# GARTEUR

ANNUAL REPORT 2017

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

# GARTEUR ANNUAL REPORT 2017

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# 1 INTRODUCTION

2017 represented GARTEUR's 45th year facilitating research and technology (R&T) collaboration in aeronautics across civil and military platforms. GARTEUR is a unique forum for European science and technology collaboration, bringing together leading representatives from industry, government departments and research institutions across Europe to investigate key challenges for European and global aeronautics. GARTEUR's scope, covering civil, defence and dual use applications in aeronautics, is unique in Europe allowing knowledge transfer between the two fields and exploiting value through this unique mechanism.

2017 also represented the second and concluding year of the UK's biennial chairmanship of GARTEUR, with the Spanish assuming the role in January 2018. During the UK chairmanship the Aerospace Technology Institute (ATI), a joint government and industry venture responsible for creating and realising the UK's civil R&T strategy for aerospace, has provided administrative and strategic support, assisted by Cranfield University.

The UK chairmanship continued its focus on developing a strategic roadmap for GARTEUR, ensuring future research activities undertaken are in line with European goals set out in the Strategic Research and Innovation Agenda (SRIA) as defined by the Advisory Council for Aviation Research and Innovation in Europe (ACARE). A great deal of progress has been made, mapping previous GARTEUR activities, demonstrating the value of work already undertaken, and defining future research agendas providing guidance to ensure programmes are at the forefront of European research. GARTEUR's Groups of Responsables now own these roadmaps, which will be regularly reviewed and updated in line with the wider strategic research agenda.

The UK is grateful to its GARTEUR colleagues for their support and collaboration over the past two years and looks forward to continuing its participation in GARTEUR during the Spanish chairmanship.

# 2 EXECUTIVE SUMMARY

The GARTEUR Annual Report 2017 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 safety and security.

Chapter 3 of this report provides a summary of Council activities, including the changes in chairmanship and membership. 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 2017 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 2017. This document is accompanied by the Annexes to the Annual Report 2017 in which the Aerodynamic (AD) and Helicopter (HC) GoRs present a more detailed account of their activities. The Annexes are available in electronic format from the GARTEUR website. Information on the GARTEUR roadmaps can be found in section 6. A list of colleagues who received certificates in recognition of their services to GARTEUR is also included. Chapter 7 provides an account of GARTEUR success stories which provides an example of the benefits GARTEUR membership in facilitating excellent research.

Finally, the Appendix includes a selection of administrative figures pertaining to GARTEUR organisation and GoR activities.

# 3 GARTEUR COUNCIL

## 3.1 Chairmanship and membership

On the 1st of January 2016, the United Kingdom succeeded France as chair of GARTEUR for a period of two years, ending on the 31st of December 2017. The UK handed over the chairmanship to the Spanish in early January 2018.

During 2017 the Chairman of the Council was Paul Griffiths of the Department of Business, Energy and Industrial Strategy (BEIS), with Malcolm Scott of the Aerospace Technology Institute (ATI) as chairman of the Executive Committee. Collette Haig from Cranfield University served as GARTEUR secretary during 2017.

## 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

- XC158 – 16th February 2017 via Telecom
- C62 – 16th and 17th March 2017, Amsterdam (NL)
- XC159 – 5th October, Madrid (ES)
- C63 – 17th and 18th November, Cranfield (UK)

### 3.2.1 XC158

XC158 was the first GARTEUR meeting to be held by telecom. The main purpose of the meeting was to develop a robust agenda for the forthcoming Council meeting (C62) and to review the outcomes from the previous XC157 and C61. Two key topics were discussed and shaped for discussion at C62.

A review of GARTEUR’s position in the existing and evolving landscape of the European R&T market should be addressed by Council delegates, particularly in relation to the mid-term review of Horizon 2020, the Strategic Research & Innovation Agenda (SRIA) and GARTEUR’s ongoing road mapping exercise. The second proposed topic was to discuss the value of adding propulsive research into GARTEUR’s remit.

### 3.2.2 C62

The first Council meeting of 2017, C62, was held in Amsterdam, hosted by the NLR on the 16th and 17th March. The meeting was chaired by Malcom Scott and discussed the above topics raised at XC158 alongside the traditional Council agenda items. An update on the progress of the road mapping exercise was discussed at length with a focus on ensuring the outputs from the workstream are implemented into GARTEUR strategy moving forward, including aligning GARTEUR activity to the wider European R&T programmes. Issues pertaining to the operational aspects of the road maps themselves were also reviewed to ensure costs were minimised, access was granted to all GoRs and above all they remained secure.

The proposal identified by the XC158 regarding expanding GARTEUR's remit to research propulsive technologies was discussed by the Council, but a decision was delayed on the matter to investigate it further.

The Council also discussed an approach from the Turkish Ministry of Transport who expressed an interest in collaborating on GARTEUR research activities. The response was open from the Council, who provided the Turkish Ministry of Transport with a written response detailing the steps required to set up a collaboration. There was no follow up from the Turkish entity to this by the end of 2017.

### 3.2.3 XC159

XC 159 was hosted in Madrid, Spain, by INTA. The meeting prepared the agenda for the forthcoming C63 and to review outstanding actions and outcomes from XC158 and C62. Four additional large topics were discussed at this meeting focusing on the activities and practices of the Working Groups and Action Groups and to review the process for a new research activity.

Following on from discussions at XC158 and C62, it was decided that GARTEUR would not pursue a research element focusing on propulsion as it was concluded that there was sufficient activity elsewhere in Europe and GARTEUR's resources could be best utilised in its existing structure.

### 3.2.4 C63

The C63 was hosted by the ATI at the new Aircraft Integration and Research Centre (AIRC) recently opened at Cranfield University and was chaired by Malcolm Scott. After review of outstanding actions, the GoR chairs gave updates from their respective fields.

A number of topics were discussed at length at C63, including a proposal from Ice Accretion Test (IAT) working group, headed by the Fraunhofer Institute, for collaboration with GARTEUR, and updates on the European Defence Agency's activities, with a view to how GARTEUR activities can align with the current strategies.

Two guest speakers gave presentations to the Council. Pete Martin from the Defence and Science Technology Laboratory (DSTL) gave an overview of work in the UK and where its research interests were fixed. Professor Graham Braithwaite of Cranfield University also gave an in-depth lecture to the Council on safety in the aerospace industry and the work being led by Cranfield University to further the research and standards in this area.

## 3.3 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 2017 the website was regularly updated by the secretary.

## 3.4 GARTEUR certificates

In 2017 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** | | |
| Christophe Griseri | Head of French delegation | DGA/DT/ST/IP/ASA |
| Frank Simon | Chair of GoR Helicopters Action Group 20 | ONERA |
| Jean-Pierre Grisval | Chair of GoR Structures & Materials (2014-2015) | ONERA |
| **Germany** | | |
| Horst Hueners | Member of the Council | DLR |
| Henning Rosemann | Member of GoR Aerodynamics | DLR |
| Geza Schrauf | Member of GoR Aerodynamics | Airbus-Deutschland |
| Herbert Bieler | Member of GoR Aerodynamics | Airbus-Deutschland |
| **Italy** | | |
| Esther Andrés | Chair of GoR Aerodynamics Action Group 52 | ISDEFE / INTA |
| Emiliano Iuliano | Vice-chair of GoR Aerodynamics Action Group 52 | CIRA |
| Massimo Riccio | Member of GoR Structures & Materials | Alenia Aermacchi |
| **The Netherlands** | | |
| Mike van Weelderen | Head of Dutch delegation | Ministerie van Defensie |
| Hans van Tongeren | Chair of GoR Helicopters Action Group 19 | NLR |
| Koen de Cock | Member of GoR Aerodynamics | |
| **Sweden** | | |
| Torsten Berglind | Member of GoR Aerodynamics | FOI |
| Ernst Totland | Member of GoR Aerodynamics | Saab |
| Joakim Schön | Member of GoR Structures & Materials | FOI |
| **UK** | | |
| Frank Ogilvie | Chair of GoR Aerodynamics (2014-2015) | |
| Chris Newbold | Member of GoR Aerodynamics | QinetiQ |
| Norman Wood | Member of GoR Aerodynamics | Airbus |

*Table 1 Awardees of GARTEUR Certificates*

# 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.

In 2017 organisations from European countries were invited to provide feedback for Horizon 2020's interim evaluation. This consultation has been used in some part to advise the Commission on the development of the successor Framework Programme (FP9).

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.

During 2016/17, the SRIA the was subject of a review, accounting for the significant developments that have happened in the aeronautics industry over the past five years. This prompted the latest review of the SRIA to ensure it is relevant to address the priorities for research and innovation in Europe. The review also offered the opportunity to simplify the document and the revised document will be produced within the parameters of a streamlined structure. An online database is also available to navigate and detail the key research areas[2].

### 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 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.

[1] ACARE - Strategic Research & Innovation Agenda – 2017 Update Volume 1
[2] ACARE - Strategic Research & Innovation Agenda – Volume 2

### 4.1.4 Mid-term review and Lab-Fab-App

In May 2017 the European Commission published the results of its mid-term review, a consultation process designed to assess whether the programme was achieving its goals and adding value to European innovation.

ASD and ACARE lead the response of the aeronautics, aviation and defence industries across Europe with significant input from member state organisations. GARTEUR supported the ACARE view – expressed within the ACARE input to the Horizon 2020 mid-term review - that further resources could be allocated to low-mid TRL projects which are important to supporting the ground-breaking projects being undertaken by the Clean Sky JTI.

In 2017 the European Commission's High-level Group of Experts, chaired by Pascal Lamy, published a report to outline a vision and strategic recommendations to maximise the impact of European research and innovation. The report entitled "LAB – FAB – APP: Investing in the European Future We Want" emphasises the key outcome that investing in research and innovation is increasingly crucial for shaping a better European future in a rapidly globalising world, where success depends ever more on the production and conversion of knowledge into innovation[3].

Its recommendations focus on maximising the impact of EU investments in research and innovation in order to increase prosperity and solve our biggest societal challenges through three main actions:

- More investment in research ("Labs");
- Better conversion of the results of science into innovative solutions that generate value for economy and society ("Fabs"); and
- Applications of the solutions for the benefit of all, involving society ("Apps").

The Group's eleven recommendations:

- Prioritise research and innovation in EU and national budgets, including a doubling of the budget of the post-2020 EU research and innovation programme;
- Build a true EU innovation policy that creates future markets;
- Educate for the future and invest in people who will make the change;
- Design the EU R&I programme for greater impact;
- Adopt a mission-oriented, impact-focused approach to address global challenges;
- Rationalise the EU funding landscape and achieve synergy with structural funds;
- Simplify further, prioritise impact over process;
- Mobilise and involve citizens;
- Better align EU and national R&I investment;
- Make international R&I cooperation a trademark of EU research and innovation; and
- Capture and better communicate impact.

The Group's proposal was not only addressed to European institutions but to the wide range of stakeholders engaged in research and innovation, such as national governments, universities, industry and research institutions.

The outcome of this group is expected to feature prominently in the definition and scoping of the future FP9 programme, the successor to Horizon 2020.

[3] Lab-Fab-App - Investing in the European Future We Want. Report of the independent High Level Group on maximising the impact of EU Research & Innovation Programmes

## 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 (EDA 2016b). 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 Commission backed a proposal in December 2016 for a European Defence Fund to support and supplement member states' national investments in joint defence capabilities. This fund was outlined in the European Defence Action Plan (EDAP) outlining how Europe will synergise its defence research spending, investing in common development of technologies and equipment of strategic importance. The plan sets out greater cooperation between member states and greater pooling of national resources.

The European Defence Fund consists of two legally distinct but complementary windows, a ‘research window’ to fund collaborative defence research projects at the EU level, and a ‘capability window’ to support the joint development of defence capabilities commonly agreed by the member states. To ensure cohesion between the two windows, a coordination board consisting of representatives from the Commission, the High Representative, the member states, the European Defence Agency, as well as industry as appropriate will oversee both activity streams. Both are being deployed in a gradual manner and the support provided by the EU budget will be tailored to the phase of the industrial cycle concerned.

The research window is already beginning to finance collaborative research in innovative defence products and technologies at EU level. The first steps toward the future programme have already been taken with the launch of the Pilot Project and the launch of the Preparatory Action on Defence Research (PADR), with a total expected budget of €90 million over three years. The budget for the PADR related actions is split in three years as follows:

- €25m in 2017 (already committed, first projects starting);
- €40m in 2018 (approved and calls for proposals open for submission);
- €25m in 2019 (to be confirmed and approved)

This funding will ultimately form part of the EU’s dedicated programme under the next Multiannual Financial Framework (MFF) with the estimated budget being around €500 million per year. The proposal for this defence research programme will be made during 2018 in order for it to be operational on 1 January 2021. The fund will aim to improve commitment to defence spending, in order to improve Europe's defence capabilities and also to strengthen the EU defence industry which is a major contribution to the European economy. In response to these developments the EDA is reviewing its engagement with industry and R&T.

The future defence research programme will benefit from a tailor-made governance structure, reflecting the specificities of the defence sector. It will be designed in light of the experience gained through the Pilot Project, the Preparatory Action and the governance structures in Horizon 2020.

