Council are also heavily involved with ACARE and this ensures that GARTEUR's research interests are strategically aligned with the SRIA, ensuring that GARTEUR remains focused and committed to the major challenges being addressed by pan-European aerospace research and innovation.

GARTEUR's representatives within ACARE have emphasised that the innovation life-cycle needs to have the right mix of projects at all levels; covering the early, critical part of the innovation pipeline as well as the 'market readiness' associated with high TRL projects.

4.1.4 GARTEUR and EREA

EREA is the Association of European Research Establishments in Aeronautics. The focus of EREA and its members is on TRL 2 to 6 and therefore play a vital role in maintaining and improving the competitiveness of our industry and dealing with societal concern.

EREA proposed a Joint Research Initiative, named Future Sky, in which development and integration of aviation technologies is taken to the European level. Future Sky is based on the alignment of national institutional research for aviation by setting up joint research programmes. Future Sky is structured in six themes: Safety, Quiet Air Transport, Energy, Urban Air Mobility, Security for Aviation and Circular Aviation.

There are many members of the GARTEUR Council that also are members of EREA, and therefore it the synergies and complementarities are taken into account in a continuous basis.

4.2 Military aeronautics

The European defence industry represents a large collaborative effort from EU members, as well as non-member states, progressing defence technologies and solutions across a variety of industrial fields, such as aeronautics, land and naval systems and electronics. The defence sector is highly innovative and centred on high-end engineering and technologies, with important cross application that extends into the civil market.

4.2.1 European Defence Agency

The European Defence Agency (EDA) is an intergovernmental agency of the Council of the European Union, comprising all EU members with the exception of Denmark and also including from non-EU member states, Norway, Switzerland, the Republic of Serbia, and Ukraine, through special administrative arrangements. Through close cooperation the EDA seeks to improve European defence by supporting the development of capabilities, and nurturing technology and research to meet future defence requirements, and to promote defence interests in wider EU policies. The EDA operates at ministerial level and connects over 4000 nationally based experts collaborating on defence projects.

4.2.2 European Union-funded defence research

The European defence fund supports the cross-border cooperation between EU countries and between enterprises, research centres, national administrations, international organisations and universities. This applies to the research phase and in the development phase of defence products and technologies. It has 2 strands. Under the research strand, the EU budget will provide funding for collaborative defence research projects. Under the capability strand, the EU will create incentives for companies and EU countries to collaborate on the joint development of defence products and technologies through co-financing from the EU budget.

As a first step, the European defence fund supports collaborative defence research and development through 2 pilot programmes with limited duration and budget:

- The preparatory action on defence research (PADR). The preparatory action on defence research provides grants for collaborative defence research with a budget of €90 million for 2017-2019.
- The European defence industrial development programme (EDIDP). The European defence industrial development programme offers co-financing for collaborative defence development projects with a budget of €500 million for 2019-2020

5 SUMMARY OF GARTEUR TECHNICAL ACTIVITIES

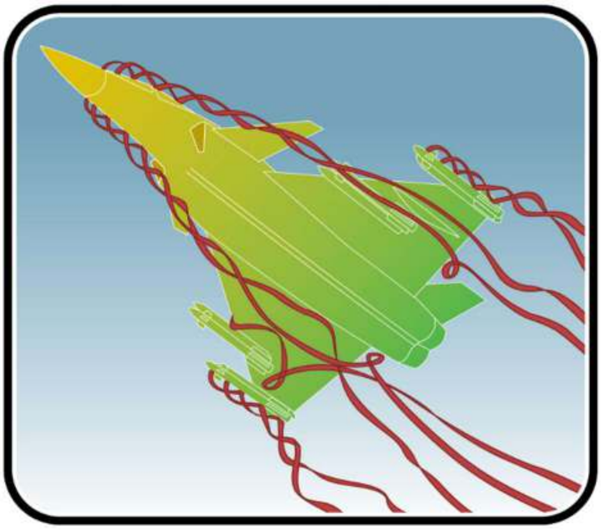
During 2019 the five GARTEUR Groups of Responsables (GoRs) continued to facilitate and deliver vital research in the field of aeronautics. The GoRs are responsible for monitoring and encouraging the progress of Action Groups (AGs) and Exploratory Groups (EGs). These groups are collaborations of researchers from national aerospace institutes, universities and industry. Although GARTEUR is not a source of funding, the GoRs constitute a powerful network and provide a unique forum for aeronautical research in Europe. The GoRs aid potential research consortia by critically reviewing their proposed research objectives and methodologies.

Without the constraints of financial accountability, the GoRs guide early stage research projects consistent with the GARTEUR road-map, which in turn is in line with European aeronautical strategy, while also allowing scope for innovative research and the development of low TRL disruptive technologies. The GoR chairs also encourage multidisciplinary research across the GoRs, with the biannual Council meetings providing excellent opportunities for the exchange of ideas and identification of dynamic partnerships.

The primary task of the GoR is to monitor Action Groups, encourage Exploratory Groups and instigate new ideas. The secondary task of each GoR is interaction with the other GoRs to promote interdisciplinary topics.

New ideas for research may be formulated by GoR members or arise within GARTEUR organisations. As GARTEUR does not offer funding, it is essential that the research is supported by the organisations themselves. Therefore, the GoR critically reviews the research objectives and methodology, but does not select particular topics over others.

Aerodynamics



5.1 Group of Responsables – Aerodynamics (AD)

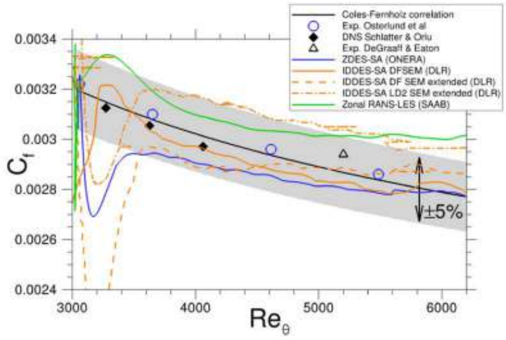
5.1.1 Overview

The GoR AD initiates and organises basic and applied research in aerodynamics. Whilst in general terms aerodynamics makes up the majority of the research done within the GoR, some of its work is multi-disciplinary. This trend is driven by industrial interests, and the importance of multi-disciplinary work is likely to increase in the future.

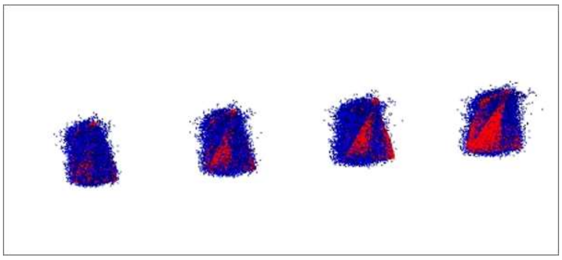
The current scope of the aerodynamic activities in the GoR covers the following:

- Aerodynamics,
- Aero-thermodynamics,
- Aero-acoustics,
- Aero-(servo-)elasticity,
- Aerodynamic shape optimization,
- Aerodynamic systems integration.

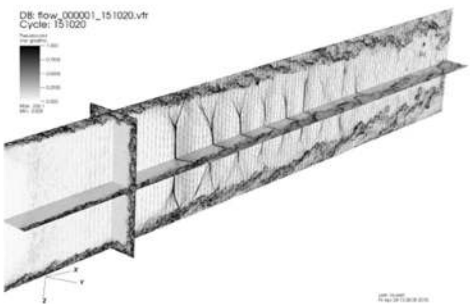
In all fields a synergy between experiments and simulations is aimed for.



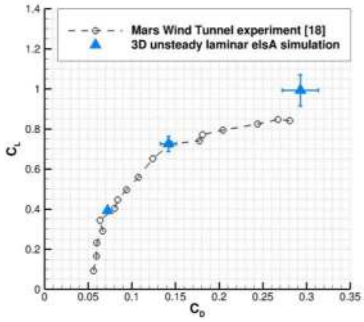
Validation of synthetic turbulence approach for a turbulent boundary layer(AG-54)



Code-to-code comparison of chaff blooming (AG-55)



Supersonic air intakes (EG-75)



Laminar separation bubbles (EG-76)

Figure 3. Illustrations of the Group of Responsables: Aerodynamics.

5.1.2 GoR-AD Activities

In 2019, GoR/AD monitored the following action groups:

AD/AG-51 *Laminar-turbulent transition in hypersonic flows*.
To understand and predict the triggering mechanisms for the transition to turbulence in hypersonic flows. For better predictions of hypersonic flows.

AD/AG-53 *Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations*.
To understand the effects of surface irregularities and inflow perturbations for the transition to turbulence over laminar wings. For the improvement and maintenance of natural laminar wings.

AD/AG-54 *RANS-LES Interfacing for Hybrid and Embedded LES approaches*.
To improve the turbulence resolving methods near boundary layers. For better simulations of aerodynamic performance in off-design conditions.

AD/AG-55 *Countermeasure Aerodynamics.*
To understand the aerodynamics of chaff and flares. For improvement of the effectiveness of the countermeasures.

The following Exploratory Groups were active:

AD/EG-72 *Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations*.
To develop and compare aero-servo-elastic models of very flexible aircraft. For the multidisciplinary design and analysis of lightweight aircraft.

AD/EG-73 *Secondary Inlets and Outlets for Ventilation*.
To redesign secondary inlets and outlets. For the reduction of parasitic drag and improved ventilation performance.

AD/EG-74 *Integration of Innovative Nozzle Concepts with Thrust Vectoring for Subsonic Aircraft*.
To investigate the benefits of thrust vectoring for civil and military aircraft. For possible new tail layouts due to increased control authority.

AD/EG-75 *Supersonic air intakes.*

To understand and control the air flow in supersonic air intakes. For better aerodynamic performance of supersonic aircraft.

AD/EG-76 *Laminar separation bubbles*.

To assess RANS turbulence models for laminar separation bubbles. For better simulation for small aircraft or in a Martian environment.

5.1.3 GoR-AD Membership

The membership of GoR-AD in 2018 is presented in the table below.