### 4.2.3 Single European Sky Military Aviation Board

There are over 11,000 military aircraft stationed in Europe[4] that must integrate into the continent's busy skies, that can see up to 35,000 flights a day[5]. As Europe continues to modernise its air traffic management with the Single European Sky (SES) programme, the EDA has adopted the role of the primary interface with EU institutions for the military community (acting without prejudice to national sovereignty) ensuring defence issues are strongly represented. With the military operating in its multiple roles of air navigation, airspace user, airport operator and regulator, they play a key role in policy decision making and the day-to-day consultation process across all areas of SES.

The EDA has established the SES Military Aviation Board (ESMAB) in response to the need for proactive coordination with states and international organisations, bringing together expertise from across the sector. Meeting every year, ESMAB provide coordination and cooperation with Member States and international organisations to prevent any adverse impact on national and collective defence capabilities.

[4] European Defence Agency, SESAR: The Military in SES/SESAR: Partnering for safe and efficient skies
[5] Eurocontrol

# 5 SUMMARY OF GARTEUR TECHNICAL ACTIVITIES

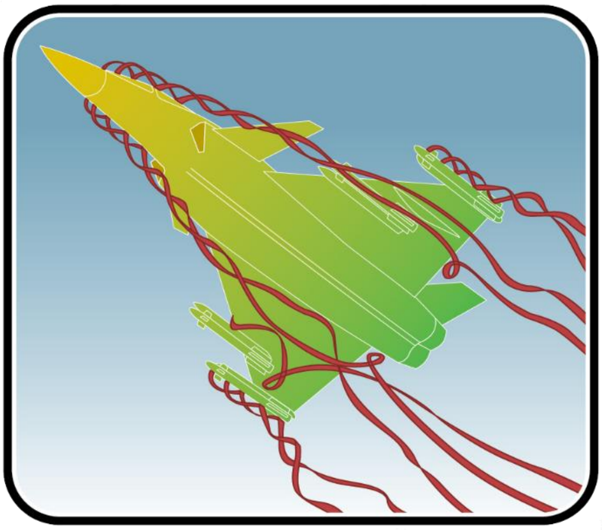
During 2017 the five GARTEUR Groups of Responsables (GoRs) continued to facilitate and deliver vital research in the field of aeronautics. The GoRs are responsible for monitoring and encouraging the progress of Action Groups (AGs) and Exploratory Groups (EGs). These groups are collaborations of researchers 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)

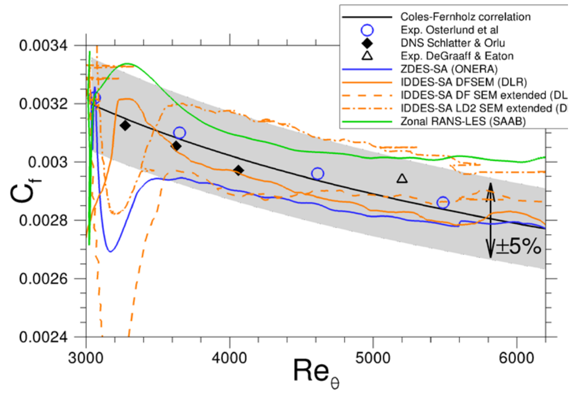
## 5.1.1 Overview

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.

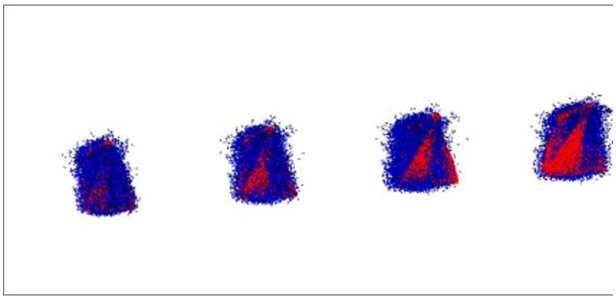
The current scope of the aerodynamic activities in the GoR covers the following:

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

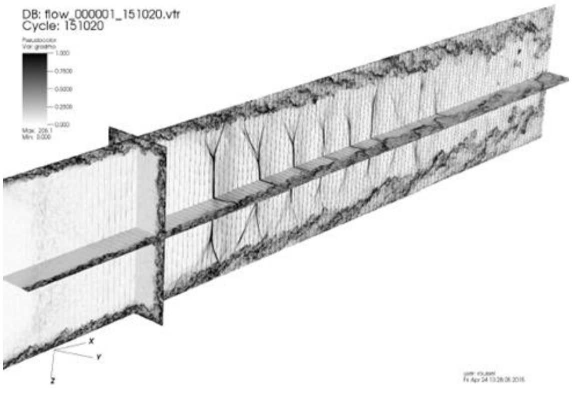
In all fields a synergy between experiments and simulations is aimed for.



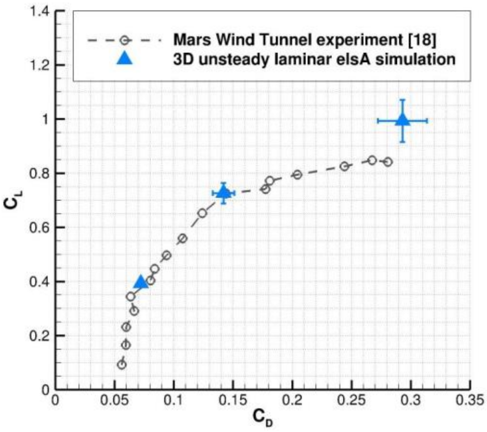

*Validation of synthetic turbulence approach for a turbulent boundary layer(AG-54)*



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




*Supersonic air intakes (EG-75)*




*Laminar separation bubbles (EG-76)*

*Figure 1: Illustrations of the Group of Responsables: Aerodynamics*

### 5.1.2 GoR-AD Activities

In 2017, 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 2017 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 2 GoR-AD Membership 2017*

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.

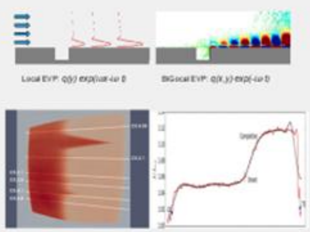
KTH have completed highly accurate simulations of the leading-edge acoustic receptivity, showing pervious results overestimating the receptivity coefficient. KTH has also performed direct numerical simulations of the interaction of acoustic waves with roughness-induced crossflow vortices, corresponding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

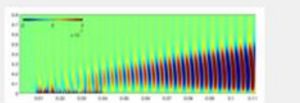
### Gap Analysis

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

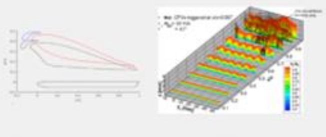


Left: TSP data from the ring wing (ALFET) experiment. Right: The use of TSP intensity ratio to determine transition.

### Receptivity model development



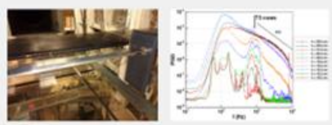
Perturbations generated by randomly distributed surfaces roughness of 5 microns.



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

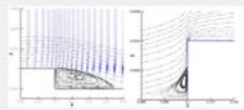
### Receptivity & transition experiment

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

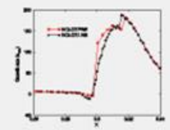


Left: Free stream turbulence was introduced through the turbulent wake of a small wing placed upstream the main wing. Right: Effect of distance from wake on generation and growth of perturbations inside the boundary layer over the ONERA D wing. h is distance between the two wings.

### Backward/Forward-facing step



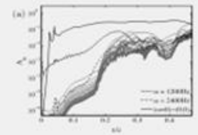
Mean-flow field from CFD.



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

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# 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

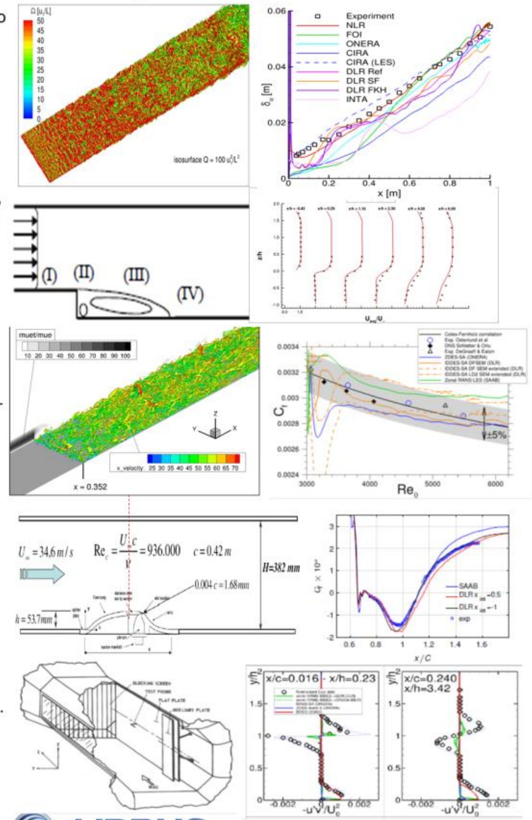
**Main objectives:** By means of comprehensive and trans-national collaborative effort, to explore and further to develop RANS-LES coupling methods in the context of embedded LES (ELES) and hybrid RANS-LES modelling and, consequently, to address the "grey-area" problem in association with the RANS and 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 $Re_\theta$ = 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 $Re_\theta$ = 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 = $2.4 \times 10^6$/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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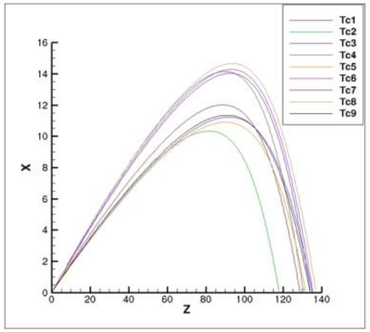
# AD/AG-55: Countermeasure Aerodynamics

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

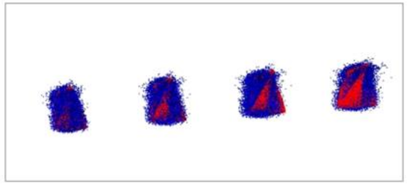
**Objectives of AD/AG-55**
The main objective is to evaluate computational methods to predict movement of countermeasures. The purpose of predicting chaff clouds is to be able to support development of tactics for usage of chaff. The trajectory of flares are important to predict accurately since the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

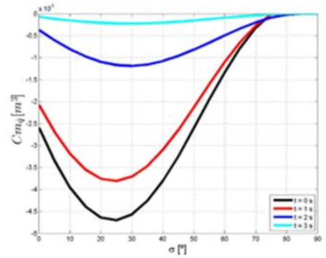
The ejection of a flare involves complicated physics. The cold flare model includes changes in shape, mass, moments of inertia in addition to 6 DoF movement. The hot flare model consists of the same features and in addition includes high boundary temperature flow and exhaust gases. The objective is to 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.

# *Aviation Security*

## 5.2 Group of Responsables – Aviation Security (AS)

### 5.2.1 GoR-AS Overview

The Group of Responsables on Aviation Security was created during the GARTEUR Council meeting in March 2014. This GoR is composed of specialists from research establishments and industry who have identified relevant topics to be studied in the aviation security area. GoR AS pursues research in aviation security dealing with both military and civil R&T.

The research fields are:

- Cybersecurity in aviation;
- Chemical, Biological and Explosive (CBE) detection;
- Dazzling; and
- Malevolent use of Remotely Piloted Aircraft Systems (RPAS).

Activity in 2017 focused on research in Cybersecurity and Malevolent use of RPAS. The decision was made not to devote much effort into Chemical Biological Explosive detection and Dazzling.

The approach in 2017 has been aimed at finalising topics for collaborative research, ensuring that they are;

- In line with FlightPath 2050;
- Represented in the ACARE SRIA update and its dedicated Challenge on Aviation Safety & Security;
- Aligned with the Preparatory Action for Defence Research (PADR) in Horizon 2020 and FP9; and
- A priority for Europe

The main actions in 2017 were:

1. To focus attention on Aviation Cybersecurity and RPAS and assess the current research landscape for these topics and identify research challenges and potential collaboration opportunities.
2. To generate involvement from industry interested in the topics.
3. To support existing initiatives in aviation security at European level and to promote harmonization among them with GARTEUR.

### 5.2.2 GoR-AS Activities

Activities undertaken during 2017 included:

- The identification of the main actors and capabilities at national level
- The analysis of the approaches in use for the GoR
- The collection of the relevant data
- The integration of data at GARTEUR level

A planning meeting was held among the AS GoR members in July 2017, in which information was shared about the current activities taking place in each Research Centre represented in order to identify common research topics. According to recent activities within cybersecurity and risk assessment for aviation systems, NLR suggested the following topics for collaboration:

a. Harmonization of the approach for development of a Cyber Security Management System for bodies operating in this area. According to the 'Framework for Aviation Cybersecurity'[6] by the AIAA the following R&D topics have been suggested:
    1. Creating secure and resilient system architectures, including methods for maintaining secure data transfer, isolating critical data, and effectively recovering from attacks;
    2. Determining system vulnerabilities;
    3. Improving attack detection; and
    4. Ensuring forensic readiness.

b. Considering the theme of cybersecurity, NLR proposed to focus on: Cyber aspects of manned and unmanned military aerospace systems in relation to mission assurance looking at digital identities, software, data, protocols and digital connections in the operational phase.
   Such themes have been investigated within international collaborations with NATO (NATO IST-151 'Cyber Security of Military Systems, NATO IST-ET-099 'Mission Assurance and Cyber Risk Assessment for Multi-Domain Unmanned/Autonomous Vehicles and Systems').

In alignment with the NLR, CIRA has devoted efforts to the theme cyber-attacks for RPAS by implementing a study on threats and vulnerabilities. Based on experiences at military level, a classification for the possible attacks has been derived and then possible mitigation approaches have been defined according to the identified impacts. Specifically, the study of vulnerabilities of GPS, C2 link, ADS-B Vulnerabilities together with the analysis of their functional consequences and assessment of their impact on flight safety have been carried out.

Furthermore, the identification of future work has commenced in preparation to launch collaborative activities and a set of possible research challenges has been derived. CIRA has performed an analysis at national level to assess the involvement of the main Italian stakeholders on this topic, including Aeronautica Militare, Law enforcement agencies, Italian Civil Aviation Authority, Leonardo (representing large industry) and SMEs. The analysis has supported the progression of the collaborative topic and the awareness about the current state of the art and scientific/technological challenges.

The NLR has also initiated the project SECOPS (integrated SECurity concept for drone OPerationS) alongside 3 SMEs in response to the SESAR2020 Remotely Piloted Aircraft Systems (RPAS) Exploratory Research Call, under Topic 06 "Security & cyber-resilience". SECOPS' objective is to push drone technology forward by ensuring that security risks in the Unmanned Traffic Management (UTM) concept are mitigated to an acceptable level. An integrated security concept at TRL2 will be developed addressing resistance of drones against unlawful interference, protection of third parties and integration of geo-fencing technology; focusing on technological options (navigation, surveillance,

*Figure 2: Illustration of Unmanned Air Traffic Management*

[6] American Institute of Aeronautics and Astronautics. Framework for Aviation Cybersecurity

in-flight updates, etc.) for both airborne and ground elements, considering legal, regulatory and social aspects.

The project aims to provide an integrated security concept ensuring that:

- Drones do not divert from their intended mission, due to unexpected interference such as cyber-attacks.
- Drones cannot deliberately be misused for illegal or dangerous activities.
- Detect and act when drones are misused (by the pilot or an external party).

According to the existing initiatives and interests, as possible specific collaboration research topics, ONERA identified the following list:

- Joint (cyber-)Security and Safety Risk Assessment and Treatment
- Data Analytics for aviation security
- Physics Cyber-Threat Models

INTA has proposed as a common theme the malevolent use of RPAS. The twofold vision for RPAS Malevolent use concerns:

- Use of RPAS as vectors for Security Breach.
- Vulnerability of RPAS in terms of Security

They both require:

1. Analysis of the threat, including their different types, classes, operational aspects as well as their effects and severity;
2. Development of ConOps. Associated means of detection;
3. Focusing on feasible solutions definition
    1. Technologies
    2. Integrated systems

According to the discussion within the GoR-AS, a good compromise for collaboration is cyber-attacks to unmanned vehicles (in civil operations), which could transform them into weapons.

The related collaborative activities could vary from: definition of a taxonomy to classify: targets to protect, malevolent actions, types of attacks, simulation of case studies, identification of possible Conops, together with the means of detection and strategies of counteraction according to the scenario, also controlling reaction time. They will be detailed in a pilot paper which will be delivered by GoR-AS in June 2018.

To support current European initiatives in aviation Security in order to avoid duplication of efforts and harmonize vision, GoR-AS members, as members of ACARE WG4 and another initiative within EREA focussing on aviation security (EREA Security for Aviation Working Group), have actively participated in specific meetings and events. The intent has been to harmonize all existing initiatives.

Recent reporting from participation in these groups regarding the updated SRIA has confirmed that the Action Areas, which represent the main categories addressed for matching Flightpath2050 goals, contain the GARTEUR topics of interest.

The existing links and interrelations among people involved in the different groups within aviation security, has avoided duplication of effort and enabled a more efficient process. Industrial partners who expressed interest for the activities of the GoR included Leonardo, Intecs, Vitrociset, and a contingent of SMEs. Furthermore ENAC, The Italian civil Aviation Authority, ENAV, the Italian Air navigation Service provider, ICSA Intelligence Culture and Strategic Analysis also expressed their interest.

At a recent meeting held in Rome, the security community supported an initiative within GARTEUR to assess the current experiences and expertise within security for aviation domain among GoR-AS, EREA Security for Aviation working group and Industrial stakeholders. The goal has been to start building a network of actors involved in security for aviation domain. A form to collect some related info has been distributed to the participants, intending to map on the new SRIA action area their research interests.

An exploratory group focussing on cyber-attacks to drones is starting in May 2018.

### 5.2.3 GoR-AS Membership

| | | |
|---|---|---|
| **Chairperson** | | |
| Angela Vozella | CIRA | Italy |
| | | |
| **Members** | | |
| René Wiegers | NLR | The Netherlands |
| Pierre Bieber | ONERA | France |
| Francisco Muñoz Sanz | INTA | Spain |

*Table 3 GoR-AS Membership 2017*

# *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

As in 2016 the activities in 2017 have been limited. The chairmanship of the GoR was transferred from the Netherlands to Sweden in 2017 and the reduced activities in 2016 also impacted the level of work in 2017.

The new Exploratory Groups identified in 2015 were never 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 2018. New EGs are expected in 2018 and work has begun to ensure these are commissioned.

### 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 4 GoR-FM Membership 2017*

# *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 aircrafts, such as tilt rotors or compounds) 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 low-order (CFD) methods, validated with relevant tests
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines etc.
- 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 etc.
- 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, aero elasticity including stability, structural dynamics and vibration, flight mechanics, control and handling qualities, vehicle design synthesis and optimisation, crew station and human factors, internal and external acoustics and environmental impact, flight testing, and simulation techniques and facilities for ground-based testing and simulation specific to rotorcraft.

A characteristic of helicopter and tilt rotor matters is the need for a multidisciplinary approach due to the high level of interaction between the various technical disciplines for tackling the various issues for rotorcraft improvement.

*Figure 3: Illustrations of the Group of Responsables Helicopters*

### 5.4.2 GoR-HC Activities

HC/AG-20 "Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction" started in October 2012. The final report was issued in January 2017.

HC/AG-21 "Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity" was launched April 2013. 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. The final report is expected to be issued mid-2018.

HC/AG-22 "Forces on Obstacles in Rotor Wake" was launched in November 2014. The objective is to investigate, both numerically and experimentally, the interactional process between a helicopter rotor wake and the surrounding obstacles and the evaluation of the forces acting on these obstacles. All experimental activities were completed in 2017 and the numerical simulations have been finished. The final report was issued in March 2018.

HC/AG-23 "Wind turbine wake and helicopter operations" was launched in November 2014. 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 - WT wake encounters. Piloted simulations have been performed or are being prepared.

HC/AG-24 "Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction" was launched in January 2015, with an initial plan to run for two years with an option to run for a third year. The extension to a 3-year duration was decided in the March 2016 Council. The main objective is to examine rotor noise propagation in the presence of a fuselage. The activity will establish an experimental acoustic database and prediction design tools for main and tail rotor noise in the influence of a fuselage (2016 activities) and will also include main/tail rotor interactions (on-going). The last test campaign initially planned for September/October 2017 was postponed to mid-2018. An extension of the group until end 2018 was accepted after C63.

### 5.4.3 List of Exploratory Groups

HC/EG-29 "Intelligent Lifeing & HUMS" was launched in 2011 and started in April 2013. Due to the difficulty to launch any activity on this important but sensitive topic, it was decided to close the group without any output.

HC/EG-36 "Rotor-Rotor Interactions" was launched in June 2016. The group is expected to provide its ToR document during 2018.

### 5.4.4 List of New Topics

The following topics are being considered for future Exploratory Groups, together with general safety related problems. The Clean Sky JTI Green Rotorcraft ITD is gathering the environmental issues. So, the next issues to be explored by GoR-HC should not be linked to environmental topics but should be oriented towards safety and comfort topics in order to extend the use of helicopters. Furthermore, the assessment and validation of numerical methods for the analysis of new compound rotorcraft configurations is considered a valuable topic for future activities (also with respect to the Clean Sky 2 Fast Rotorcraft IADP Programme activities). In this regard, there are a number of experimental aerodynamic databases, developed in past EU funded projects, that should be further exploited.

Topics that are under consideration include:

- Safety (Crash, HUMS, Crew Workload, all weather operations)
- External noise (noise annoyance generated by helicopter and its impact on population, noise perception)
- Internal noise (Transmission Loss of fuselages submitted to Turbulent Boundary Layer)
- Low order models for new rotorcraft configurations to examine aerodynamic/rotor interactions
- Verification & Validation (Metrics for the Qualification of Simulation Quality)
- Ice accretion and performance prediction on rotary wings

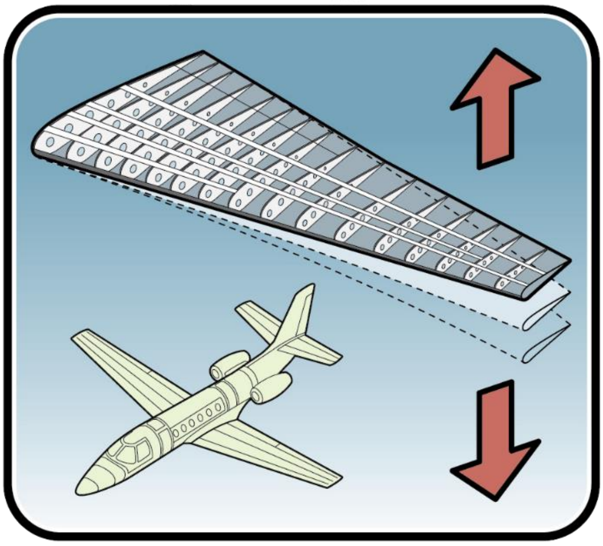
### 5.4.5 GoR-HC Membership

Membership of the Group of Responsables Helicopters (2017):

| | | |
|---|---|---|
| **Chairperson** | | |
| Philippe Beaumier | ONERA | France |
| **Vice-Chairman** | | |
| Klausdieter Pahlke | DLR | Germany |
| **Members** | | |
| Joost Hakkaart | NLR | The Netherlands |
| Lorenzo Notarnicola | CIRA | Italy |
| Mark White | University of Liverpool | United Kingdom |
| Rainer Heger | Airbus Helicopters | Germany |
| François Xavier Filias | Airbus Helicopters | France |
| Antonio Antifora | Leonardo | Italy |
| **Observer** | | |
| Richard Markiewicz | DSTL | United Kingdom |

*Table 5 GoR-HC Membership 2017*

# *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:

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

### 5.5.2 GoR-SM Activities

Two Action Groups and three Exploratory Groups were active during 2017;

SM/AG-34 Damage repair in composite and metal structures (SUN). The main objective is to establish a definition of effective repair techniques both for civil and military aircraft structures through the development of numerical/experimental methodologies. Other benefits include minimization of down-time for repair operations and associated costs, to promote the repair of components instead of their substitution and to reduce the certification costs and the time for certification for repaired structures.

SM/AG-35 Fatigue and Damage Tolerance Assessment of Hybrid Structures (NLR). The main objectives are to establish validation of the basic assumptions for any applied spectrum manipulation techniques, examine the capabilities and benefits of a probabilistic approach, determine the optimum way to account for thermal loads in a non-thermo test set-up. These should lead to a joint 'best practice' approach for testing of hybrid airframe structural components. Key issues include environmental conditions, material scatter/ statistical significance, spectrum reduction issues, spectrum truncation issues.

SM/EG-39 Design for high velocity impact on realistic structure. The EG follows on from SM/AG-30. Work to find a suitable and willing lead partner for a potential SM/AG-36 has hindered the launch and discussions are still taking place going into 2018.

SM/EG-42 Bonded and bolted joints. EG was initiated by FOI, but due to budget cuts FOI won't be able to manage or participate in the AG. Despite this an early draft for a proposal was prepared. Based on the member feedback a reorientation of the EG with a focus on bonded joints is discussed. Management of the AG was open going into 2018.

SM/EG-43 Additive Layer Manufacturing. EG was formally started in 2014 with an AG proposal following, although still not completed.

Future exploratory groups that are being considered are;

- Multifunctional materials;
- Multi-scale dynamics of joints: modelling and testing;
- New methodologies for thermal-mechanical design of supersonic and hypersonic vehicles;
- Composite fire behaviour;
- Structural uncertainties; and
- 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 Sanmilan | INTA | Spain |
| Tomas Ireman | SAAB | Sweden |
| Anne Denquin | ONERA | France |
| Bert Thuis | NLR | The Netherlands |
| | | |
| **Industrial Points of Contact** | | |
| Andrew Foreman | QinetiQ | United Kingdom |
| Roland Land | Airbus Defence and Space | Germany |
| Mathias Jessrang | Airbus | Germany |
| Angel Barrio | Airbus Defence and Space | Spain |
| Hans Ansell | SAAB | Sweden |
| Robin Olsson | SWEREA Sicomp | Sweden |
| Caroline Petitot | Airbus | France |
| Luc Hootsmann | Fokker | The Netherlands |

*Table 6 GoR-SM Membership 2017*

# 6 GARTEUR ROADMAPS AND LINKS TO OTHER EUROPEAN PROGRAMMES

## 6.1 GARTEUR Road-maps

Throughout the UK Chairmanship, the development of the GARTEUR roadmaps has been a priority issue. Over the 45 years of its existence, the forum 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.