Chairman		
Harmen van der Ven	NLR	The Netherlands
Vice-Chairman		
Fernando Monge	INTA	Spain
Members		
Eric Coustols	ONERA	France
Giuseppe Mingione	CIRA	Italy
Heribert Bieler	Airbus Operations GmbH	Germany
Bruno Stefes	Airbus Operations GmbH	Germany
Frank Theurich	Airbus Operations GmbH	Germany
Per Weinerfelt	SAAB	Sweden
Magnus Tormalm	FOI	Sweden
Kai Richter	DLR	Germany
Industrial Points of Contact		
Thomas Berens	Airbus Defence & Space	Germany
Nicola Ceresola	Leonardo Company	Italy
Michel Mallet	Dassault	France
Didier Pagan	MBDA	France
Luis P. Ruiz-Calavera	Airbus Defence & Space	Spain

Table 3. GoR-AD Membership 2019.

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD/AG-53: Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations

Action Group Chairman: Ardeshir Hanifi, KTH
Group of Responsables: Aerodynamics

Background

The transition process of boundary layers is mainly characterised by three stages. These are generation, growth and breakdown of disturbances. The process of birth of disturbances inside a boundary layer is called receptivity. Disturbances can be generated by surface roughness or other sources of forcing like free-stream turbulence or the acoustic field. Understanding the receptivity process and ability to accurately model/compute it belong to key issues for a reliable transition prediction. It is noteworthy that commonly used transition prediction methods lack any information about the receptivity.

Programme

Objectives of AD/AG-53
Main objective of the proposed activities is to understand the effects of surface irregularities and perturbations in incoming flow on transition in three-dimensional flows and efficiency of transition control methods. The activities cover both experimental and numerical investigations.

Approach
The activities are grouped under three topics:
- Acoustic receptivity in 3D boundary-layer flows
- Receptivity to free-stream perturbations
- Effects of steps and gaps on boundary-layer perturbations

Experiments on effects of free-stream perturbations using the ONERA D profile. Experimental and numerical work concentrated on effects of steps and gaps. The intention is to use a similar configuration as that used in Bippes' experiments. Numerical investigations of acoustic receptivity in 3D boundary layers. Comparison of direct numerical simulations with simpler methods like linearized Navier-Stokes computations and adjoint methods.

Partners: KTH, FOI, CIRA, ONERA, DLR, Imperial College, Airbus, Airbus Group Innovations
Project duration: September 2013 – December 2016

The Outcomes

Results/benefits
Understanding of capability of existing prediction methods through comparison with experimental and DNS data, and improvement of these computations.

Main achievements
Detailed wind tunnel tests have been performed at ONERA to investigate the effects of freestream turbulence on laminar-turbulent transition on a wing. A change in the instability characteristics is observed when freestream turbulence is increased.

IC has developed a number of numerical tools for receptivity analysis of three-dimensional flows. A number of different flow cases has been investigated, including instability of the flow behind bumps and gaps (ring-wing experiment case).

The ring wing experiments (ALFET project) has been conducted by AGI. A range of gaps with realistic filler depths has been studied and the effect of laminar-turbulent transition was assessed. The results shows, somewhat contrary to expectations, that for a filled gap on a natural laminar flow wing at cruise conditions, there is a marked forward movement in transition for gaps as shallow as D/L=0.02.

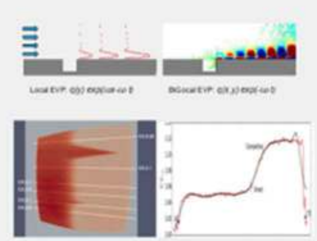
KTH have completed highly accurate simulations of the leading-edge acoustic receptivity, showing pervious results overestimating the receptivity coefficient. KTH has also performed direct numerical simulations of the interaction of acoustic waves with roughness-induced crossflow vortices, corresponding to the experiments performed within the RODTRAC project.

DLR has improved its in-house numerical tools (NoLoT code) for linear stability analysis of boundary-layer flows past forward- and backward-facing steps. Further, in order to experimentally investigate the stability of three-dimensional flows, DLR has designed and performed a set of wind tunnel experiments.

CIRA has further developed its acoustic receptivity tools based on the adjoint methods and investigated an empirical transition prediction method, which is based on the solution of a transport equation for some local flow parameters.

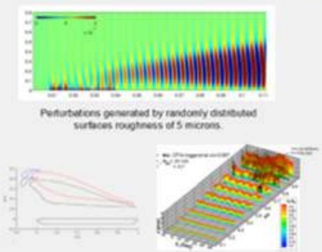
Gap Analysis

BiGlobal Stability Analysis a new approach to solve the spatial modes associated with the flow modifications generated by the step-gap region.



Left: TSP data from the ring wing (ALFET) experiment. Right: The use of TSP intensity ratio to determine transition.

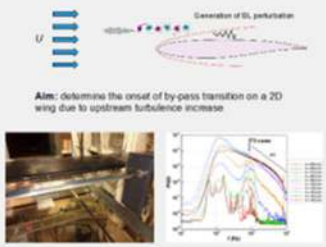
Receptivity model development



Perturbations generated by randomly distributed surfaces roughness of 5 microns.

Different designs of the displacement bodies for DLR experiments (left). Visualization of the measured perturbation field (right).

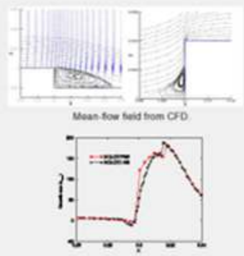
Receptivity & transition experiment



Aim: determine the onset of by-pass transition on a 2D wing due to upstream turbulence increase

Left: Free stream turbulence was introduced through the turbulent wake of a small wing placed upstream the main wing. Right: Effect of distance from wake on generation and growth of perturbations inside the boundary layer over the ONERA D wing. *h* is distance between the two wings.

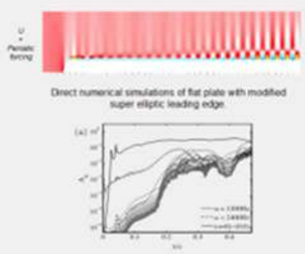
Backward/Forward-facing step



Mean-flow field from CFD.

Disturbance growth rate from PSE and LNS for a flow past a backward-facing step (step at x=0.3)

Leading-edge acoustic receptivity



Direct numerical simulations of flat plate with modified super elliptic leading edge.

Amplitude evolution of the steady and unsteady disturbances for interaction of acoustic waves with surface roughness in the boundary layer over a swept wing.

AIRBUS GROUP | CIRA | DLR | FOI | Imperial College London | KTH | ONERA THE FRENCH AEROSPACE LAB

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD/AG-54: RaLESin

RANS-LES Coupling in Hybrid RANS-LES and Embedded LES

Action Group Chairman: Professor Shia-Hui Peng (FOI)

Background

Hybrid RANS-LES modelling aims at turbulence-resolving simulations, in particular, for unsteady aerodynamic problems with massive flow separation and extensive vortex motions, benefitting from the computational efficiency of RANS (Reynolds-Averaged Navier-Stokes) and the computational accuracy of LES (Large Eddy Simulation). Its development has been greatly facilitated by industrial needs in aeronautic applications.

Over nearly two decades since the earliest DES (detached Eddy Simulation) model by Spalart and co-workers, a number of alternative hybrid RANS-LES modelling approaches have been developed in previous work, being validated in and applied to a wide range of turbulent flows. In the EU framework program, a series of noticeable collaborative work has been dedicated to improved hybrid RANS-LES methods, as well as to applications of hybrid RANS-LES models in numerical analysis of numerous flow problems in relation to, typically, unsteady aerodynamics, flow& load control and aero-acoustics. While hybrid RANS-LES modelling has been proved a powerful methodology in these and other previous work, its weakness and drawback has also been revealed for further improvement

AG54 has been established after EG69 and the work has been set up on the basis of AG49, which has explored the capabilities of a number of existing models in resolving underlying physics of typical aerodynamic flows. AG54 focuses further on effective RANS-LES coupling methods towards novel and improved hybrid modelling and embedded LES modelling.

Partners: Airbus-F, Airbus-Innovations (formerly EADS-IW), CIRA, DLR, FOI (AG Chair), INTA, NLR,ONERA (AG vice-Chair), Saab, TUM, UniMan, ZHAW

Programme/Objectives

Main objectives: By means of comprehensive and trans-national collaborative effort, to explore and further to develop RANS-LES coupling methods in the context of embedded LES (ELES) and hybrid RANS-LES modelling and, consequently, to address the "grey-area" problem in association with the RANS and LES modes and their interaction so as to improve ELES and hybrid RANS-LES modelling for industrial applications.

Work program: The work in AG54 is divided into three tasks. Task 1 and Task 2 deal with non-zonal and zonal hybrid RANS-LES methods, respectively, and an overall assessment of the developed methods is conducted in Task 3.

Task 1: Non-zonal modelling methods

(Task Leader: **NLR**)
For models with the location of RANS-LES interface regulated by modelling (not prescribed), typically, for DES-type and other seamless hybrid methods. Two TCs are defined.

TC M1 Spatially developing mixing layer
Initiated from two BLs of U_1 = 41.54 and U_2 = 22.40 m/s, respectively, with Re_θ = 2900 and 1200. Focus on modelling/resolving initial instabilities of the mixing layer.

TC O1 Backward-facing step flow
Incoming BL with U = 50m/s and Re_h = 40000. Focus on modelling/resolving the free shear layer detached from the step (h = step height).

Task 2: Zonal modelling methods

(Task Leader: **UniMan**)
For models with the location of RANS-LES interface prescribed, Including embedded LES. Two TCs are defined.

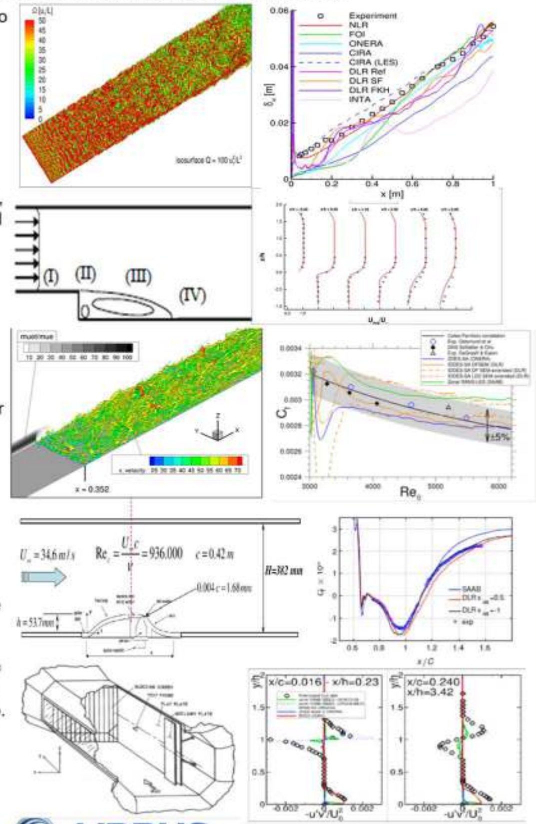
TC M2 Spatially developing boundary layer
Inflow defined with U = 70m/s and Re_θ = 3040. Focus on turbulence-resolving capabilities on the attached BL after the RANS-LES interface.