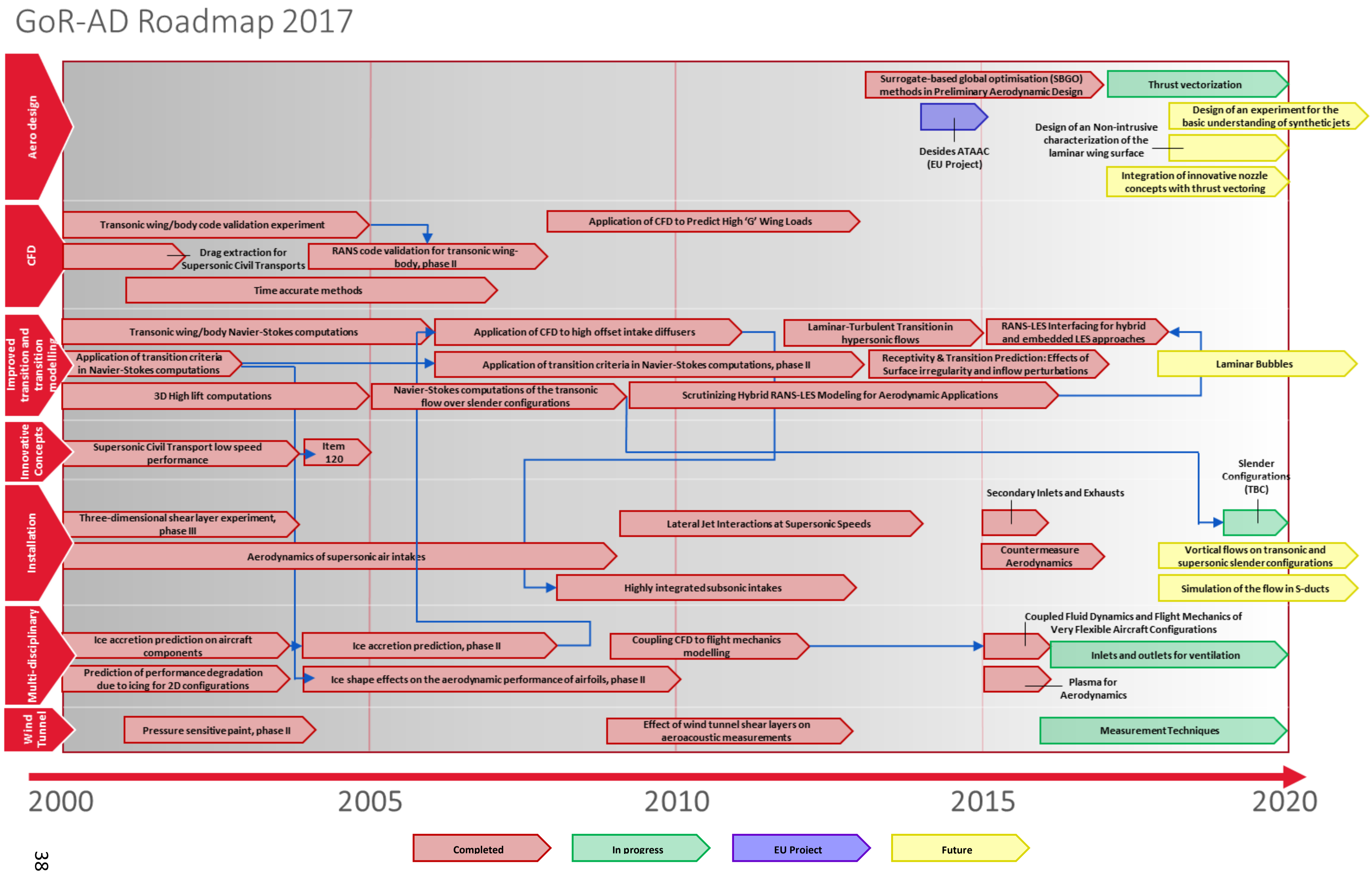



*Figure 4: Roadmap for GoR Aerodynamics*

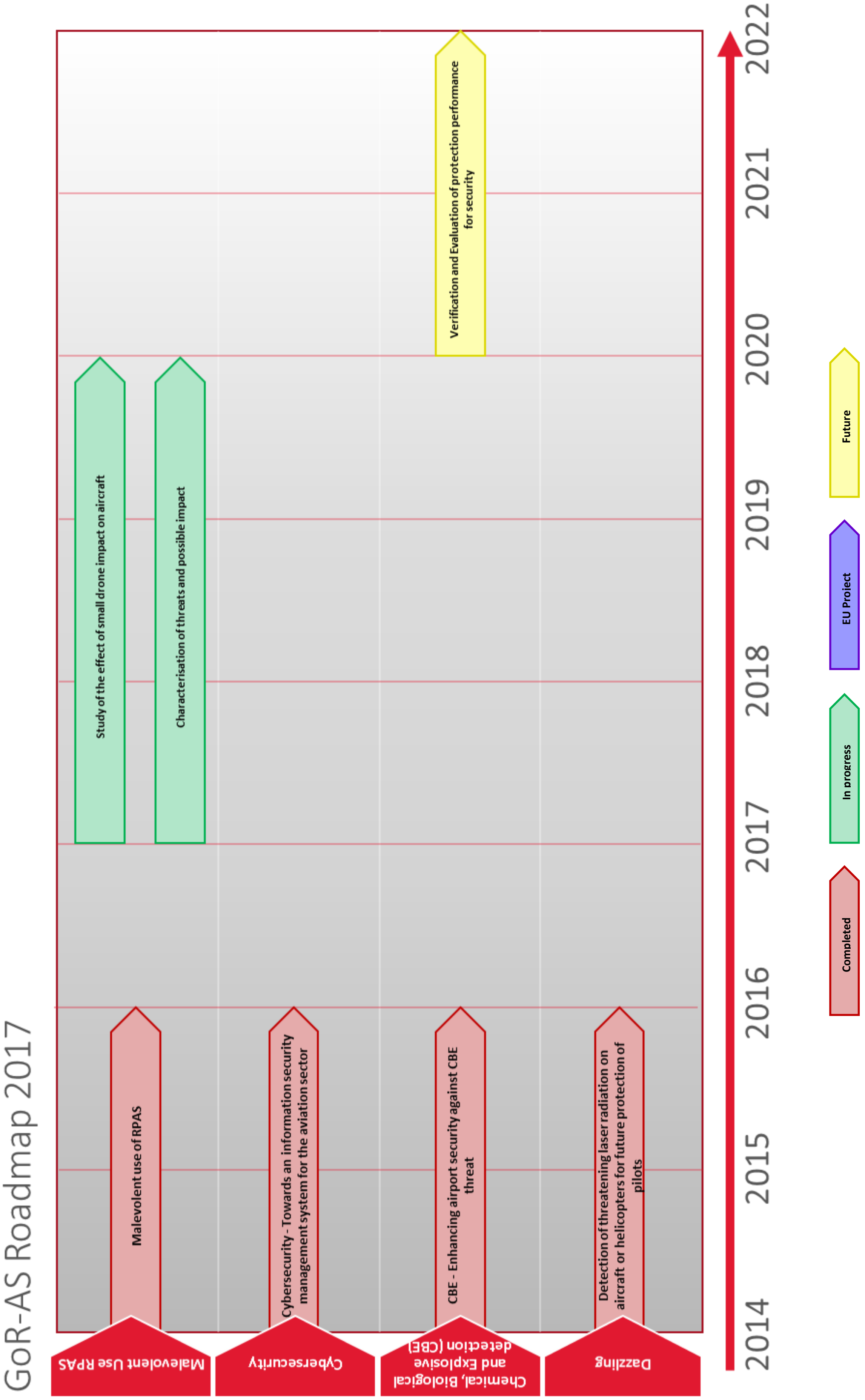



*Figure 5: Roadmap for GoR Aviation Security*

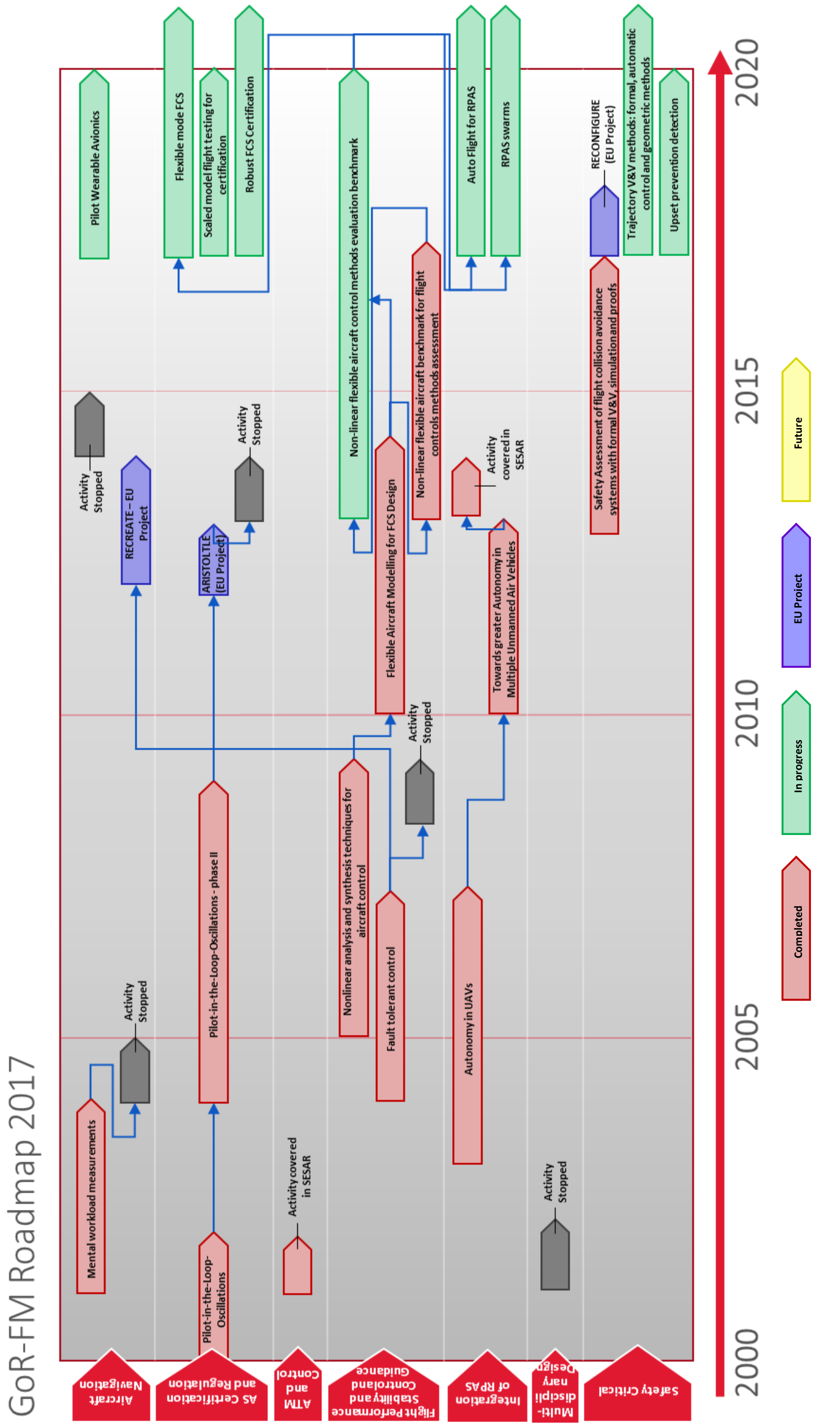



Figure 6: Roadmap for GoR Flight Mechanics, and Integration

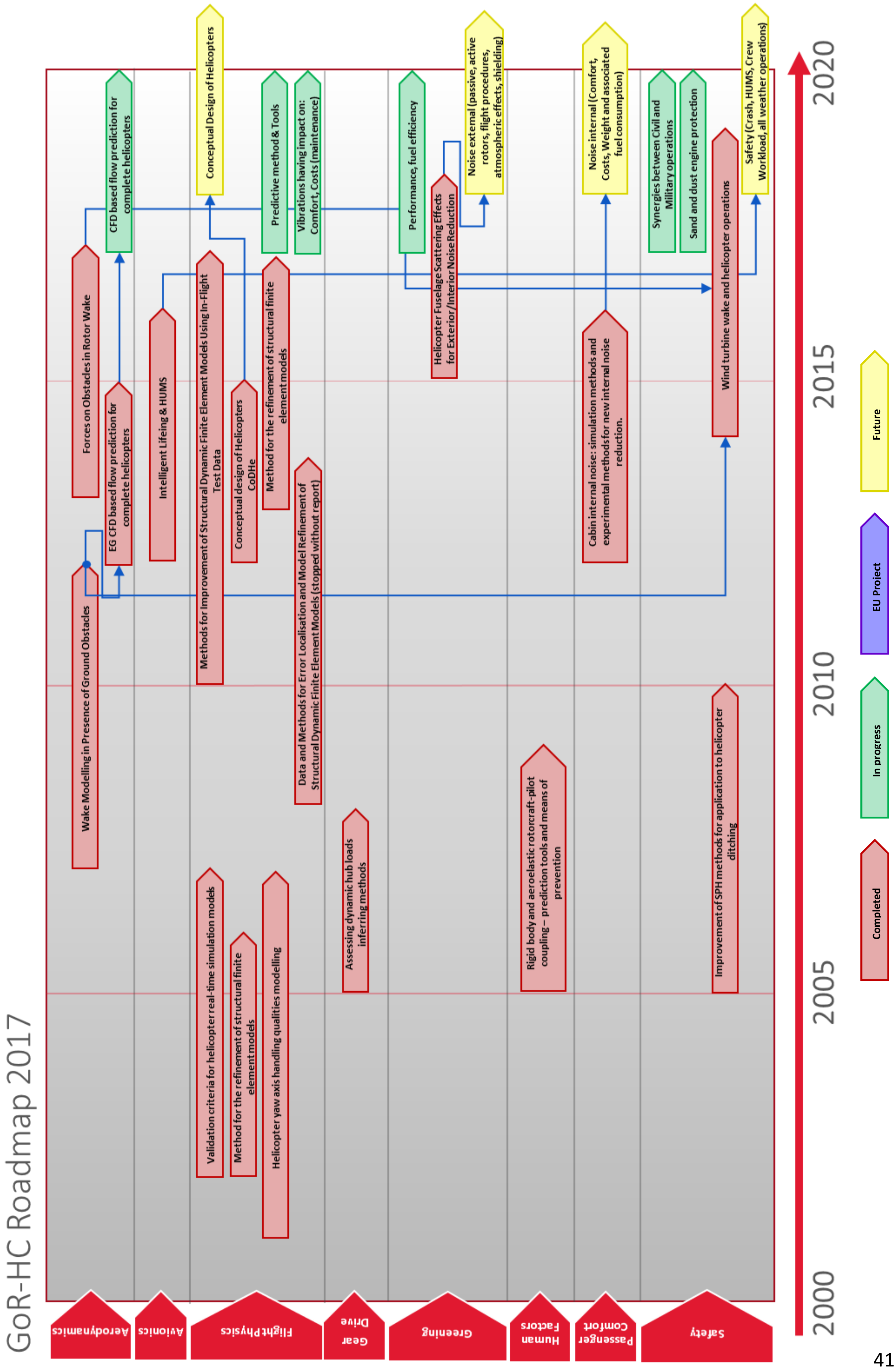



*Figure 7: Roadmap for GoR Helicopters*

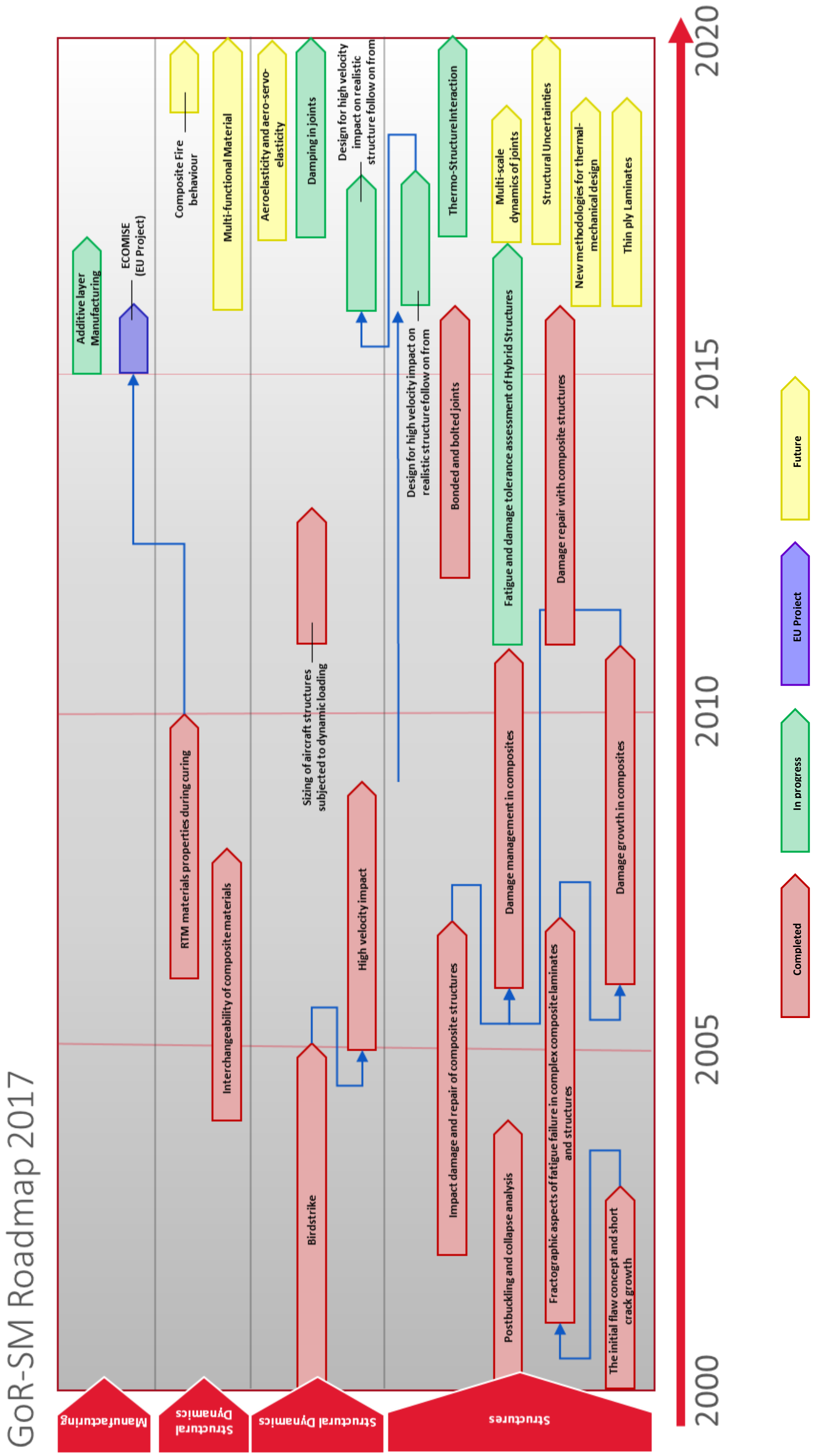



*Figure 8: Roadmap for GoR Structures and Materials*

## 6.2 Alignment with European Programmes

GARTEUR projects have had strong links with EU Framework projects for over three decades. As GARTEUR does not provide financial support for projects it is necessary for the GoRs to investigate funding opportunities from the EU or other sources as illustrated in Figure 9 below.

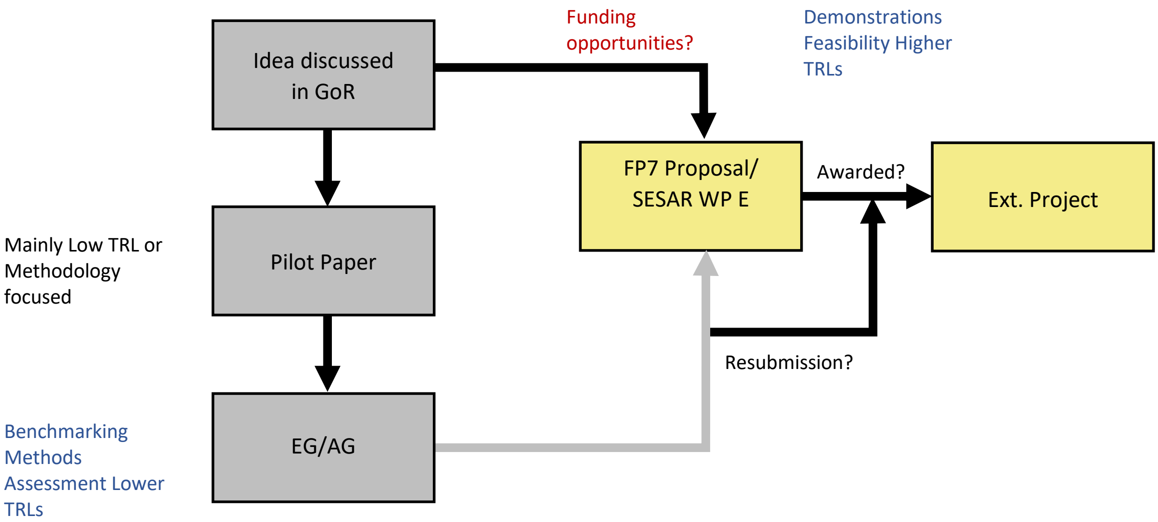