TC O2 NASA hump flow
Incoming BL has U = 34.6m/s, Re_c = 936000 (c = hump length). Focus on the turbulence-resolving capabilities on the flow separation over the hump.

Task 3: Modelling assessment

(Task Leader: **ONERA**)
Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.

TC M3 Co-flow of BL and wake
Re = 2.4x10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.



Results

- Further calibration and evaluation of hybrid RANS-LES methods of zonal and non-zonal modelling in computations of all test cases.
- Improved modelling formulation to enhance turbulence-resolving capabilities with special focus on "grey-area" mitigation.
- Assessment and verification of improved modelling in computations of different test cases by means of cross comparisons.

Summary:
The project kick-off took place in 2014. Since then, AG54 has had four progress meetings with the following results reported by AG members.

- Evaluation of existing baseline hybrid RANS-LES models in TC computations, including SST- & SA-IDDES, HYB0, HYB1, X-LES, ZDES, 2-eq. based hybrid zonal model, 2-velocity method, WMLES, LES, RSM-based hybrid model and other variants.
- For non-zonal hybrid RANS-LES modelling, improvement has been made on, among others, stochastic backscatter model plus temporal and spatial correlation, velocity-gradient-based energy backscatter, vorticity-based length scale and other verified hybrid length scale, commutation terms etc..
- For ELES and zonal hybrid RANS-LES modelling, methods of generating synthetic turbulence has been examined, among others, the synthetic eddy method (SEM) and its improved variant (e.g., DFSEM).
- All test cases have been well defined and experimental data have been used for modelling validation and verification.
- Progress of AG work has been made in line with the plan. Computations of TCs have been progressed well with relevant results reported and in cross plotting of partners results.
- Progress meetings were held in Oct. 2014, Oct. 2015, Nov. 2016 & Nov. 2017, respectively.

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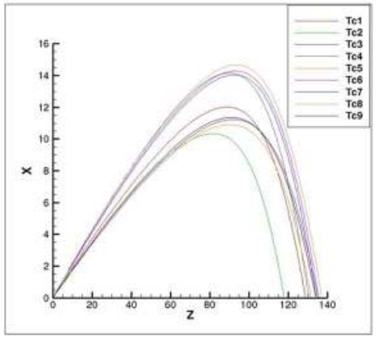
GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD/AG-55: Countermeasure Aerodynamics

Action Group Chairman: Torsten Berglind, FOI (torsten.berglind@foi.se)

The Background

Countermeasures are used to decoy enemy tracking systems. Two commonly used countermeasures are chaff and flares, which are the main focuses of this action group.
Chaff is a radar countermeasure consisting of small pieces or threads of metal or metalized glass fibre. Flares are used against IR-seeking missiles. They are a few decimetres in length and can have built in propulsions systems. In the test cases of this action group, counter-measures are ejected from generic aerial platforms. Their trajectories are significantly affected by the surrounding air.



Experimental flare tracks

The Programme

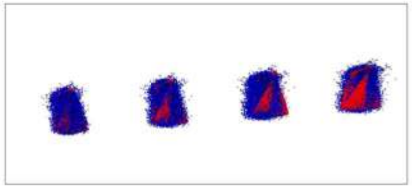
Objectives of AD/AG-55
The main objective is to evaluate computational methods to predict movement of countermeasures. The purpose of predicting chaff clouds is to be able to support development of tactics for usage of chaff. The trajectory of flares are important to predict accurately since the flare might damage the aircraft.

Approach
There are two main methods to simulate chaff dispersion, an Eulerian approach in which the chaff concentration is represented as a scalar field, and a Lagrangian approach in which individual chaff are tracked. Both methods are applied in a separate post processing step, assuming that the countermeasures do not affect main flow field properties.

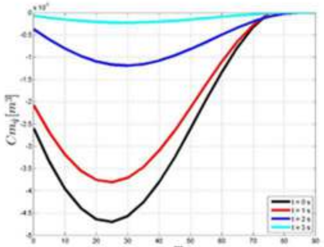
The ejection of a flare involves complicated physics. The cold flare model includes changes in shape, mass, moments of inertia in addition to 6 DoF movement. The hot flare model consists of the same features and in addition includes high boundary temperature flow and exhaust gases. The objective is to determine an appropriate level of modelling the flare that gives sufficiently accurate flare trajectories.

Partners: Airbus Defence & Space, Etienne Lacroix, FOI, MBDA, NLR

Project duration: January 2015 – June 2018



Lagrangian simulation of spherical chaff dispensed from a generic helicopter, FOI's results in blue and NLR's in red. The temporal increment between the chaff clouds is 0.1 sec.



Pitch damping coefficent

The Outcomes

Expected results/benefits
The action group is expected to yield increased understanding of simulation of chaff dispersion and flare trajectory modelling. A natural outcome is also that the partners obtain improved simulation tools

Management issues
One physical meeting, where all member organisations except LaCroix participated, was held at NLR in Amsterdam April 18th and 19th. In addition, four tele-conference meetings where hold on January 31st, June 20th, September 12th and November 8th.
This Action Group has applied for a 6 month extension since some additional computations and the major part of writing the final report remain.
The next tele-conference meeting is planned on February 7th. Eventually, there will be an additional physical meeting in Madrid during spring 2018.

Main achievements
A thorough investigation of deviations between FOI's and NLR's results has led to good agreement of the computational results. Evaluation has started comparing the movement of mass centre and standard deviation of chaff particle clouds.
Aerodynamic databases have been created for both the cold flare and hot flare models. Airbus D&S and MBDA have delivered a model for the aerodynamic damping of the flare.

FOI AIRBUS DEFENCE & SPACE LACROIX Protection Superiority MBDA MISSILE SYSTEMS nlr

Aviation Security

5.2 Group of Responsables – Aviation Security (AS)

5.2.1 GoR-AS Overview

The GoR AS focusses on basic and applied research in Aviation Security, exchanging ideas and experiences matured in different contexts. This topic is quite new in the scenario and expertise and results are spread over different activities. Most of work has a significant amount of multi-disciplinary content especially in domain different from aviation, so a lot of efforts have been dedicated to analyse external sources of information and assess current initiatives on aviation security with the aim to get awareness on the state of the art and build within Garteur a coherent harmonised approach with the external initiatives. This trend is driven by industrial interests, which have been properly analysed and the importance of multi-disciplinary work is likely to increase in the future. Two thesis have been finalised to build a common knowledge on topics of interest in the AS area.

The current scope of the security activities in the GoR covers the following:

- Cybersecurity for aviation critical assets
- Drone as threats and solutions

5.2.2 GoR-AS Activities

In 2019, working for the action group, by developing approached to protect critical infrastructures by intruder's attacks, GoR/AS has monitored the external funded initiatives on the topics of interest.

Specifically at AERODAYS2019 in Bucharest, the AS group (CIRA, INTA) and remotely via phone calls with ONERA and NLR, proposed the idea to participate in a H2020 call under H2020-SESAR-2019-2 (SESAR 2020 EXPLORATORY RESEARCH), topic asking for protection of airport operations by intruder's attacks.

ONERA, INTA and CIRA started to define the concept. They contacted other industrial stakeholders to participate in the call for proposal and in the development of the research concept.

Specifically they contacted:

- Eurocontrol
- ENAIRE, the Spanish Air Navigation Service Provider
- Aena, the first airport operator company in the world by number of passengers.

- SoulSoftware SRL
- Aerospace Laboratory for Innovative components (ALI Scarl)
- Two Italian companies providers of counter drone solutions.

The concept was developed and shared/finalised with the consortium and the proposal submitted obtaining a very high score, but due to budget constraints it was put in the reserve list.

The GoR AS approached the topic with basic and applied research in Aviation Security, exchanging ideas and experiences matured in different contexts (Rams analysis, operations, artificial intelligence to support detection and recognition, standardization and conops..).

Efforts have been dedicated to analyse external sources of information and assess current initiatives on aviation security with the aim to get awareness on the state of the art and build within GARTEUR a coherent harmonised approach with the external initiatives. This trend is driven by industrial interests, which have been properly analysed and the importance of multi-disciplinary work is likely to increase in the future.

A common knowledge on such a topic in the AS area has been developed and the ASGoR core team is continuously monitoring other initiatives and involving other European key stakeholders.

The current scope of the security activities in the GoR covers the following:

- Cybersecurity for aviation critical assets
- Drone as threats and solutions

The idea has been to launch such a topic as an action, it has built expertise about the chosen topic to start applying for collaboration opportunities.

5.2.3 GoR-AS Membership

Chairman		
Angela Vozella	CIRA	Italy
Vice-Chairman		
Francisco Munoz Sanz	INTA	Spain
Members		
Pierre Bieber	ONERA	France
Rene Wiegers	NLR	Netherlands
Andreas Bierig, Hans-Albert Eckel	DLR	Germany
Clive Goodchild	BAE Systems	UK

Table 4. GoR-AS Membership 2019.

Flight Mechanics, Systems and Integration

5.3 Group of Responsables – Flight Mechanics, Systems and Integration (FM)

5.3.1 GoR-FM Overview

The Group of Responsables for Flight Mechanics, Systems and Integration 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, including, but not limited to:

Aircraft multidisciplinary design aspects;

- Flight performance, stability, control and guidance;
- Aircraft navigation and mission management;
- Air traffic management and control;
- Integration of remotely piloted systems in the air spaces;
- Safety critical avionics functions and embedded systems;
- Scientific and technical expertise for air systems certification and regulatory aspects.

Noticeably, GoR-FM is not active in the rotary wing domain, where the GARTEUR Helicopter GoR leads.

5.3.2 GoR-FM Activities

The activities in 2019 have been limited to keep exploring new opportunities for joint approach.