*Figure 9 Illustration of how links are established between GARTEUR and other European programmes*

The main focus for GATEUR is to promote low TRL topics and benchmarking of methods. The availability of funding for such projects within the EU Framework programmes varies over time, however as shown in the technical reports from the GoRs in the previous section and in greater detail in the accompanying Annexes, knowledge and methods developed within the GARTEUR projects are the basis for participation in projects on higher TRL levels. Figures 10 to 12 are additional illustrations of the links between GARTEUR Action Groups and EU projects, as provided by GoR Aerodynamics and GoR Helicopters.

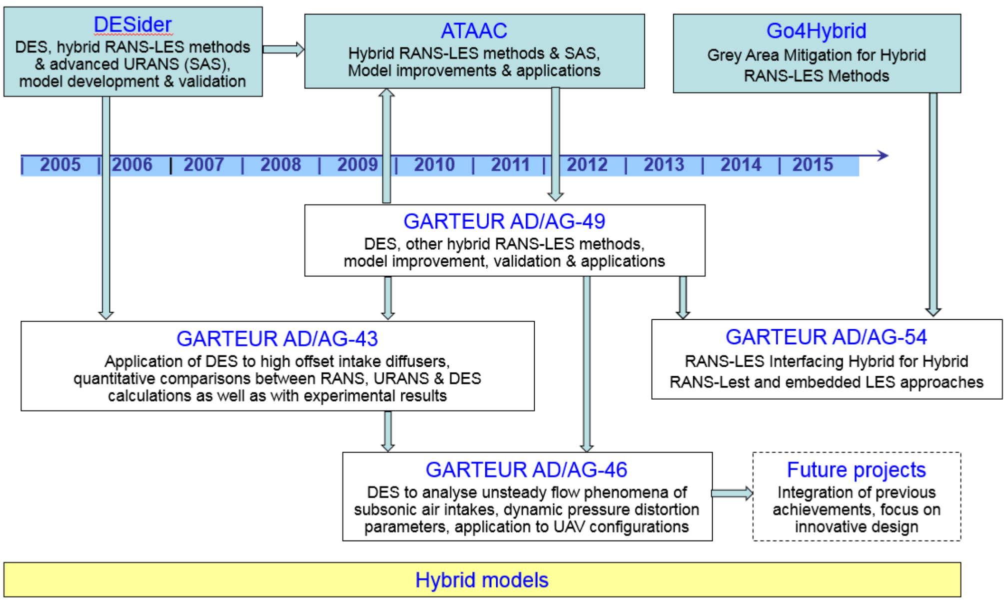



*Figure 10 Links between EU-projects/proposals and GARTEUR AD/AG-43, AD/AG-46, AD/AG-49 and AD/AG-54*