The new Exploratory Groups identified in the past are still pending to be activated despite several efforts to staff the groups.

New topics discussed in 2016 were turned into pilot papers during 2017 but no Exploratory Group was established as the FM GoR meeting had to be postponed to 2019. New EGs are expected in 2019 and work has begun to ensure these are commissioned.

At present, topics under consideration are around the following research subjects described in 5.3.3.

5.3.3 GoR-FM Rolling plans

FM GoR Research Objectives	Subjects	CAT	2014	2015	2016	2017	2018	2019
C	Portable avionics	PP						
A	Electric RPAS	PP						
B	Smart RPAS swarms	PP						
A	Upset condition detection, prevention and mitigation	PP						
A	Verifiable adaptive robust control.	PP						
A	RPAS as validation flight test platform	PP						
B	RPAS autoflight	PP						
A	A Non-linear control benchmark EG28	PP/EG			No EGs started, possible restart 2019			
A	A Trajectory V&V Methods EG29	PP/EG						

AG		EG		Pilot Paper	
	Existing		Existing		Existing
	Planned		Planned		Planned

FM GoR Research Objectives - Legend	
A	Development and benefit assessment of advanced methods for analysis and synthesis of flight control systems for aircraft with both conventional and non-conventional aero structural configurations.
B	Development of advanced methods for UAV mission automation
C	Development and benefit assessment of advanced aircraft capabilities into ATM/ATC related applications

5.3.4 GoR-FM membership

Chairperson		
Mr. Martin Hagström	FOI	Sweden
Members		
Mr. Leopoldo Verde	CIRA	Italy
Mr. Philippe Mouyon	ONERA	France
Mr. Bernd Korn	DLR	Germany
Mr. Wilfred Rouwhorst	NLR	The Netherlands
Mr. Jaime Cabezas Carrasco	INTA	Spain
Industrial Pints of Contact		
Mr. Laurent Goerig	Dassault	France
Mr. Philippe Goupil	Airbus	France
Mr. Hans Kling	Saab	Sweden
Mr. Martin Hanel	Airbus Defence and Space	Germany

Table 5. GoR-FM Membership 2019.

Helicopters

5.4 Group of Responsables – Helicopters (HC)

5.4.1 GoR-HC Overview

The GoR-HC 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.

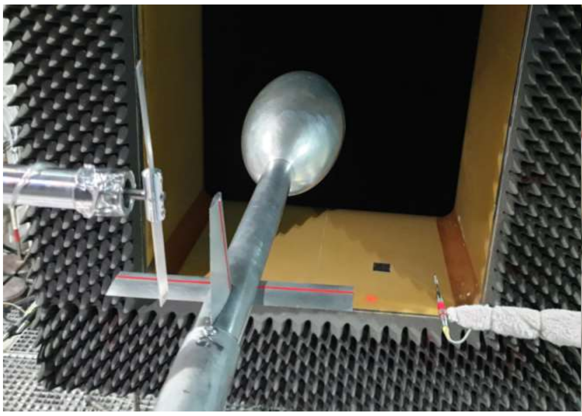
The GoR-HC initiates, organises and monitors basic and applied, computational and experimental multidisciplinary research in the following areas and in the context of application to rotorcraft vehicles (helicopters and VTOL aircraft, such as tilt rotors, compounds and multicopters) and systems technology.

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

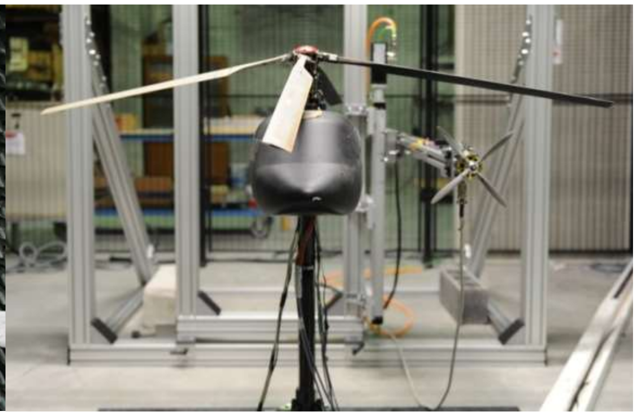
- Decrease costs (development and operation) through Virtual Engineering using numerical tools based on low-order (analytical, BEM) to high-order (CFD) methods, validated with relevant tests campaigns
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines, more electric rotorcraft ...)
- Increase security, 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, …
- Integrate rotorcraft better 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 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, tilt rotor, compound and multicopter 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.



Scattering Test with rotor model(HC/AG-24)



Generic Main Rotor/Propeller Configuration (ONERA) (HC/AG-25)

Figure 4. Illustrations of the Group of Responsables Helicopters.

5.4.2 GoR-HC Activities

In 2019, GoR/HC monitored the following action groups:

HC/AG-21	*Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity* Main goal of the project is the development of new simulation assessment criteria for both open-loop predictive fidelity and closed-loop perceived fidelity. Final simulation trials were done in 2016 and analysed in 2017. All technical activities are closed. The final report is in its proof reading phase and finalization is expected in 2020.
HC/AG-23	*Wind turbine wake and helicopter operations* The objectives are the analysis of the behaviour of helicopters in a wind turbine wake, the identification of the safety hazards and the definition of measures to mitigate identified safety issues. Partners have updated their computational flow

	and flight mechanics tools. Turbulent unsteady wind turbine wake fields have been computed and have been used to assess handling qualities of helicopter – Wind Turbine wake encounters. Piloted simulations have been performed. The final report was delivered in January 2019.
HC/AG-24	*Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction* The main objective is to examine 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 influence of a fuselage (2016-17 activities) and also include main/tail rotor interactions (on-going). The last test campaign initially planned for September/October 2017 was postponed to I/2019. The final report was delivered in October 2019.
HC/AG-25	*Rotor-Rotor-Interaction* The main objective is to investigate, both numerically and experimentally the effect of rotor / rotor and rotor / propeller wakes interactions on high speed rotorcraft operating in low speed conditions with the aim to establish low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes. The AG started in October 2019.

5.4.3 List of Exploratory Groups

The following Exploratory Groups were active:

HC/EG-38	*Verification & Validation: Metrics for the Qualification of Simulation Quality* To define metrics for the qualification of the quality of rotorcraft simulations, as a contribution to the Verification and Validation (V&V) process of numerical codes. The progress in this EG was limited and the workshop didn't bring the expected clarity for the next steps. As the topic is very relevant HC GoR will try support this EG in order to produce meaningful Terms of Reference for possible AGs.
HC/EG-39	*Testing and modelling procedures for Turbulent Boundary layer noise* To identify ways how to reduce the flow induced noise in rotorcraft. The chairman is currently a visiting scientist at NASA working on other topics. He will take up the EG-lead after his return in Sept. 2020.
HC/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 multi-rotor vehicles. This EG was identified in 2019 and is expected to be active in 2020.

5.4.4 List of New Topics

New topics which are under consideration are:

Acoustics of drone / e-VTOLs (noise sources)

To understand, predict and reduce the noise of drones / eVTOLS.

Modelling of electric systems for e-VTOLS (pre-design)

To provide simple relations for considering the electric system of eVTOLS in predesign.

Drone impact on Helicopters (rotating parts)

To gain insight in the severity level of drone rotor blade interactions.

Ice accretion and performance prediction on rotary wings

To improve the assessment of performance degradation when flying with rotorcraft in icing conditions.

Human Factors issues and Training methods for complex automation in cockpit

To improve the overall performance of the pilot / rotorcraft system in accomplishing misisons

PSP/TSP for rotors/propellers (drone,e-VTOLS...)

To assess the potential and the limitations of pressure and temperature sensitive paint in rotorcraft wind tunnel tests.

5.4.5 GoR-HC Membership

The membership of GoR-HC in 2019 is presented in the table below:

Chairperson		
Klausdieter Pahlke	DLR	Germany
Vice-Chairman		
Joost Hakkaart	NLR	The Netherlands
Members		
Mark White	Uni. of Liverpool	United Kingdom
Arnaud Le Pape	ONERA	France
Antonio Visingardi	CIRA	Italy
Francois-Xavier Filias	Airbus Helicopters	France
Rainer Heger	Airbus Helicopters	Germany
Antonio Antifora	Leonardo	Italy
Observer		
Richard Markiewicz	DSTL	United Kingdom

Table 6. GoR-HC Membership 2019.

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

HC/AG-23: Wind Turbine Wakes and Helicopter Operations

Action Group Chairman: Richard Bakker (richard.bakker@nlr.nl)

Interest of the research

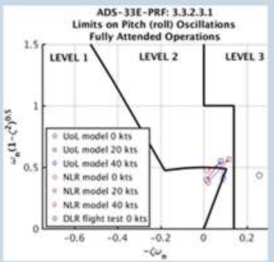
AG-23 investigates the impact of large wind turbine wakes on the flight safety of rotorcrafts.

Background

The amount of energy produced by wind turbines is still on the rise and seems to continue to do so in the near future. In addition the rotor size of wind turbines increases, with current rotor diameters that may range up to 126m.

At the same time we see the development that helicopters operate more and more in non-regulated airspace with the advent of medical air services, police surveillance and fire fighting helicopters etc., where they may encounter the air wakes from wind turbines.
More and more wind farms consisting of a large number of wind turbines are spreading across the North Sea. Also the military with their low level flying exercises are more likely to come upon the wind turbine wakes at some moment in time. Ultimately the likelihood of air traffic encounters with wind turbine wakes is increasing, showing the need for a detailed study on the interactions of rotorcraft and the wind turbine wake.

An extensive study of the wind turbine wake and its effect on helicopter flight with regard to stability, handling quality and safety has not yet been performed. The Action Group under the Garteur Group of Responsables Helicopters (GoR-HC) will aim to investigate the issue. This will be done by performing a survey on the wind turbine wake characteristics and using this data for the identification of relevant flow phenomena for the study of its effects on rotary flight.



Programme/Objectives

Objectives

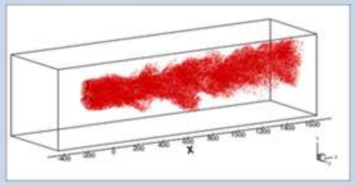
Despite the amount of literature on both wind turbine wakes and helicopter – fixed wing tip vortex encounters, not much research has been done on the interactions of wind turbine wakes and helicopter flight.
The aim of the Action Group is to set up a team of researchers from universities and research institutes to cooperate and perform the following activities:
•Perform a survey of available experimental and analytical wake data for typical wind turbines. Collect and assemble the data to produce a database of wind turbine wake properties. Identify appropriate wake characteristics with regard to the effect it has on the helicopter flight characteristics
•Define representative test cases for a wind turbine and helicopter combination. Several combinations of small/large helicopter and wind turbines, depending on available experimental data, available helicopter models, pilot-in-the-loop facilities etc. should be considered
•Perform computations and piloted simulator experiments and analyse the effects of wind turbine wake on the stability, handling qualities and safety aspects of a helicopter
•Validate the results of the computational tools and simulator trials with available experimental data.
•The group should provide recommendations for legislation and disseminate the findings to the appropriate authorities and parties concerned.

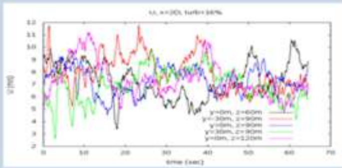
Programme

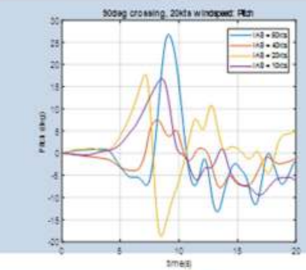
The programme consists of 5 work packages

0. Project Management and Dissemination
1. Wind turbine wake identification
2. Wind turbine wake experiments and computations
3. Helicopter - Wind turbine off-line simulations
4. Helicopter - Wind turbine wake piloted simulations.

The kick-off of the Action Group HC-AG23 took place 6 November 2014







Results

- Partners have updated their computational tools and have computed (turbulent) unsteady wind turbine wake fields
- Experimental data and calculated wind turbine wake velocity fields were shared, and have been used to harmonize the off-line simulation activities with a common wake velocity field
- Handling qualities of the UoL/DLR/NLR BO105 reference helicopter, have been compared w.r.t. stability, bandwidth, response, coupling etc. to use as a common helicopter reference model
- Piloted simulations have been performed or are being prepared
- WTN 250 Offline (Virtual Airdyn) and Piloted simulations show serious degradation of handling qualities levels. Considerable pilot effort at lower helicopter speeds with 30 knot wake
- NREL 5MW piloted simulations show rating 3 and higher for WT wake crossing (work on-going)

Members of the HC/AG-23 group are:

G. Barakos	University of Glasgow
M. Pavel	Technical University Delft
A. Visingardi	CIRA
P. M. Basset	ONERA
F. Campagnolo	Technical University Munich
M. White	University of Liverpool
S. Voutsinas	NTUA
B. Van der Wall	DLR
R. Bakker	NLR

GARTEUR Responsable:

J. Hakkaart	NLR

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

HC/AG-24: Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction

Action Group Chairman: Jianping Yin (Jianping.yin@dlr.de)

Background

A negative undesirable by-product of the helicopter during its operation is noise generation. Both the main and the tail rotors (including Fenestron) of a helicopter are major sources of noise and contribute significantly to its ground noise footprint. With rising concern for environmental issues and increasingly stringent noise regulation, helicopter noise has gained importance in comparing with performance, safety and reliability.

The main research effort in the past was concentrated on the helicopter rotor noise generation and the reduction of the noise. Extensive work, both theoretical and experimental helped to deepen the understanding of the noise generating mechanisms. Even though the scattering of noise generated by helicopter rotors has been recognized as a significant influence on the noise spectra and directivity, the research effort towards the scattering of noise, especially the scattering of tail rotor noise has not been studied extensively.

To accurately predict the effective helicopter external noise under the influence of the fuselage, advanced analysis tools that overcome the so-called free-field limitation of classical acoustic analogy methods are required. For this purpose, validations of the tools with the experiment data need to be conducted. Until now little activities for generating such database for validation are conducted. Moreover, the evaluation of the scattered acoustic field is of interest for the prediction of the internal noise in the fuselage and its vibrations that, in turn, are a source of interior noise. In addition, the possibility to develop and install acoustically treated panels (liners) on some parts of the fuselage and thus estimate the effect of a wall impedance on the external noise levels, require a particular care in the choice of the wave model. Concerning the helicopter interior noise, vibro-acoustic numerical analyses of different physical sophistication levels require the accurate knowledge of the acoustic pressure distribution on the external skin of the fuselage, and this can be only predicted through an accurate external noise computation.

Programme/Objectives

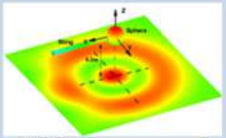
Objectives

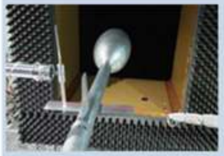
The present research work will address noise propagation in presence of the fuselage. The principal objective of HC-AG24 is then to promote activities to:

- establish unique quality database - for unsteady scattered acoustic pressure on the fuselage and in the far field as well as flow field, including flow refraction and convection effect;
- validated prediction design tools for main and tail rotor noise under influence of fuselage - including main/tail rotor interactions;
- proof of rotor noise reduction through adding acoustic absorbing liner on the part of fuselage.

The timescale for the project is three years during which the following topics are to be addressed:

- Investigate the capability and reliability of tools capable of predicting the effects of noise scattering problems;
- Perform computations of numerical benchmark cases and incorporation of the convective flow effects;
- Study the possibility to account for a surface impedance;
- Define representative test cases for generating a data base with a generic configuration, including sound pressure and flow field data





The work programme is structured in three work packages:

➢ WP 1: Simulation on the acoustic scattering effect

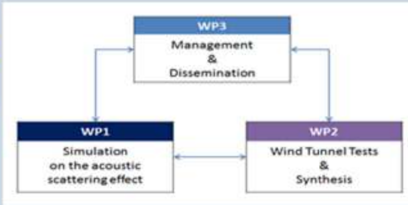
- Code adaptation & prediction
- Code validation & improvement of prediction tools
- Evaluation of noise scattering of various components using validated codes

➢ WP 2: Wind Tunnel Tests & Synthesis

- Model preparation
- Test preparation
- Model setup and installation
- Test matrix & instrumentation
- Test conduct
- Test data compilation & distribution
- Test data analysis

➢ WP 3: Management & Dissemination

- Action group Management
- Exploitation & Info dissemination
- Technology Implementation Plan (TIP)



Results

The action group started the activities in 1st of January 2015.

Six technical review meetings were conducted since the beginning of the action group. The following results were achieved during this period:

1. Description of available analytical, experiment test cases including database completed and distributed;
2. The common simulations for the sphere and NACA0012 wing scattering defined and the results comparied with the test. In addition the comparison results published in ERF 2016, 2017;
3. The Sphere scattering tests composed of 3 spheres, two support systems, and two noise sources were conducted and the results published in ERF 2016; Model tail rotor were manufactured, tested and published in ERF 2018;
4. Specifications on the test for the GARTEUR helicopter scattering defined. The generic helicopter were manufactured; tests for generic helicopter with three different sources has been conducted in 2019 at DLR Acoustic Wind Tunnel Braunschweig (AWB);
5. GARTEUR activities on acoustical methods and experiments is published in 2018 CEAS Aeronautical Journal;
6. 9 publications and 8 reports related to group were produced

Members of the HC/AG-24 group are:
(only contact persons are listed here)

M. Barbarino	CIRA (Vice Chairman)
C. Testa	CNR-INSEAN
J. Yin	DLR (Chairman)
H. Brouwer	NLR
G. Reboul	ONERA
L. Vigevano	Politecnico di Milano
G. Bernardini	Roma TRE University

GARTEUR Responsable:
K. Pahlke DLR

Centro Italiano Ricerche Aerospaziali
Marine Technology Research Institute
THE FRENCH AEROSPACE LAB

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

HC/AG-25: Rotor – Rotor Wakes Interactions

Action Group Chairman: Ronan Boisard (ronan.boisard@onera.fr)

Background

Almost all conventional helicopters have several rotors, from the classical helicopter with a main rotor and a tail-rotor, which has an anti-torque function, or the less classical tandem configuration with two side-by-side rotors, or the helicopters with co-axial rotors, or even tilt-rotors. In the context of the development of high speed compound helicopters, the main rotor cannot be used as an efficient propulsive device at high speed and most of the time a propeller has to be added in order to reach high advancing velocities. This multiplicity of rotors is also up-to-date in the field of UAVs, where the lifting function is more and more distributed on several rotors (sometimes more than 4).


The simultaneous use of rotating blades distributed around the airframe with planes of rotations that may differ adds a lot of aeromechanical complexity and can lead to complex unsteady interactions between the wakes emitted by the blades of the rotors or the propellers. It is legitimate to assume that such interactions, of aerodynamic nature, can have a significant impact on vibrations, on radiated noise and on aerodynamic performance, especially but probably not exclusively, in low speed conditions.

An overview of the available literature outline the fact that Rotor / Rotor and Rotor / Propeller wake interactions has been identified since the beginning of compound helicopters as extremely important for aircraft maneuverability and performances and is still an important concern for next generation of VTOL vehicles like multicopters. However, experimental databases are either extremely old or protected by the manufacturers. In such conditions it is almost impossible to improve and validate numerical tools without performing new experiments. Concerning the physical understanding of the interactions, the literature is scarce. Manufactures only focus on the overall aircraft stability, maneuverability and performances, and academic work is almost nonexistent, probably linked to the lack of freely available experiments.