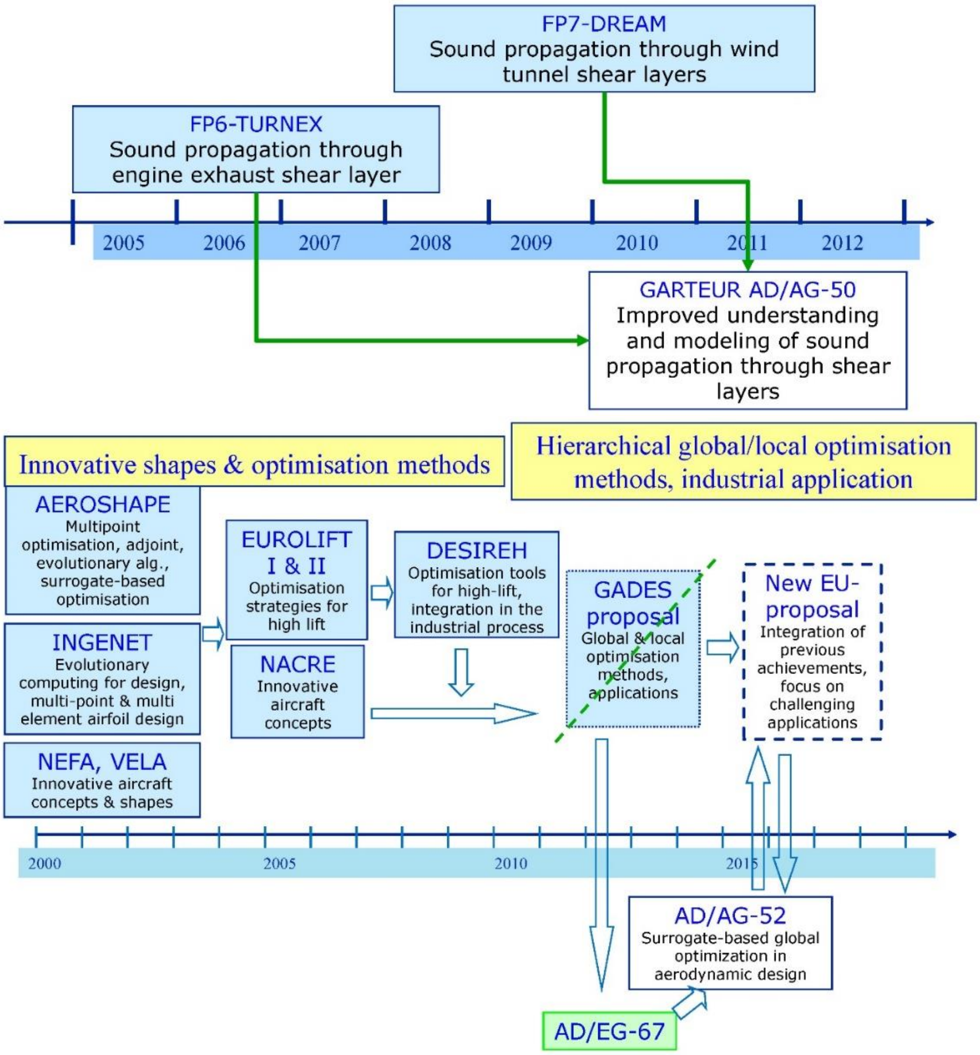
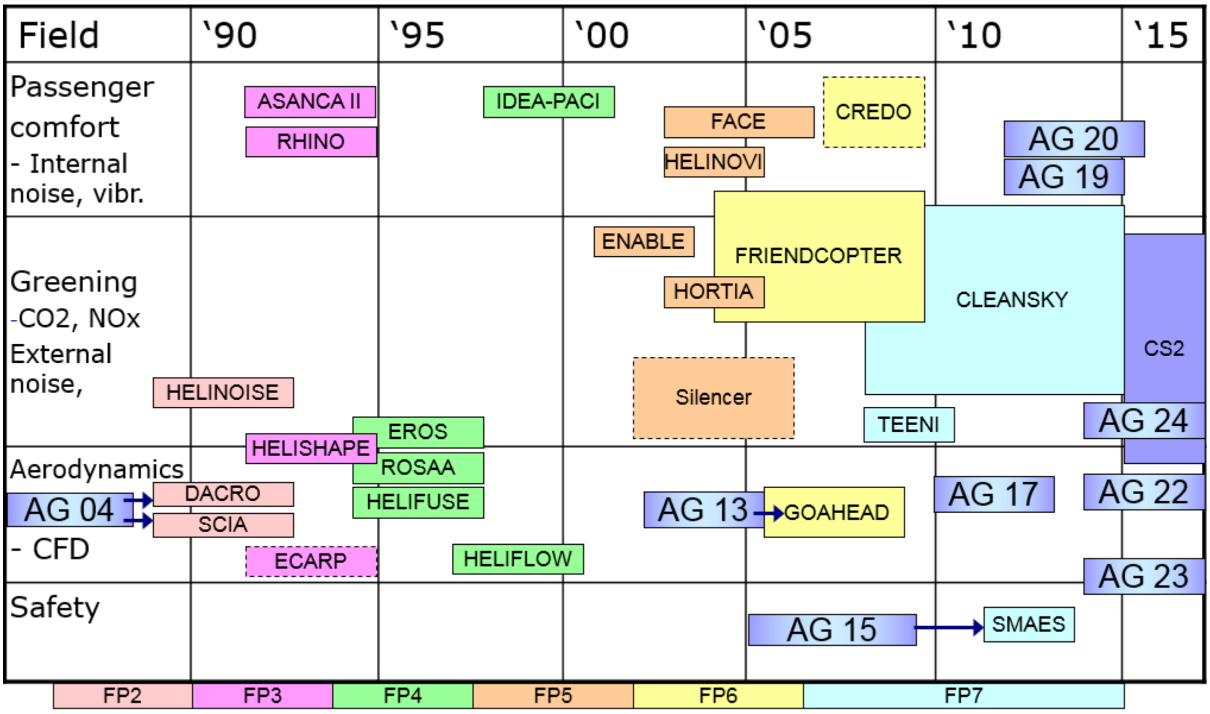



*Figure 11 Links between EU-projects/proposals and GARTEUR AD/AG-50 and AD/AG-52*



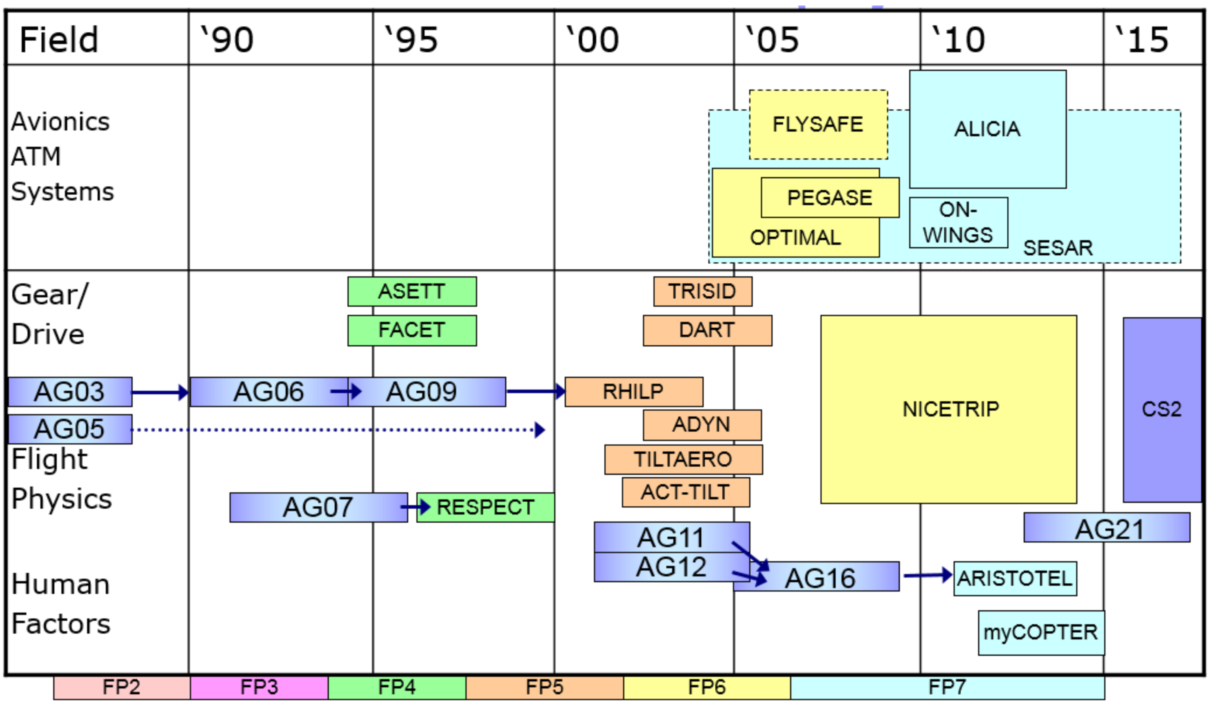




*Figure 12 Relation between HC/AGs and EU projects*

# 7 GARTEUR SUCCESS STORIES

GARTEUR Action Groups AD-AG49 and HC-AG20 represent two success stories from 2017. Both groups demonstrate the highly innovative research and broad European collaborations that are typical of GARTEUR AGs. AD-AG49 explored and evaluated selected hybrid RANS-LES modelling approaches, and HC-AG20 investigated simulation methods and experimental methods for new solutions for internal noise reduction.

## 7.1 GoR AD-AG49: Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications

**Background**

Simulation of turbulent flows has often been conducted following three main approaches: Direct Numerical Simulation (DNS) which resolves all turbulent scales (and thus no turbulence model invoked); Large Eddy Simulation (LES) which resolves large-scale eddies (larger than a predefined filter width that is usually proportional to the local grid size) and models the effect of unresolved small eddies (namely, unfiltered subgridscale eddies); and statistical modelling based on Reynolds-Averaged Navier-Stokes equations (RANS). Despite extensive development, however, none of the above methods has yet emerged as indisputably superior and applicable to general turbulent flow problems of engineering interest in terms of both computational accuracy and efficiency.

Hybrid RANS-LES modelling (including DES – Detached Eddy Simulation) combines RANS (Reynolds-Averaged Navier-Stokes) and LES (Large Eddy Simulation) modelling approaches. Its development has been greatly facilitated by industrial needs in aeronautic applications, particularly in CFD analysis of unsteady aerodynamic flows characterised by massive separation and vortex motions. Computations using a hybrid RANS-LES model are able to provide turbulence-resolving simulations. Several hybrid RANS-LES modelling approaches have been developed in previous work, being validated and applied to a wide variety of turbulent flows.

**Objectives**

The activities of AG49 targeted comprehensive exploration and evaluation of some selected DES and hybrid RANS-LES methods for both fundamental and industry-relevant aerodynamic flows. The emphasis was placed on a systematic investigation of some significant modelling problems in predicting typical aerodynamic flow features, including shear-layer instabilities, boundary layer separation and subsequent detached vortex motion and vortex breakdown. To resolve these and other related flow physics appropriately, some further investigation and improvement of the RANS-LES modelling, as well some related numerical issues, was undertaken.

In summary, the general objectives of AG49 were

- To make comprehensive evaluation, assessment and improvement of DES and other hybrid RANS-LES methods in modelling both fundamental and industry-relevant flows based on available and detailed experimental data.
- To contribute a database of hybrid RANS-LES approaches in resolving/modelling typical aerodynamic flow physics, which conventional RANS methods may fail to capture.
- To draw some relevant "best practice" guidelines for aerodynamic industries in terms of the pros and cons of hybrid methods in modelling some important aerodynamic flow problems.

- Ultimately, to facilitate the use of hybrid RANS-LES methods in aeronautic industries.

To achieve these objectives, a number of numerical computations were carried out, addressed in two technical tasks (Tasks 1 & 2) based on hybrid RANS-LES computations for four test cases (TC), and some best-practice guidelines were summarized in Task 3.

Task 1 focused on an exploration of modelling approaches through computations of fundamental flows in validation against available experimental measurements, where two test cases were addressed, namely, a turbulent mixing-layer flow (TC 1.1) and a backward-facing step flow (TC 1.2). This enabled in-depth analysis of hybrid modelling performance in resolving some typical and important aerodynamic flow features, in particular on the free shear layer emanating from incoming RANS modelled boundary layer and resolved by the LES mode.

With the results computed by AG members, cross comparisons were conducted. They showed that the standard DDES-type models present a degraded predictive capability, as compared to the other hybrid RANS-LES methods in resolving the initial shear-layer instabilities. The degradation is mainly attributed to the “grey-area” problem related to the RANS to-LES switching with delayed re-establishment of resolved turbulence. Detailed comparison with the experiment also reveals the importance of the prediction of the incoming (upstream) boundary layer.

Making one step forward, Task 2 focused on hybrid RANS-LES computations of complex aerodynamic flows. Two test cases were addressed, namely, the F15 three-element high-lift configuration (TC 2.1) and the VFE-2 Delta wing with a round leading edge (TC 2.2). The emphasis of Task 2 has been placed on an assessment of hybrid RANS-LES methods used by AG members in computations of industry-relevant aerodynamic flows. Cross-plotting was made of the results contributed by involved partners. For the high-lift flow, the lack of ability in DDES modelling was highlighted when dealing with the confluence of RANS modelled boundary layer and LES-resolved wakes behind the slat-wing and wing-flap gaps. This may significantly affect the prediction of the boundary layer separation on the flap trailing edge. For the Delta-wing flow, the resolution of the primary and secondary vortex formation and interaction is shown to be an essential issue for accurate predictions. The secondary vortex seems to be more difficult to resolve. The lessons learned, and the experience gained throughout the project work were summarised in Task 3.

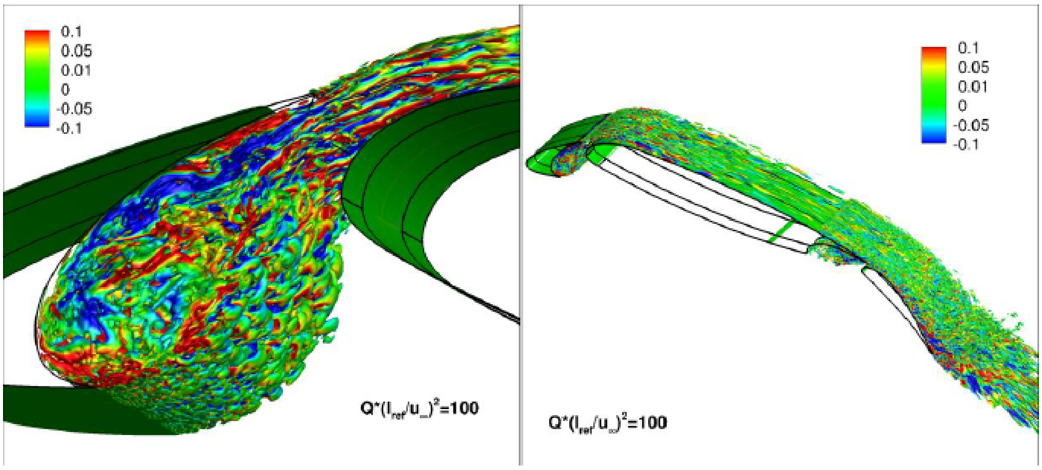



*Figure 13: Illustration of the flow in the slat cove region and on the upper side of the wing obtained by ONERA using ZDES in mode I+II+III*

**Results**

The work in AG49 was a collaborative exploration of several hybrid RANS-LES modelling approaches in computations of four different test cases by means of cross comparisons. In the framework of the project several existing hybrid RANS-LES models were investigated. Moreover, numerous improved variants were initially explored in the procedure of the project work. These improvements in general showed desirable performance in the modelling, particularly, in resolving the initial development of shear-layer instabilities as compared to the original model.

A full report of the project can be accessed in the technical report published by S.-H Peng, S. Deck, H. van der Ven, T. Knopp, P. Catalano, C. Lozano, C. Zwerger, J. C. Kok, A. Jirasek, F. Capizzano and C. Breitsamter.[7]

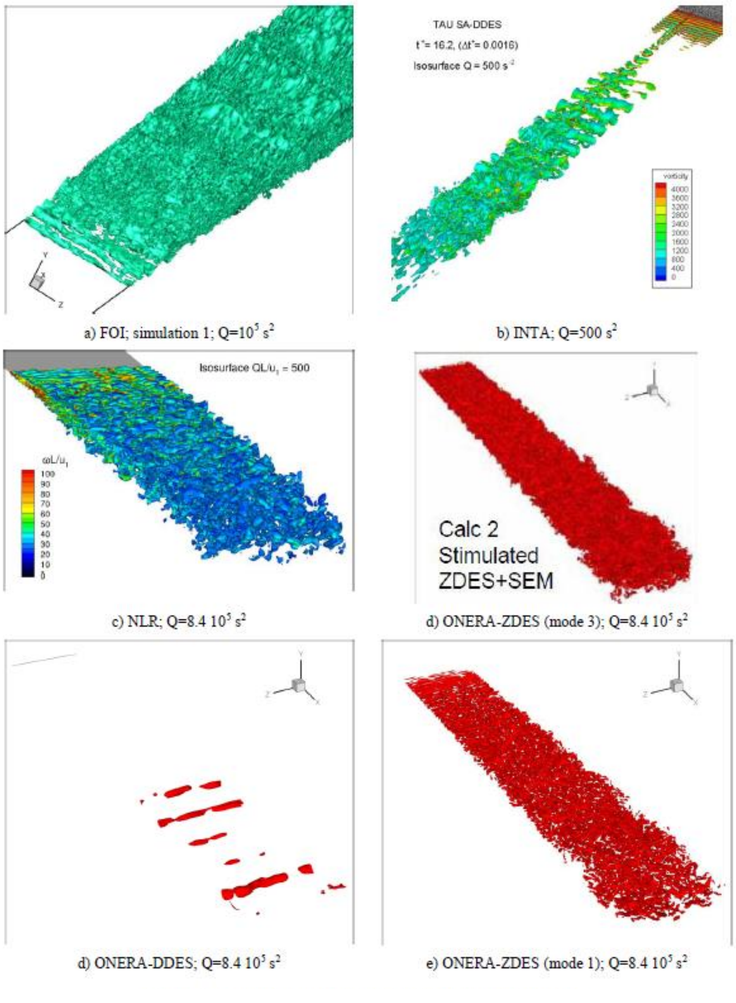



*Figure 14: Instantaneous Q-contours for the different simulations*

[7] S.-H Peng, S. Deck, H. van der Ven, T. Knopp, P. Catalano, C. Lozano, C. Zwerger, J. C. Kok, A. Jirasek, F. Capizzano and C. Breitsamter: Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications

## 7.2 GoR AD-HC20: Simulation Methods and Experimental Methods for New Solutions for Internal Noise Reduction

**Background**

Improvement of internal acoustic comfort in aircraft has always been an important area of research in the aeronautics industry. This is particularly true within the cabin of a helicopter, where passengers are in close proximity to sources that contribute to interior noise, such as the main and tail rotors, engines, main gearbox (tonal noise) and aerodynamic turbulence (broadband noise).

These sources generate bending vibrations of the entire tail boom, induced vibrations in the cabin at blade passing frequencies (up to 60 Hz), transient vibrations of rotor blades (2-10 Hz) and structure borne noise induced by gear meshing within gear-boxes (500-5000 Hz). External noise (up to 4000 Hz) is also transmitted by acoustic leakages between fuselage and doors.

For a safe, comfortable and healthy helicopter, the following requirements are decisive:

- Cabin vibration levels below 0.05 g for steady flight and 0.11g for transition flight (derived from the EC Directive 2002/44/EC on whole-body vibrations);
- Cabin noise levels between (80÷85) dBA for steady flight and 87 dBA for transition flight (derived from the EC Directive 2003/10/EC on interior noise).

It appears that conventional passive systems (trim panels and passive anti-resonance isolation systems, as well as classical vibration absorbers and pendulum absorbers) are still the main way to control the acoustics of the cabin, whereas active systems (active vibration and noise control), despite much laboratorial studies spanning the past few decades, are applied only in particular cases to complement passive solutions (structure piezo control, strut vibration control, active noise reduction headrest, etc.). It is due to difficulties providing algorithm robustness (instability of time convergence), with a spatial reduction (particularly in the medium and high frequency range) and due to a critical balance in terms of added mass and electrical power.

**Objectives**

The activities in the new HC/AG-20 constitute the conclusion of HC/EG-28, addressing the problem of helicopter internal noise, in particular in terms of design, characterization or active control of vibration applied to helicopter panels, in order to improve the acoustic comfort. These activities from HC-EG28 taken forward by HC-AG20 were;

- Application of different types of simulation methods to design and optimize composite trim panels according to common acoustic cost functions and to validate numerical approaches by tests in laboratory.
- Application of different types of experimental techniques to characterize composite trim panel acoustic radiating in both a standardized test set–up and a generic helicopter cabin.
- Experimental methods to separate correlated and uncorrelated acoustic sources in cabin. This identification is essential to reproduce internal noise from experimental database and to apply sound source localization methods as beamforming or holography.

The HC-AG20 group presented a number of papers at the 2016 European Rotorcraft Forum summarising the activities of members work packages. The papers are outlined below.

**Experimental Test of Semi-Active Shunt Damping on A Helicopter Trim Panel**[8]

High stiffness and low mass mean coincidence frequencies of lightweight structures are low compared to classical aluminium structures. This explains the reason for a weak transmission loss of lightweight structures made of glass or carbon fibre reinforced plastics. Therefore, passive solutions are widely investigated to increase the transmission loss of lightweight helicopter trim panels.

Lightweight structures made from carbon fibre reinforced plastics offer great potential in reducing structural mass, which results in higher payload and lower fuel consumption. But with increased stiffness, reduced wall thickness and lower density, they have the disadvantage of lower damping and coincidence frequencies compared to conventional differential metal constructions. Both aspects lead to an increased sensitivity of lightweight structures concerning vibration and noise radiation. In the same manner, the acoustic transmission loss is affected.

Special noise and vibration treatment is therefore needed to ensure passenger cabin comfort. Within the premise of HC-AG20, two helicopter trim panels are studied which are structurally optimized for an increased transmission loss.

An additional opportunity for a further improvement of the transmission loss is offered by active noise and vibration treatment, such as active structural acoustic control (ASAC). The drawback of active control methods is their need for complex system models and electronics.

In addition to these two concepts, piezoelectric shunt damping is investigated.

Hereby piezoelectric transducers are applied to a vibrating structure to convert mechanical vibration energy into electric energy. Together with an appropriate electric shunt network connected to the electrodes of the transducer, the transducers can be used for vibration attenuation.

To investigate the potential of piezoelectric shunt damping, experimental measurements of damped panels were investigated. To achieve a broadband effect, negative capacitance circuits are used therefore. First, preliminary measurements are performed at a steel panel, where a very good damping effect is demonstrated. Second the helicopter trim panel is equipped with piezoelectric transducers and shunt circuits. In this case the damping effect is much less compared to the pre-tests at the steel panel.

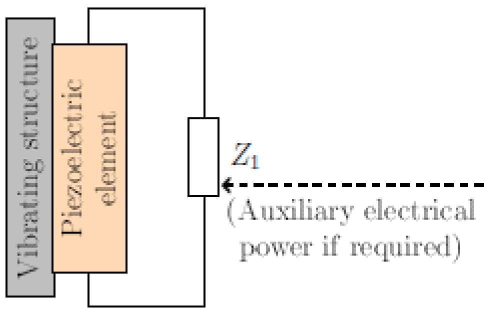



*Figure 15: Working principle of piezoelectric shunt damping*

During the first test, the trim panel is excited with a point force and the surface vibrations are measured with a laser scanning vibrometer and in the second test the trim panel is excited with a diffuse sound field. The results suggested that the negative capacitance shunt is less effective on a higher damped structure.

Through HC-AG20, the applicability of piezoelectric shunt damping to improve the vibroacoustic characteristics of sandwich helicopter trim panels was investigated. Therefore, preliminary tests of a

[8] Pohl. M, Haase. T: Experimental Test of Semi-Active Shunt Damping on A Helicopter Trim Panel

multiple individual negative capacitance circuit damping systems were performed on a steel panel. From these tests, a remarkable reduction of the structural vibration could be obtained.

Subsequently, a comparable system was transferred to a sandwich panel. For the purposes of a fair comparison, the same number of transducers was used. Measurements of the vibration reduction as well as the improvement of the TL indicate a reduced damping effect of the negative capacitance compared to the steel panel. Based upon numerical simulations, it seems obvious, that a combination of the higher intrinsic damping of the sandwich panel and a much lower piezoelectric coupling of the transducers are responsible for this severe loss of function.

Therefore, the concept required some changes for future applications. The most important improvement is constituted by matching the piezoelectric transducer to the structural characteristics of the sandwich panel in order to increase the piezoelectric coupling. By this, the overall performance of the negative capacitance damping will be enlarged in the same manner. Secondly the influence of other transducer distributions, number or quantity and arrangements should be investigated besides the regular shape used for the tests in this paper.

**Benchmark for Experimentation of Acoustic Transmission Loss Applied to Helicopter Trim Panels**[9]

The purpose of this paper was to present an experimental benchmark study involving three different laboratories (NLR in the Netherlands, ONERA in France and DLR in Germany) and measurement techniques relative to the measurement of TL applied to reference trim panels.

The test panels were clamped in an aperture between a reverberant room and a (semi-) anechoic room. Excitation was generated by broadband noise to produce a diffuse acoustic field in the reverberant room.

For this experiment two types of trim panels were tested, a "standard" trim panel (panel 1) with honeycomb and an "optimized" trim panel (panel 2), with thick foam to have a "dilatation effect" in the medium frequency range. Both panels have a surface of 0.90 x 0.90 m2 with the standard" trim panel (Figure 16) having a thickness of 11.7 mm and the "optimized" trim panel (Figure 16) a thickness of 21.7 mm. Both panels have been tested in the different laboratories having been made available by ONERA.

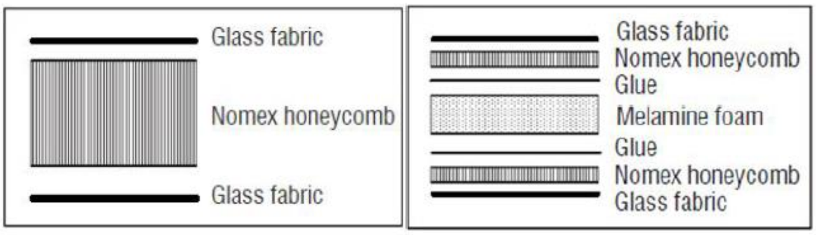



*Figure 16: Composition of trim panels, left: "Standard" trim panel, right: "Optimized" trim panel*

[9] Wijntjes. R, Simon. F, Haase. T, Unruh. O, Tijs. E: Benchmark for Experimentation of Acoustic Transmission Loss Applied to Helicopter Trim Panels

The two test panels were measured at ONERA, DLR and NLR according the standard TL method. At this stage the test panels were clamped to have the same boundary conditions. No additional restrictions were specified to be able to investigate the difference between the facilities and way of operation. Figure 17 shows the results of the “standard” trim panel and Figure 10 the “optimized” trim panel. See figure 18

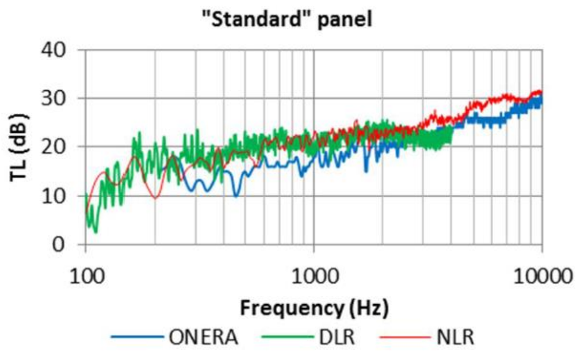



*Figure 17: TL measurement results of panel 1*

For the “standard” trim panel the three facilities displayed a similar behaviour with the TL increases with approximately the same slope.