Programme/Objectives

Objectives

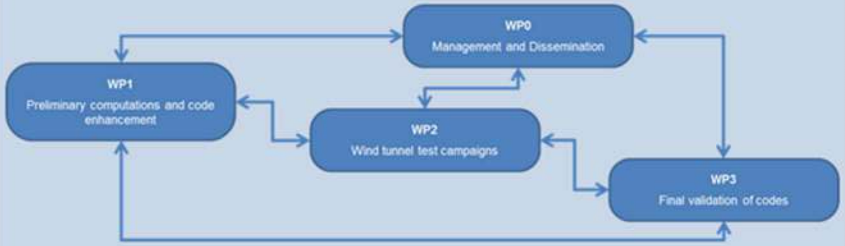
The principal objective of HC-AG25 is then to promote activities which could contribute to a better understanding and prediction of the aerodynamics of rotor / rotor wake interactions. This will be achieve by:

- Providing to the community extensive experimental databases about different kind of rotor / rotor and rotor / propeller interactions
- Validation and improvement of state of the art computational tools against experiments
- Improvement of low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes

The time frame for this program is three years during which both experiment and numerical simulations will be performed

The work programme is structured in four work packages:

- WP0 – Management & Dissemination: is aimed at the fulfilment of all the obligations concerning the project management and the dissemination of the results.
- WP1 – Preliminary Computations & Code Enhancements: deals with a preparation phase during which partners are involved in literature review and preliminary computational activities
- WP2 – Wind Tunnel Test Campaigns: concerns the performance of the different wind tunnel test campaigns:
  1. Rotor – Propeller Interactions (ONERA)
  2. Mach scaled Rotor – Propeller interactions (PoliMi)
  3. Rotor – Rotor Interactions (DLR)
- WP3 – Final Validation of Codes: is aimed at the final validation of the numerical tools proposed by partners.



Results

The action group started its activities on 1st of October 2019.

All the foreseen wind tunnel test campaigns are in a preparation phase.

The geometry of the Onera wind tunnel test was shared and all the partners involved in the numerical activities have start some pre-test computations.

Members of the HC/AG-25 group are:
(only contact persons are listed here)

R. Boisard	ONERA (Chairman)
A. Visingardi	CIRA (Vice-Chairman)
M. Kessler	IAG
G. Gibertini	PoliMi
T. Schwarz	DLR
S. Voutsinas	NTUA
G. Barakos	UoG

GARTEUR Responsable:

A. Lepape	ONERA

University of Stuttgart
Institute of Aerodynamics and Gas Dynamics

Centro Italiano Ricerche Aerospaziali

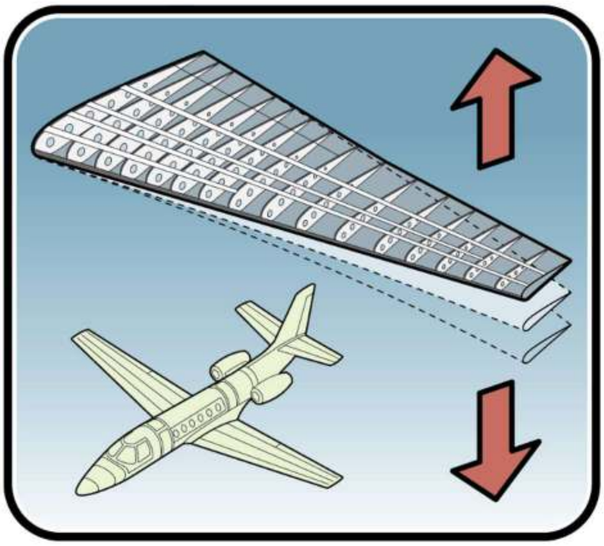
POLITECNICO MILANO

DLR

University of Glasgow

ONERA
THE FRENCH AEROSPACE LAB

Structures and Materials



5.5 Group of Responsables – Structures and Materials (SM)

5.5.1 GoR-SM Overview

The 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. Especially the integration of new functionalities is a key to further enhance the performance of materials. 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 group is active in theoretical and experimental fields of structures and materials to strengthen development and improvement of methods and procedures. Of great importance is the mutual stimulation of the diverse scientific approaches. Experiments give new insights into the mechanisms of structural behaviour that can be included in improved theoretical models. Finally, the theoretical results must be verified and validated by comparison with results from suitable experiments or trials.

The activities within the Action Groups cover several aspects of new technologies, new structural concepts and new design and verification criteria. Recent and current work is devoted to:

- Fatigue and damage tolerance assessment of hybrid structures;
- Damage repair in composite and metal structures;
- Bonded and bolted joints;
- Additive layer manufacturing.

5.5.2 GoR-SM Activities

In 2019, GoR/AD monitored the following action groups:

SM/AG-34	*Damage repair with composites* This AG started in the second half of 2012 and originated from SM/EG-40.
SM/AG-35	*Fatigue and Damage Tolerance Assessment of Hybrid Structures* This AG started in March 2012 and is a result from SM/EG-38.

The following Exploratory Group was active:

SM/EG-43	*Development of additive layer manufacturing for aerospace applications* The EG was formally started at the GoR fall (2014) meeting. A first meeting to set-up the project was held in April 2015. Since 2016 there have been only a few coordination activities among the partners. At the last GoR meeting, however, the topic was prioritized and it was decided to include additive manufactured plastics.

New topics which are under consideration are:

Multi-functional Materials with a focus on improving the electrical conductivity and structural health monitoring (SHM)
Multi-scale dynamics of joints: modeling and testing
New Methodologies for thermal-mechanical design of Supersonic and hypersonic vehicles
Composite Fire Behaviour
Structural Uncertainties
Aeroelasticity and aero-servo-elasticity
Thin ply laminates
Standardization of ice adhesion characterization

5.5.3 GoR-SM Membership

Chairperson		
Peter Wierach	DLR	Germany

Members		
Domenico Tescione	CIRA	Italy
Aniello Riccio	SUN	Italy
Javier San Millan	INTA	Spain
Thomas Ireman	SAAB	Sweden
Florence Roudloff	ONERA	France
Bert Thuis	NLR	The Netherlands

Industrial Points of Contact		
Roland Lang	Airbus Defence & Space	Germany
Angel Barrio	Airbus Defence & Space	Spain
Mathias Jessrang	Airbus Operations	Germany
Hans Ansell	SAAB	Sweden
Robin Olsson	RISE/Swerea SICOMP	Sweden
Andrew Foreman	QinetiQ	United Kingdom

Table 7. GoR-SM Membership 2019.

6 INTERNAL ANALYSIS AND GARTEUR ROADMAPS

6.1 Internal Analysis

During 2018, and aligned with established lines of action for the Spanish Chairmanship period, specifically the development of a Strategic Plan, the following activities were performed:

- Identification of Strengths, Weaknesses, Opportunities and Threads (SWOT).
- Prioritization of the SWOT items.
- GARTEUR self-assessment and positioning exercise.
- Main research streams.

The outcomes of the aforementioned activities will be used as the framework to define an action plan and the Strategic Plan in 2019.

6.2 GARTEUR Roadmaps

For an organization like GARTEUR is of a paramount importance to not only know what we have done, and doing but also what we will do during the upcoming years. The portfolio of EGs and AGs materializes the GARTEUR mission.

Over the 45 years of its existence, GARTEUR has developed an extensive research and technology portfolio delivering a wealth of leading edge projects. Research has traditionally focused on early stage, low TRL (Technology Readiness Level) technologies, guided by the wider European priority research areas as set out in section 4 and specifically the ACARE SRIA targets.

The civil aeronautical roadmaps are guided by the Strategic Research and Innovation Agenda (SRIA) developed by ACARE, providing a technology pathway to achieve the goals set out by Flightpath 2050. Defence drivers, out of scope for the SRIA, have been defined and driven by the respective Governments of the GARTEUR member states. Consultation through GARTEUR and its members, alongside the European Defence Agency (EDA), has allowed a coherent focus for defence goals. The roadmaps review past and current GARTEUR research activities providing a strategic pathway for technology development, ensuring future GARTEUR research activities align with the wider European strategic programmes.

The complete assessment of GARTEUR research activities across the five GoRs has focused on research undertaken through the Exploratory and Action Groups maximising impact. The chairs and members of the GoRs systematically review the relevance of the work being investigated in the Action Groups, Exploratory Groups or EU collaborations to the wider GARTEUR strategy, in addition to identifying links and interdependency between projects. The roadmaps also enable identification of collaboration opportunities both within and across the GoRs, providing a mechanism to measure impact against ACARE and defence targets. Further to streamlining research areas, the roadmaps also highlight where gaps may exist, from which an assessment can then be made as to whether these need to be acted upon or considered out of scope.

The established roadmaps in 2017 are under revision, and therefore the information in the following figures has not been updated. The main streams identified in the internal analysis will feed the future versions.

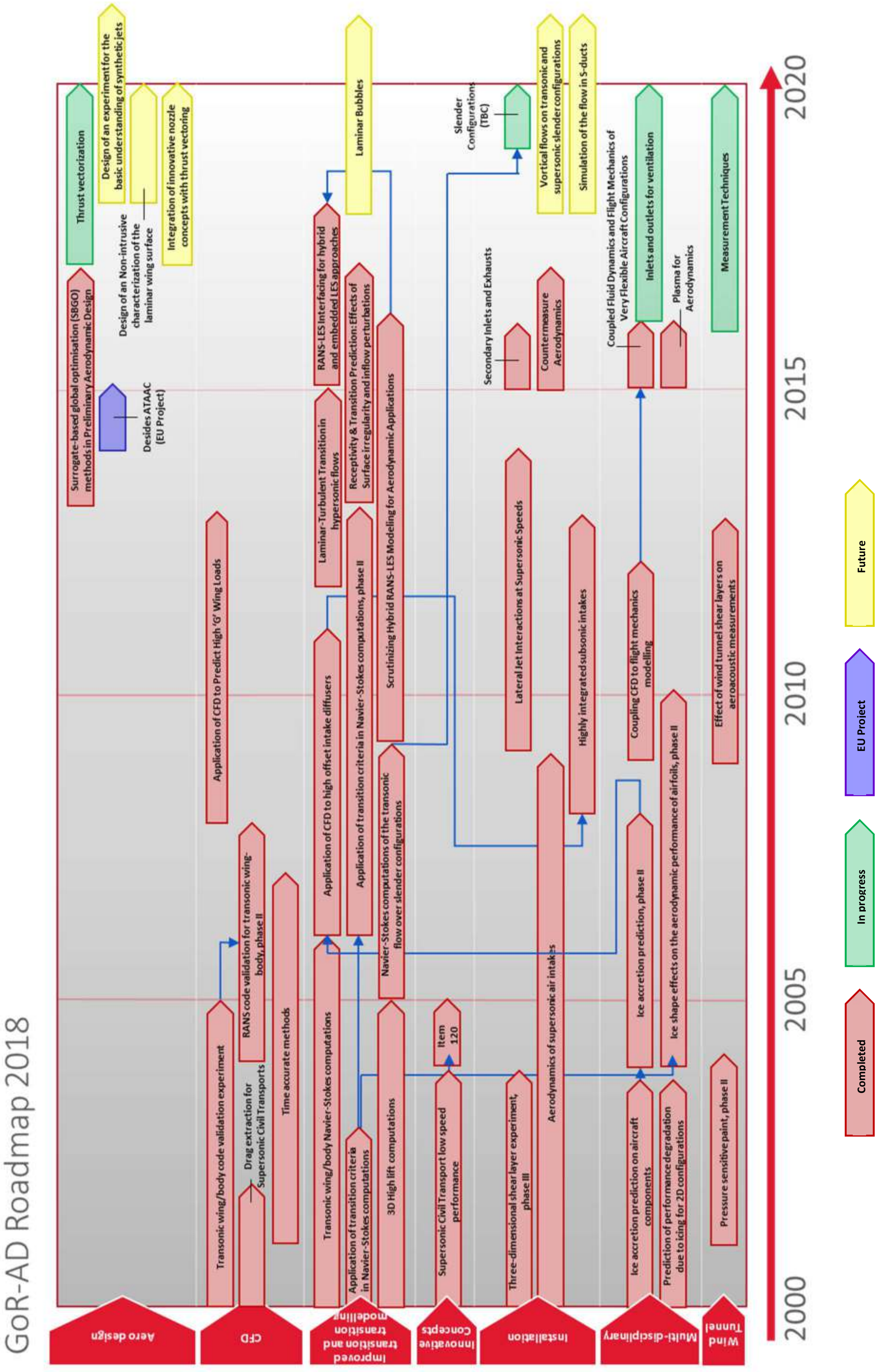


Figure 5. Roadmap for GoR Aerodynamics.

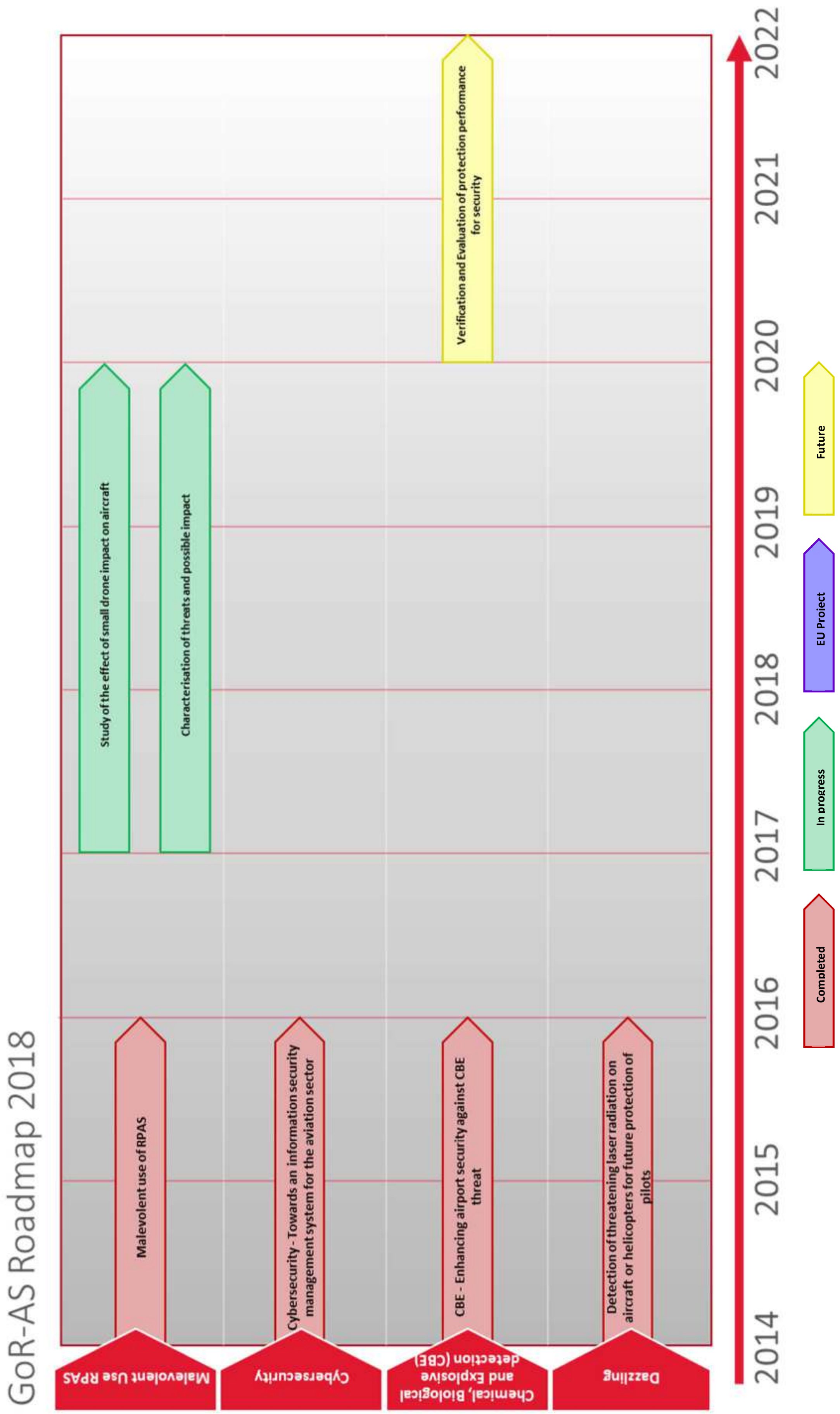


Figure 6. Roadmap for GoR Aviation Security.

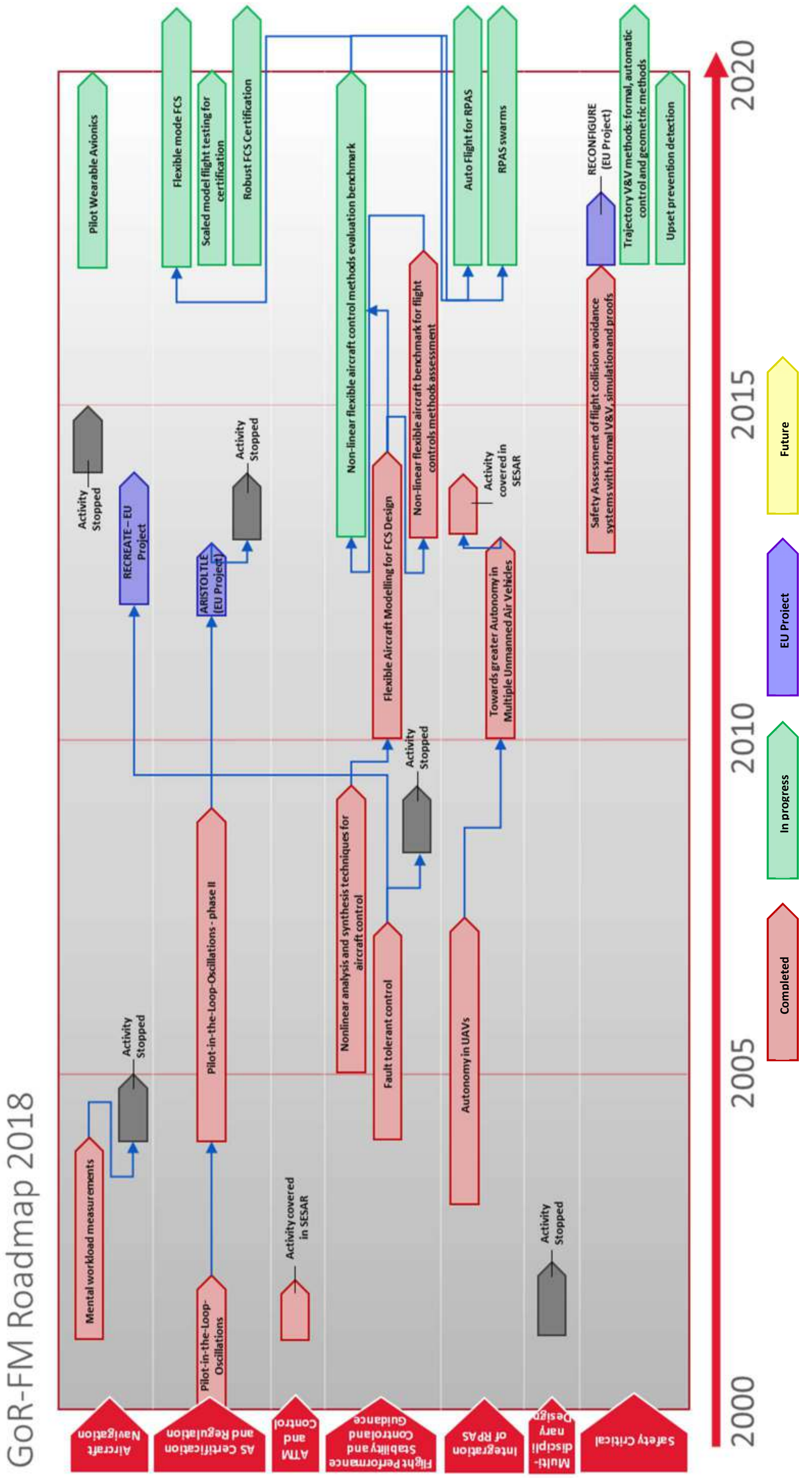


Figure 7. Roadmap for GoR Flight Mechanics and Systems Integration.