For the “optimized” trim panel the measurements of DLR and NLR were within limits, equal. The majority of the measurement results show a difference within the repeatability error. In the frequency region of 2 kHz to 3 kHz the difference increases.

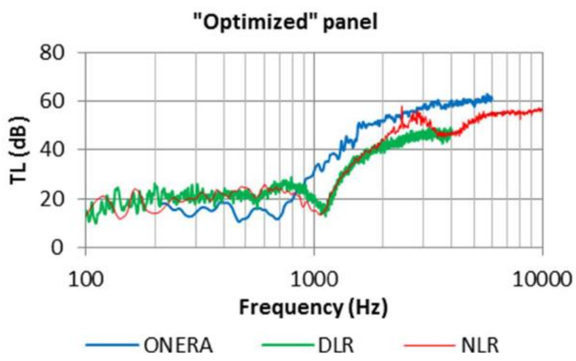



*Figure 18: TL measurement results of panel 2*

The radiated power can also be determined "in situ" and straightforwardly with a single probe called Microflowns containing a particle velocity sensor combined with a conventional microphone in a so-called PU probe. Intensity measurement is acquired by PU probes to differentiate radiation of various parts of a panel and to extract Transmission Sound power (novel Microflown enabled based transmission loss method) but also acoustic reflection and impedance.

The feasibility of in situ transmission loss tests were also explored within HC-AG20. Conditions used for standardized transmission loss tests were analysed, i.e. sample mounted in between a reverberant room and a semi anechoic room. The intensity was measured with a PP probe and a PU probe on the rear of a sample in the anechoic room. Secondly, the intensity was measured with a PU probe on the front side of the material inside the reverberant room. The input sound power estimated from this measurement should approximate the input sound power measured with the standard procedure involving sound pressure measurements in the reverberant room. The sensors used are depicted in Figure 19.

For the in-situ transmission loss measurement, the sample was installed in free field conditions (i.e. in a room with few reflections). A sound source was placed at one side of the material, and the ingoing and transmitted intensity were measured with PU probes on both sides of the sample. The boundary conditions and incident sound field for the in-situ measurements are different compared to the standard TL measurements.

The two results at the facility of NLR show good comparison. The two measurements are within the repeatability error with some small outliers. In front of the sample, PU probes can be used because they do not have P/I index problems. Behind the sample, particle velocity is less affected by reflections than sound pressure or intensity.

This research provides a comparison between different facilities (NLR, DLR and ONERA) and measurement techniques (conventional and in situ) to measure the transmission loss applied to two reference trim panels. Repeat measurements at a single facility showed that the amount of deviation is within limits, 95% of the data is within a maximum difference of 2 to 3 dB.


*Figure 19: Sensors used for in-situ feasibility study*

Between facilities the deviation is higher (about twice as high), although the same ISO standards are used to perform the measurements. It is possible to compare trends in the data, but the results are not accurate enough to compare absolute values between different facilities.

The PU probes of Microflown demonstrated good results when used in the conventional transmission loss measurement setup and the same results are obtained with a sound pressure sensor - sound intensity probe combination and two PU probes.

The possibility of measuring transmission loss in situ has been investigated for several sample types, if the sample is large enough it is possible to measure the transmission loss correctly. The reference trim panels used were too small resulting in a reduction of the measured transmission loss, therefore making it impossible to compare the results with the conventional transmission loss method.

**Benchmark for Modelization of Acoustic Transmission Loss Applied to Helicopter Trim Panels[10]**

Transmission loss simulations, based on analytic modelling or Finite and Boundary Element-type techniques, can be achieved to evaluate the effect of the main parameters or to optimize the nature and arrangement of layers, especially for trim panels. Nevertheless, because of the computational time needed for an optimization process, analytical or semi-analytical models are widely used, although suited to an infinite panel size or a finite panel size with simple boundary conditions (simply supported, clamped or free conditions). Accurate modelling of multi-layered trim panels for vibration and acoustic analysis presents many challenges, mostly due to their highly heterogeneous anisotropic constitution in the thickness direction and the wide frequency range of interest.

Effort in modelling plate problems has been and is still currently devoted to identifying which aspects of the 3D mechanical behaviour should be accounted for and properly modelled in a 2D mathematical framework, in order to obtain sufficiently simple yet reliable models without unnecessary complexity. This is a basic requirement of industry, where the accuracy of the model should not come at the cost

[10] Simon. F, Haase. T, Unruh. O, Ghiringhelli. G. L, Parrinello. A, Vescovini. R: Benchmark for Modelization of Acoustic Transmission Loss Applied to Helicopter Trim Panels

of excessive computational expense, in particular if the model is to be used for iterative design and/or optimization studies.

HC-AG20 aimed to benchmark numerical activity through a study involving different models in order to estimate their framework for using for realistic trim panels.

Numerical methods, independently conceived by the research groups in HC-AG20 in the frame of the structural dynamics and applied to vibroacoustics, were therefore compared. They refer to different implementations of the dynamic structural modelling of a panel under external acoustic loads. Three methods take into account the finite size of panel, i.e. "multi-layered model" (ONERA), FE-model (DLR) and SL Ritz (PoliMI). Two other methods lie in more analytical frames applied to infinite panels i.e. "transverse dilatation model" (ONERA) and TMM (PoliMI). In particular, for TMM, exploiting the Transfer Matrix approach, a windowing technique is also required.

The results were satisfactorily comparable despite the difficulties in modelling dynamic problems in the specific frequency range. All the methods are able to catch typical physical phenomena, e.g. the TL decay due to the double wall effect in Panel 2. Furthermore, they match with experimental data. All the methods exploit 3D constitutive material relationship, thus some of the required data are often unavailable from standard testing activities and they can have non-negligible effects on the results. The comparison with experiment data evaluates the effectiveness of the different approaches that can be used in the frame of actual design.

The little time required by the analysis of "infinite" approaches, a few seconds against many minutes of other approaches, and a negligible time for model building make TMM and "transverse dilatation model" suitable candidates for optimization activities.

**Concept Of “Fractal” Helicopter Trim Panel[11]**

The reduction of structural vibrations and acoustic radiation has become increasingly challenging due to the mass reduction and use of lightweight materials. Sandwich honeycomb core panels have been widely used for decades and are still of great interest to researchers in order to improve strength and reduce weight. The weight reduction is unfortunately responsible for a rise in the panel acoustic transmission over the critical frequency, which must be compensated.

This study, as part of HC-AG20, investigates the vibroacoustic behaviour of sandwich constructions locally overloaded by a pre-fractal mass distribution. The structural mechanical model consists in a homogenised beam in simple bending, approximated by finite differences and solved numerically to form a modal basis (eigenvalues and eigenvectors). The self-similar mass distribution is presented and integrated using local overloading within the structure, which leads to a strong localisation of the beam transverse displacement. An analysis of the integrated density of states points out localised modes and their types (central or lateral localisation). Finally, acoustic coupling is modelled through a radiation resistance matrix from a discretisation of the structure into rectangular elementary radiators. Simulations exhibit a smaller radiation efficiency and lower modal critical frequencies. These results are encouraging for reducing the acoustic radiation of lightweight structures.

[11] Derré. J, Simon. F: Concept Of “Fractal” Helicopter Trim Panel

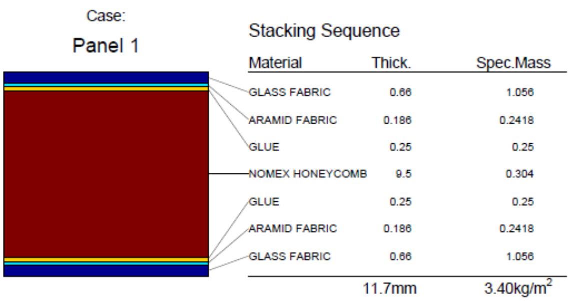



Figure 20: Panel 1

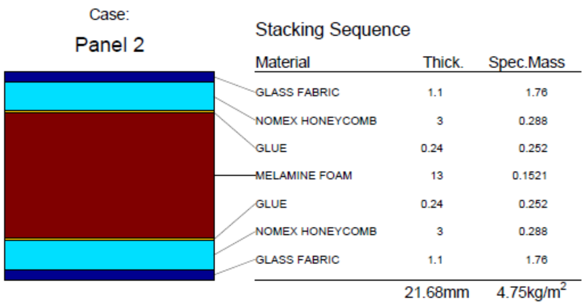



Figure 21: Panel 2

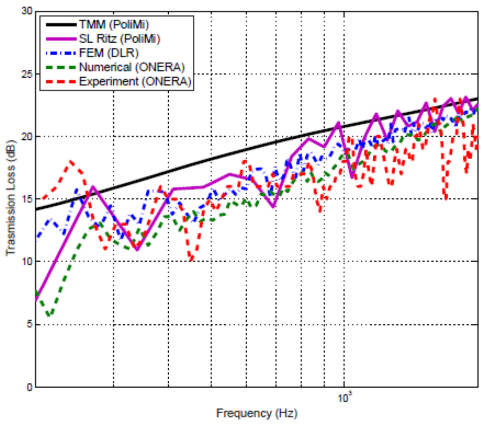



Figure 22: TL simulations and measurement for Panel 1

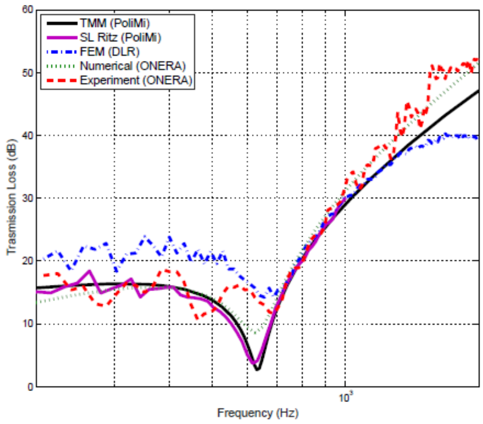



Figure 23: TL simulations and measurement for Panel 2

In noise reduction, several strategies are based on the passive principle of structural vibration reduction to minimize the radiated noise. Damped viscoelastic material can be added onto the sandwich external skin, either covering all the panel surface or localised as small patches. Another technique used in the helicopter industry consists in filling out the honeycomb core with small elements such as empty spheres made of elastomer. Nonetheless, instead of reducing the global vibration amplitudes, the wave propagation in the vibrating material can be modified by introducing additional elements within the structure.

The additional elements (irregularities, heterogeneities or others) can be distributed within the initial structure, following a periodic, random, as well as self-similar patterns. The structure itself can be composed of several sub-parts connected to form a multi-span system. In both cases, material and geometrical discontinuities create diffraction, reflection, transmission and even dissipation phenomena, which lead to the appearance of stop-bands and pass-bands in the frequency content, as well as a concentration of the mechanical energy and thus the localisation of the structure mode shapes. Therefore, the structure can be considered as a mechanical filter for wave propagation.

For HC-AG20, the key idea is to use the geometrical cell network of the honeycomb core, and to fill out some cells by following a self-similar scheme. Indeed, the transition between two structures of different natures and densities (empty cell and cell fully filled of spheres) could be seen for a bending wave as a mechanical impedance discontinuity, leading to multiple scattering phenomena. Thus, the idea is to use the properties of the full cell network to create localised modes, resulting of wave pseudo-stationarity between heterogeneities.

There are two main particularities to the study. The first one is the application of pre-fractal distribution to a composite material, i.e. a sandwich beam. The second one is that the loading is realized within the material core, meaning that the structure load-bearing capability is not altered, which is of prime importance from a mechanical point of view. Sample panels have already been realized and characterized in transmission with promising results. From an industrial point of view, the manufacturing of such panels has been carried out manually without any specific issues.

The paper published at ERF 2016 presents the vibroacoustic model of a sandwich beam overloaded by a pre-fractal distribution of masses. The sandwich structure is modelled as a homogenised material under simple bending dynamics, then discretised and approximated by a finite difference method. Heterogeneities are integrated within the material such as additional masses distributed following a Canto-like set. The eigenvalue problem is then solved numerically to obtain the in vacuo modal basis.

The self-similar mass distribution is presented and integrated using local overloading within the structure, which leads to a strong localisation of the beam transverse displacement. An analysis of the integrated density of states points out localised modes and their types (central or lateral localisation). Finally, acoustic coupling is modelled through a radiation resistance matrix from a discretisation of the structure into rectangular elementary radiators. Simulations exhibit a smaller radiation efficiency and lower modal critical frequencies. These results are encouraging for reducing the acoustic radiation of lightweight structures.

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# 9 LIST OF TABLES AND FIGURES

## 9.1 List of Tables



## 9.2 List of Figures

# 10 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)
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
ISDEFE: Ingeniería de Sistemas para la Defensa de España (Spain)
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
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

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