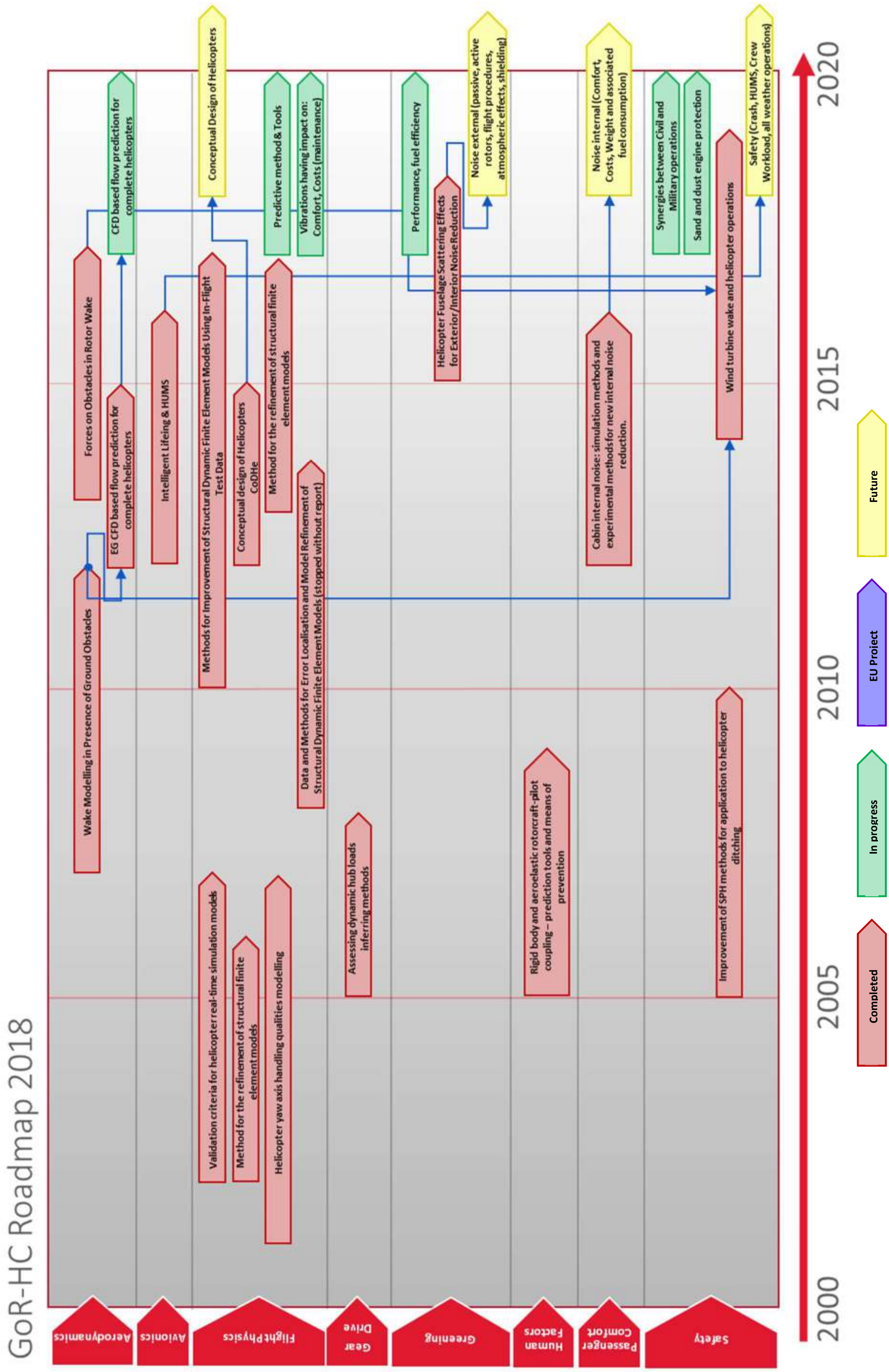


Figure 8. Roadmap for GoR Helicopters.

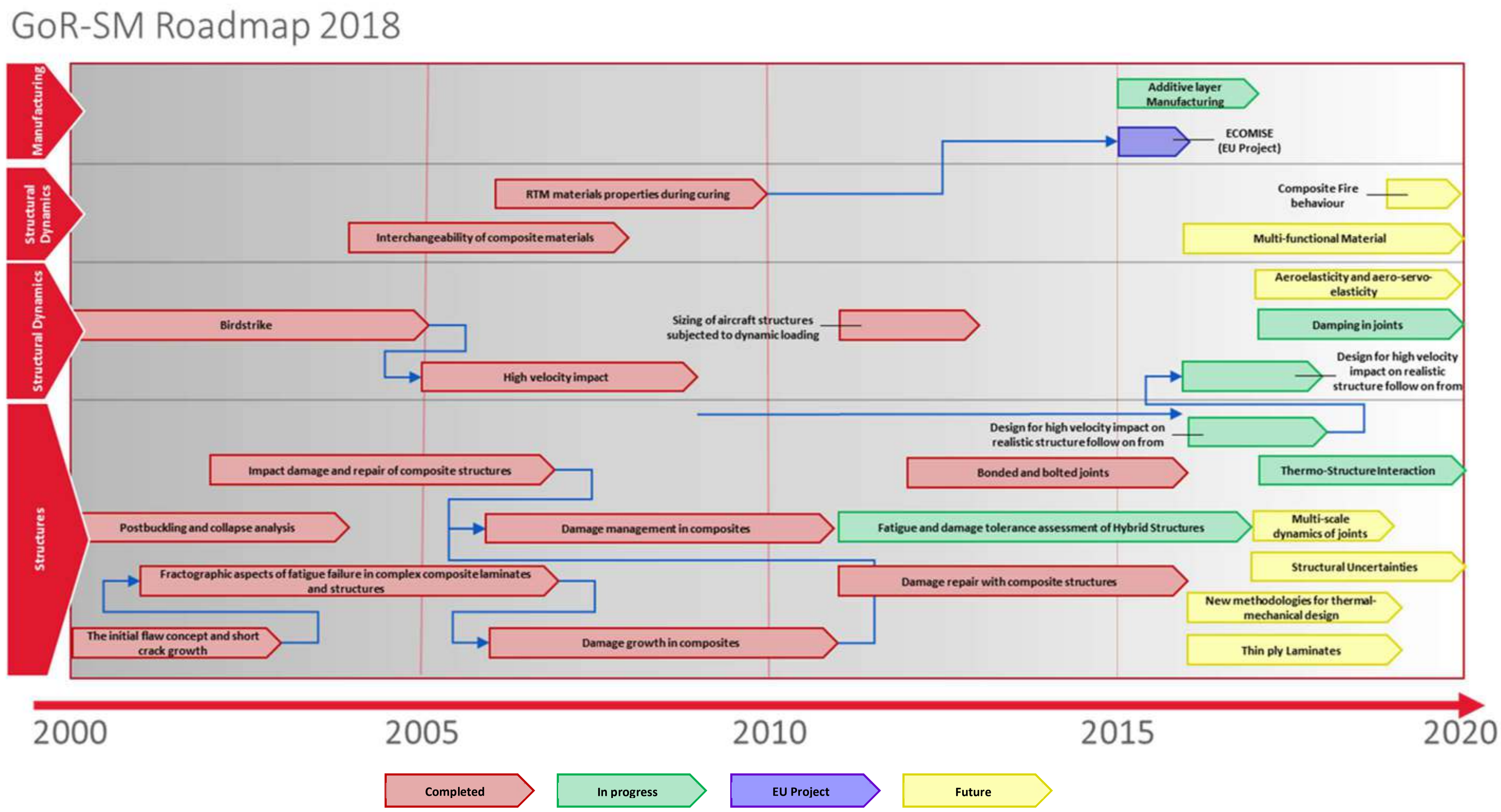


Figure 9. Roadmap for GoR Structures and Materials.

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8 LIST OF ABBREVIATIONS

ACARE: Advisory Council for Aviation Research and Innovation in Europe

AG: Action Group

AIRC: Aircraft Integration and Research Centre

ATI: Aerospace Technology Institute (UK)

BEIS: Department of Business, Energy and Industrial Strategy (UK)

CIRA: Italian Aerospace Research Centre

DGA: Direction Générale de l'Armement (France)

DLR: German Aerospace Centre

DNS: Direct Numerical Simulation

DSTL: Defence and Science Technology Laboratory (UK)

EASA: European Union Aviation Safety Agency

EDA: European Defence Agency

EDAP: European Defence Action Plan

EDRP: European Defence Research Programme

EG: Exploratory Group

ESMAB: European Defence Agency Single European Sky Military Aviation Board

ETP: European Technology Platform

EU: European Union

FOI: Swedish Defence Research Agency

FP: Framework Programme

GARTEUR: Group for Aeronautical Research and Technology in Europe

GoR: Group of Responsables

- AD: Aerodynamics
- AS: Aviation Security
- FM: Flight Mechanics, Systems & Integration
- HC: Helicopters
- SM: Structures & Materials

IAT: Ice Accretion Test

IPoC: Industrial Points of Contact

INTA: National Institute of Aerospace Technology (Spain)

JTI: Joint Technology Initiative

LES: Large Eddy Simulation

MALE RPAS: Medium-Altitude Long Endurance Remotely Piloted Aircraft System

MFF: Multiannual Financial Framework

NLR: Netherlands Aerospace Centre

ONERA: Office National d'Etudes et Recherches Aérospatiales (France)

PADR: Preparatory Action on Defence Research

PPP: Public-Private Partnership

RANS: Reynolds-Average Navier-Stokes

RPAS: Remotely Piloted Aircraft System

R&T: Research & Technology

RTD: Research & Technology Development

SEO: Search Engine Optimization

SES: Single European Sky

SESAR: Single European Sky Air Traffic Management Research

SME: Small and Medium-sized Enterprise

SRIA: Strategic Research & Innovation Agenda

TRL: Technology Readiness Level

UTM: Unmanned Traffic Management

XC: Executive Committee

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

GARTEUR Organisation 2019

GARTEUR Chair Country 2018-2019: Spain
Council Chair: Mr Bartolome Marques, Spain

XC Chair: Mr. Francisco Muñoz, Spain
Secretary: Mr. Jose Garcia, Spain

Function	**France**	**Germany**	**Italy**	**Netherlands**	**Spain**	**Sweden**	**United Kingdom**
Head of Delegation	J. L'Ebraly	J. Bode	G. De Matteis	C. Mekes	B. Marques	A. Blom	P. Griffiths
XC Member	O. Vasseur	-	L. Paparone	K. Wijnberg	F. Muñoz Sanz	E. Bernhardsdotter	S. Gates
Other Members of Delegation	P. Beaumier	H. Hemmer M. Fischer	-	C. Beers	J.F. Reyes-Sánchez	R. Stridh N. Tooloutalaie	S. Weeks S. Pendry M. Scott

GROUPS OF RESPONSABLES									
Aerodynamics (AD)		**Aviation Security (AS)**		**Flight Mechanics, Systems & Integration (FM)**		**Helicopters (HC)**		**Structures & Materials (SM)**	
GoR AD members		**GoR AS members**		**GoR FM members**		**GoR HC members**		**GoR SM members**	
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N. Ceresola	IT	AS IPoCs will be included very soon		L. Goerig	FR	HC IPoCs included above		A. Barrio Cardaba	ES
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